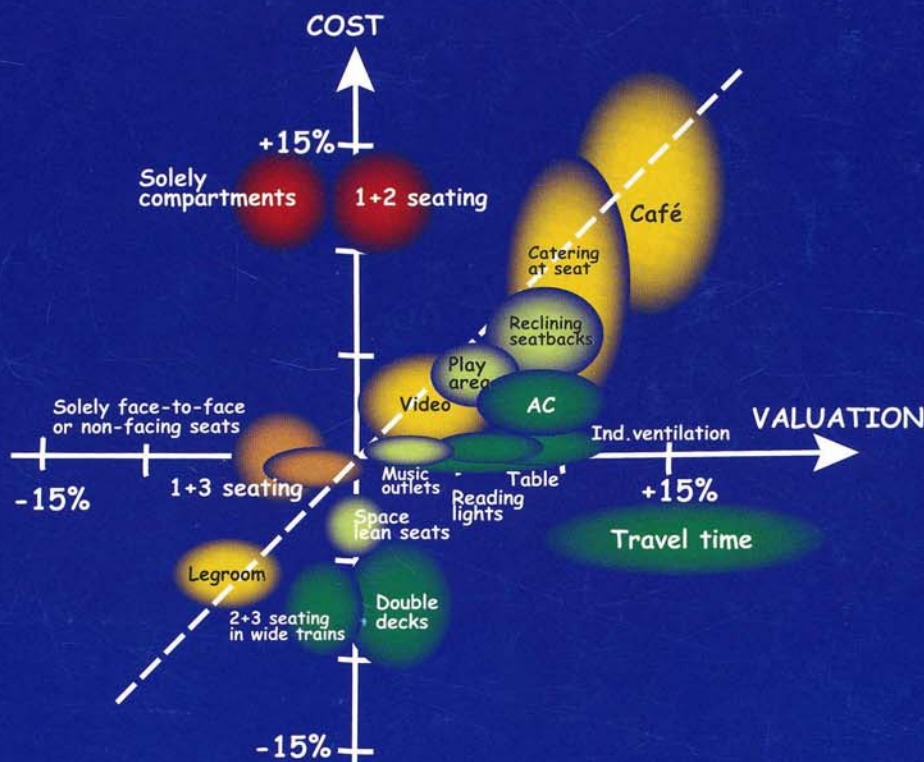




EVALUATION OF PASSENGER TRAIN CONCEPTS

- methods and results of measuring travellers' preferences in relation to costs



Karl Kottenhoff

Div. of Traffic and Transport Planning

With support
from



JÄRNVÄGSGRUPPEN KTH
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Title / Titel

EVALUATION OF PASSENGER TRAIN CONCEPTS - METHODS AND RESULTS OF MEASURING PASSENGERS' PREFERENCES IN RELATION TO COSTS

UTVÄRDERING AV PERSONTÅGSKONCEPT - METODER OCH RESULTAT FRÅN STUDIER AV TÅGRESÄNÄRERERS PREFERENSER I RELATION TILL KOSTNADER

Abstract

This project aims to find means of reducing the cost and thereby the price of tickets and, at the same time, enhance the level of attractiveness so that profitability improves. Calculations reveal that the increased utilisation of space and higher speeds are two of the most important factors when it comes to cutting costs. Attractiveness factors have been quantified into monetary valuations using stated preference methodology. The most important conclusions from SP studies as far as methodology is concerned are that "packages" of comfort and service measures should be evaluated to reduce the risk of over-valuation, that the values estimated from SP co-vary strongly with travelling times and ticket prices and that people with higher ticket prices usually have higher valuations in absolute monetary terms.

Commuters ascribe a high value to good seating comfort. This finding and the economic advantages to be gained from having a joint train type indicate that it should be beneficial to have one standard train for fast regional and inter-regional services. Double-decker trains or wide-bodied trains with 2+3 seats side-by-side are effective ways of reducing cost levels. Attributes that command a high willingness-to-pay include shorter travelling times, low noise and vibration levels, good ventilation (AC), varied seat configurations with reclining seats and service attributes such as radio/music outlets at seats and free coffee and tea in each coach. The impression of modernity itself also plays an important role in enhancing the level of attractiveness.

Sammanfattning

Projektet innehåller fakta, modeller, analyser och idéer som kan användas för att stärka persontrafikens lönsamhet och konkurrenskraft. Tonvikten ligger på fordonsegenskaper för attraktiv och effektiv regional och interregional persontrafik. Lågt pris är viktigt men även kort restid och allahanda komfort, service- och kvalitetsfaktorer, t.ex. bekväma sittplatser, goda gångegenskaper och hög modernitet. Sådana s.k. sekundära attribut får höga värderingar i stated preference-intervjuer, men betalningsviljan för ett paket av flera åtgärder blir ofta mindre än summan av de enskilda värderingarna. Rapporten innehåller en diskussion kring metodfrågor, särskilt behandlas stated preference metoder i relation till psykologisk forskning om värderingar och beslut. De viktigaste åtgärderna för att sänka tågtrafikens kostnader är att ta fram fordon med mer effektivt utrymmesutnyttjande och att höja medelhastigheten. Arbetsresenärer har visat höga värderingar av sittplatskomfort. Detta samt det ekonomiskt fördelaktiga i att ha en gemensam tågtyp talar för ett standardtåg för snabb regional och interregional tågtrafik. Dubbeldäckade tåg eller breda tåg med 2+3 platser i bredd är effektiva sätt att sänka kostnadsnivån.

Foreword

Railway is an interesting technical system and travelling by train has many human aspects. Electrically-powered railways could make a certain contribution to a good society and sustainable environment in the long term. Unfortunately, railways are still finding it difficult to come up to expectations. Research is needed to show the railways the way to develop.

In 1991, I was offered to make research at KTH on the development potential for passenger rail traffic. I quickly found that there was real potential to reduce the cost of train services if the vehicles could be utilised more effectively. Interviews with rail passengers were used to determine their reactions to possible measures in terms of comfort and service. In the spring of 1995, I presented a dissertation for a Licentiate of Engineering in Swedish.

The Rail Group at KTH then has set up a joint-venture project entitled "Efficient trains for future passenger services" where the results from my research was an important basis. In 1997 a prestudy was presented. One of its proposals was to make trains more effective by having wider carbodies. This proposal was quickly implemented – already at the end of 1998, the first wide-bodied trains in Sweden were commissioned.

As the results of our work have started to spread, I have continued to work on evaluating additional measures. Seventeen different interview studies using the stated preference method are included in the present work. I have attempted to understand and circumvent the problems associated with the results of these interviews with travellers. It is important to remember that KTH's motto is "Science *and* Art". A combination of science and engineering art is often required to master reality.

My supervisor, Professor Bo-Lennart Nelldal, has been a tremendous support and has always taken an interest in the results of my work. My (former) colleague Stina Rosenlind as well as degree project students, Pär Båge, Lotta Schmidt, Lars Segerman and Karin Törnström has contributed to some of the interview studies presented in this thesis. It has also been interesting to collaborate with Professor Evert Andersson and other engineering colleagues at the Railway Group at KTH. Karin Brundell-Freij from the Lund Institute of Technology and Staffan Widlert from the Swedish Institute of Communications Analysis has helped me to understand a few theoretical aspects of logit models. Jeanette Kliger has translated or revised most parts of the thesis. Several of my colleagues in the train group and in the Division of Traffic Planning have also contributed valuable comments.

Most of my work has been financed by the KFB (Swedish Communication Research Board). SJ and a few regional transit authorities have let me make interviews in their trains – finally even in X2000. I would like to thank everyone, even if I have forgotten to mention you by name!

My family has been affected by my post-graduate research in that I have worked at strange times, such as five in the morning, and that I have sometimes been ever so slightly irritated! Thank you for your understanding Elsa, Erika and Birgitta!

Karl Kottenhoff, April 1999

Förordet på svenska

Järnvägen är ett intressant tekniskt system och järnvägsresande innehåller många mänskliga aspekter att studera. Eldriven järnväg kan ge ett visst bidrag till en bra miljö och en långsiktigt hållbar samhällsutveckling. Tyvärr har järnvägen ännu svårt att nå upp till sin möjliga potential. Forskning behövs för att visa vägar till utveckling för järnvägen.

1991 blev jag erbjuden att forska vid KTH kring utvecklingsmöjligheter för persontrafiken. Ganska snart fann jag att det finns en stor potential att sänka tågtrafikens kostnader om fordonen kan utnyttjas bättre. Genom att göra intervjuer med tågresenärer började jag få en bild av hur de skulle reagera på förändringar av komfort och service. Våren 1995 lade jag fram en licentiat avhandling där resultaten så långt presenterades.

Järnvägsgruppen vid KTH, som är en tvärvetenskaplig grupp, startade därefter ett projekt "Effektiva Tågssystem" där resultaten från min forskning utgjorde en viktig grund. Under 1997 presenterades en förstudie som bland annat rekommenderade att framtida persontågsfordon skulle göras bredare. Resultaten blev snabbt implementerade – redan i slutet av 1998 beställdes de första breda tågen i Sverige.

Samtidigt som resultaten från vårt arbete börjar få spridning har jag arbetat vidare med att utvärdera ytterligare åtgärder. Sjutton olika intervjuundersökningar med stated preference metod ingår i arbetet. Jag har försökt förstå och komma runt problem kring resultaten från dessa intervjuer med resenärer. I Sverige skämmas det ibland om militärer som föredrar kartan framför verkligheten: När kartan och verkligheten inte stämmer överens väljer militären att lita på kartan. Inom forskningen finns verkligheten och de vetenskapliga teorierna. Det gäller att komma ihåg att KTH's devis är "Vetenskap och Konst". Ofta behövs en kombination av vetenskap och ingenjörskonst för att bemästra verkligheten.

Min handledare professor Bo-Lennart Nelldal har varit en stöttepelare som alltid intresserat sig för resultaten av arbetet. Min (tidigare) kollega Stina Rosenlind såväl som examensarbetarna Pär Båge, Lotta Schmidt, Lars Segerman och Karin Törnström har bidragit med några av de intervju studier som presenteras i denna avhandling. Det har också varit givande att få samarbeta med professor Evert Andersson och andra ingenjörskollegor inom Järnvägsgruppen, KTH. Karin Brundell-Freij från Lunds Tekniska Högskola och Staffan Widlert, numera chef för Statens Institut för Kommunikationsanalys, har hjälpt mig att se över de teoretiska delarna kring logit-modeller. Flera av mina kollegor inom tåggruppen och inom avdelningen för Trafikplanering har också kommit med värdefulla synpunkter. Jeanette Kliger har översatt eller språkgranskat stora delar av avhandlingen.

Kommunikationsforskningsberedningen (KFB) har finansierat det mesta av mitt arbete. SJ och några länstrafikbolag har låtit KTH göra intervjuer på olika slags tåg, till slut även ombord på X2000. Tack till alla, även er jag glömt att nämna!

Min familj har märkt av doktorerandet genom att jag arbetat på konstiga tider, till exempel klockan fem på morgonen och genom att jag ibland varit lättirriterad. Tack för förståelsen Elsa, Erika och Birgitta!

Karl Kottenhoff, april 1999

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Summary

Politicians would like the railways to help to solve future transport and environmental problems. People can travel to and from work and on business during the day on modern trains which are faster than any other alternative on journeys of intermediate length. Moreover, travelling times on comfortable trains can be utilised more effectively than those in cars, buses and aircraft.

One problem nowadays is that it is often difficult to operate rail traffic with sufficient business profitability. At the same time, many people feel that travelling by train is too expensive. This is primarily due to the fact that it is expensive to produce trains and rail traffic. In some cases, the railway has to reduce scale and, in many cases, train services must be made more attractive.

This project aims to find means of reducing the cost and thereby the ticket price and, at the same time, enhance the level of attractiveness so that the profitability of the railways improves. This will enable rail traffic to expand *under its own steam* (!) and play an increasingly important part in the society of the future. This project concentrates on long-distance regional and inter-regional train services.

One of the objectives in the KTH project entitled "Efficient passenger trains for future passenger services", of which this dissertation is a part, is "trains at half price". This objective is thus interpreted as the new relationship between the value of trains and the cost that can be obtained when the value increases and the cost level is reduced simultaneously. This project primarily investigates the importance of various characteristics in passenger trains in terms of cost levels and the way different timetable, comfort, on-board service and quality attributes are evaluated by passengers. By presenting these evaluations in monetary terms, it is possible to compare them with the corresponding cost.

In order to conduct a relatively comprehensive analysis of the importance of trains, the following structures for both the range of services and the demand are presented. One structure classifies vehicle characteristics and one structure classifies the attributes which are of interest to travellers. These structures are shown in Figure 0.1.

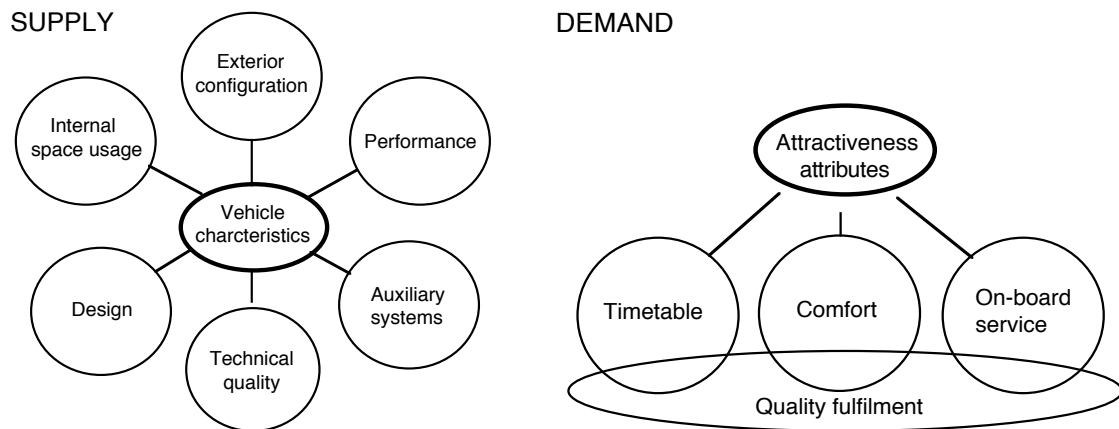


Figure 0.1 Classifications of vehicle characteristics and travellers' standard attributes. The words in the circles are headings for classes of characteristics /attributes.

The classification of the trains and services, the supply, is seen from the designer's angle. The most important aspects can be divided into the following groups: the exterior configuration (of the trains), the use of interior space and performance.

The travellers' attractiveness attributes are classified according to their need for good timetables, comfort and service on board, as well as the assumption that the quality a traveller expects will be provided. This means, for example, that a short travelling time is a timetable attribute, while the absence of delays is a quality requirement. In the same way, access to headphone outlets is a service attribute, while the function of electronic signs, headphone outlets and so on is a quality attribute. An alternative structure could have included latent attributes such as "flexibility", "opportunity to work" and so on.

To investigate the potential for cutting the cost of train traffic, an economic cost model has been developed. It is based partly on the Swedish Rail Administration's model for cost calculations and partly on internationally available cost data. The model has been used to define the elasticity of cost in terms of a number of parameters. The results reveal that the utilisation of space is one of the most important parameters. Space has an elasticity value of 0.5 (a 10% increase in the utilisation of space reduces the cost per passenger-kilometre of train traffic by 5%).

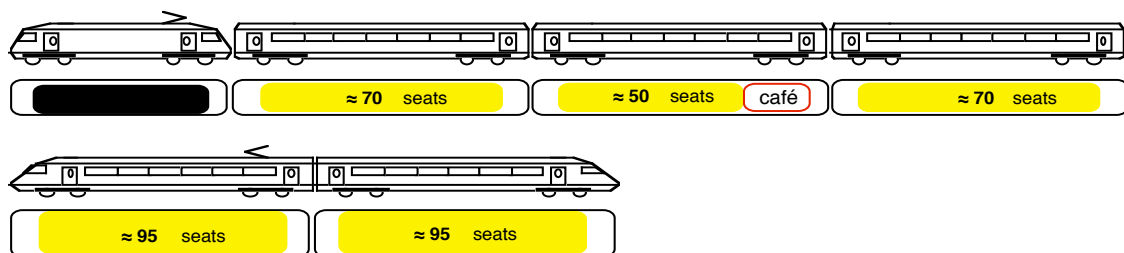


Figure 0.2 Increasing space utilisation – using smaller trains for the same seating space. Note that the EMU train is wider, thereby permitting comfortable 3+2 seating.

The conclusion is that the cost level can be significantly reduced, if trains can be reduced in size, while retaining the same number of seats. As an improvement in the utilisation of space can be suspected to have a negative effect on comfort, this factor has been studied in detail. A number of stated preference interviews with rail passengers have been conducted. Different types of standard can be traded off against one another and so, for this reason, among others, the value of a large number of vehicle and operating attributes has been analysed. A number of evaluations have been reported in previous studies, but, in order to obtain current evaluations of relevant attributes, a large number of stated preference studies have been conducted.

The first two studies (1992) focused primarily on space-related comfort attributes such as legroom, reclining backrests and the number of seats side by side (across the width of the car). The value of complete interior design concepts has been studied in new and refurbished trains, such as German and Swedish InterRegio cars. Research reports indicated that the value of a number of comfort/service measures cannot be added together simultaneously. For this reason, in 1995/96, we studied the way these evaluations can be influenced by grouping and presenting train attributes in different ways.

In 1994, a unique opportunity to study the value of train traffic compared with bus traffic was presented. Buses with a very high standard of interior design, "train interiors", operated in parallel with and in co-ordination with trains, the Kustpilen train in Blekinge in the south of Sweden. This study revealed that the train is valued more highly than the bus, even when most of the accessibility, timetable and comfort differences that normally exist are neutralised.

A number of small studies have been conducted to examine the value of aspects including night trains and day trains, train compartments, travelling by train in tunnels and specially (re-)built test coaches such as the BrainTrain coach and InterRegio Max coach.



Figure 0.3 Interior of the "InterRegioMax" test coach with 2+3 seating.

A summary of the above studies is presented together with calculations of the cost of different measures. In this way, it has been possible to make rough cost-benefit assessments. They are summarised in Figure 0.4.

Many measures are positively valued. Using terms such as value, valuation or even willingness-to-pay does not always mean that passengers are actually willing to accept higher ticket prices if they receive the measures. In Swedish trains, where most of my studies have been made, many of the investigated attributes have already been at the "high" level. For example, most of the trains already have fairly comfortable seats with reclining seatbacks, 20 cm legroom, a mixture of face-to-face and face-to-back seating, individual reading lamps and tables at each seat, a café or bistro, while some trains have additional comfort and service features. So the values in many cases could be understood as a negative value if the standard level is reduced.

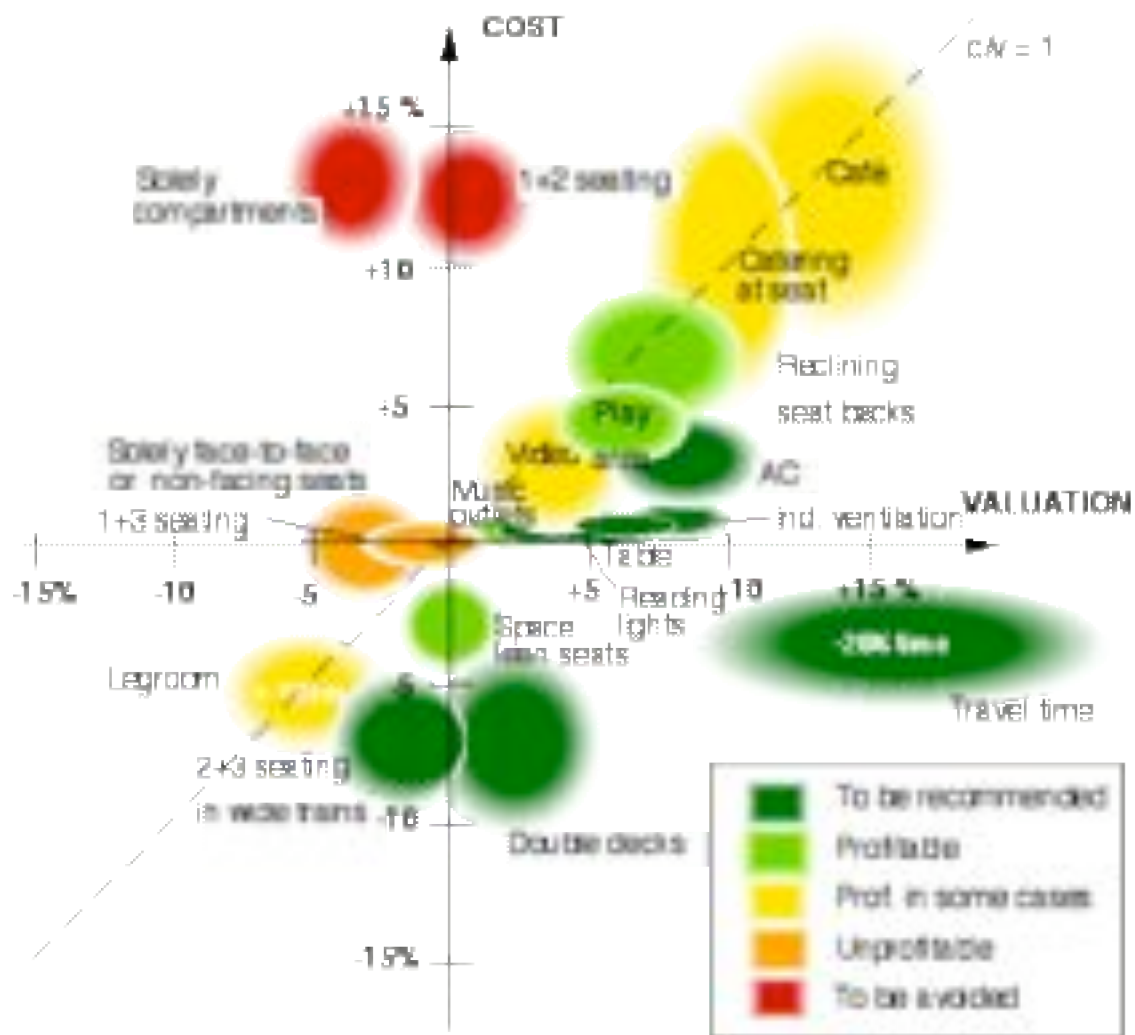


Figure 0.4 Ball-park marks for valuation (willingness to pay) and effect on the train service cost of different factors or undertakings.

To interpret the results of these studies, it is important to have a good knowledge of the way people make judgements and choices. An analysis has therefore been made of behavioural research results relating to the way judgements and choices are made. This analysis reveals that the valuation estimates obtained via stated preference experiments should be discussed. Special attention has been paid to reasons which may produce the seemingly high valuations of secondary attributes relating to comfort and service on board. The problem is two-fold and can be illustrated with the following example. The estimated value from SP interviews of "slightly less noise" is almost 10% of the fare and the valuation of "slightly less shaking and vibration" is around 10%. The next questions are intuitive.

- Is it really as important to reduce the noise level as it is to cut prices by 10%?
- At the same time, is the value of reducing both noise and shaking levels equal to their sum – 20%?

Using the experience acquired from previous studies and new ideas as the starting point, a final stated preference study was conducted in the spring of 1998; it included more than 20 timetable, comfort and service attributes, which were grouped together in packages at an upper level. This level was conducted using pairwise stated choices. At the lower level, the value of the three packages was divided between individual attributes. This was done using best/worst conjoint plus an even simpler method – a list on which people were asked to indicate the most important attribute. The results of this final study were compared with those of previous studies and the level of agreement was relatively good. The so-called "package effect" was less in this study than in many previous studies.

Project conclusions

The most important conclusions from the SP studies as far as methodology is concerned are as follows.

- "Packages" of comfort and service measures should be evaluated to obtain the total value and thereby reduce the risk of over-valuation. The next step can involve dividing the value of these packages into sub-measures using the attributes included in the packages.
- The monetary valuations that are obtained in stated preference experiments co-vary strongly with travelling times and ticket prices. People with long travelling times and/or high ticket prices usually have higher valuations in absolute money terms.
- Variations in taste between different individuals in evaluation studies should be taken into account, as they are thought to affect the accuracy of the weights that are obtained for different attributes. This probably applies in particular in so-called "unlabelled" stated preference designs.

The most important conclusions as far as the railway supply and costs are concerned are as follows.

- Passenger rail services can be produced far more inexpensively than they are at present. If all the changes discussed in this study are implemented, the cost could be halved in comparison with non-modernised locomotive train services.
- The most important measures when it comes to reducing the cost of train traffic are to produce vehicles with better, more effective internal space utilisation and to increase the average speed. This will make it possible to utilise the staff and the vehicles more effectively. Smaller trains lead to lower investment, maintenance and energy costs.
- Shorter travelling times are given positive values by travellers. At the same time, they reduce the cost of train traffic. If this reduction in costs is passed on in part to travellers by cutting ticket prices, the benefit of high speeds to travellers will be two-fold.
- Travellers value not only good timetable factors but also a host of comfort, service and quality characteristics on board trains. These so-called secondary attributes mostly receive high valuations in SP interviews, but it is important to remember that the value of a package of measures is lower than the sum of the individual values.

-
- People who travel to work by train – daily travellers – give a high value to good comfort, higher in the case of seating comfort than many other groups of travellers and, in particular, more than those who state that they seldom travel by train.
 - The above finding and the economic advantages to be gained from having a joint train type for several different market segments indicate that it should be beneficial to have *one standard train* for large parts of the regional and inter-regional rail travel market. There is a real need for a train type which is suitable for both fast regional and inter-regional traffic.
 - Double-decker trains or wide-bodied trains with five seats next to one another are effective ways of reducing cost levels. These train types and today's trains differ only marginally in terms of travellers' evaluations. The values travellers assign to double-deckers are neutral or slightly positive, while the value for five seats next to one another is slightly negative; on average, a couple of per cent of the ticket price. Double-deckers are cost-effective for long loco-hauled trains, while wide-bodied trains are efficient even for shorter multiple unit trains.
 - There are many comfort and service measures which cost less than the values they are assigned and which ought to be able easily to trade off some deterioration in the space standard.

The questions that have not yet been studied in sufficient detail include the way non-train travellers are affected by different measures and the way the demand for train journeys is affected by the standard of train traffic.

Another approach, involving a change in the structure of the characteristics of train services and travellers' attributes, such as the use of latent attributes, could help to make an even better analysis of interesting measures possible.

The Railway Group at KTH will use the "TrainLab" project to continue its research on passenger environment and, in collaboration with train manufacturers, design technical systems that provide a *maximum of comfort in a minimum of space*. The results of this thesis will also be used in models for traffic exploration that are being developed by the division of Traffic & Transport Planning at KTH.

Sammanfattning

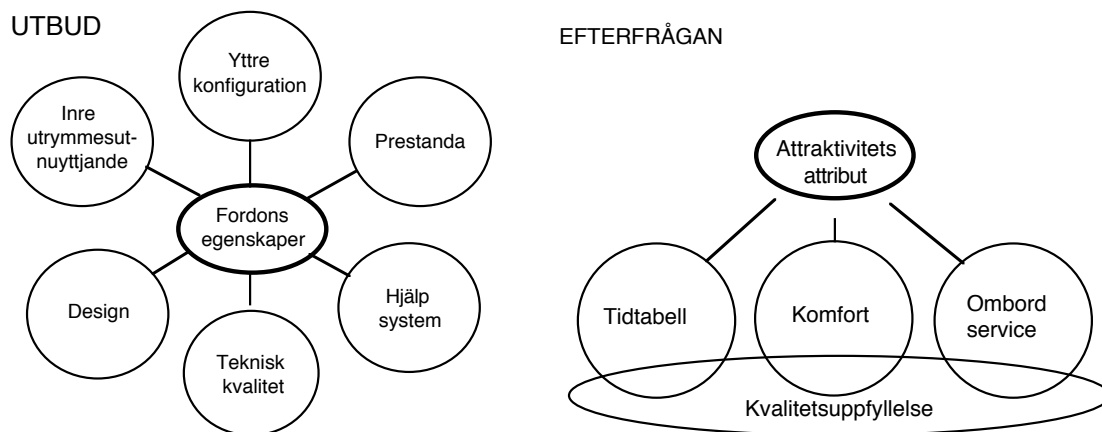
Modern persontrafik med tåg kan få stor betydelse för medborgarna, näringslivet och för den regionala utvecklingen. Människor kan göra resor över dagen till arbete och i tjänsten med moderna tåg, vilka på medellånga avstånd är snabbare än alla andra alternativ. Restiden kan i komfortabla tåg dessutom utnyttjas bättre än i bil, bussar och flygplan.

Ett problem idag är dock att det ofta är svårt att bedriva tågtrafik med företagsekonomisk lönsamhet. Samtidigt upplever många människor att det är för dyrt att åka tåg. Det beror i första hand på att tåg och tågtrafik är dyrt att producera. I några fall måste tågen göras billigare och driften av dem förenklas så att tågtrafiken kan bli lönsam i något mindre skala. Generellt bör tågtrafiken göras attraktivare att använda.

Detta projekt syftar till att finna åtgärder för att minska kostnaderna och därmed priset samt att öka attraktiviteten så att järnvägens lönsamhet ökar. Härigenom kan järnvägstrafiken expandera mer *av egen kraft* och få en större betydelse i det framtida samhället. Studien avser i första hand långväga regional och interregional trafik.

Denna avhandling görs inom ramen för forskningsprogrammet "Effektiva Tågssystem". Ett mål för detta program är förenklat uttryckt "Tåg till halva priset". Detta tolkas därvid som det nya förhållande mellan tågens värde och kostnad som kan uppnås då kostnadsnivån sänks samtidigt som attraktiviteten ökar. Detta projekt undersöker huvudsakligen vilken betydelse olika egenskaper hos persontåg har för kostnadsnivån och hur olika tidtabells-, komfort-, ombordservice- och kvalitetsattribut värderas av passagerarna. Genom att värderingarna presenteras monetärt kan de jämföras med kostnaden för motsvarande åtgärder på fordonen och/eller trafikeringen.

För att kunna göra en relativt heltäckande analys av tågens betydelse behövs en struktur för såväl utbuds- som efterfrågesidan – en strukturering av fordonens egenskaper och en strukturering av attribut som är intressanta för resenärerna. Denna klassificering framgår av nedanstående figurer.

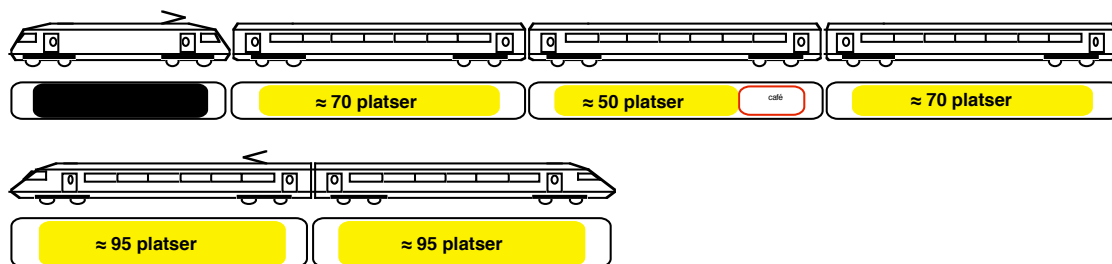


Figur 0.1Sv Klassificering av fordonsegenskaper och resenärens standard attribut. Orden i cirkelarna är rubriker för grupper av egenskaper respektive attribut.

Klassificeringen på utbuds/effektivitetsidan utgår från ett tekniskt perspektiv. De viktigaste aspekterna kan sorteras in under (tågens) yttre konfiguration, inre utrymmes användning och prestanda. Resenärs/attraktivitetssidan utgår från resenärernas behov av bra tidtabell, god komfort och service ombord samt att den kvalitet hon väntar sig kan uppfyllas. Det sista innebär t.ex. att kort restid är ett tidtabellsattribut medan frånvaro av förseningar har sorterats in under kvalitetsuppfyllelse. På samma sätt är tillgången till hörlursuttag ett service attribut medan funktionen hos elektroniska skyltar, hörlursuttag etc. är kvalitetsattribut. En alternativ strukturering kunde ha inkluderat latent attribut av typen "flexibilitet", "arbetsmöjlighet" etc.

För att undersöka potentialen att sänka tågtrafikens kostnader har en kostnadsberäkningsmodell utvecklats. Denna bygger delvis på Banverkets modell för kostnadsberäkningar och delvis på internationellt tillgängliga kostnadsuppgifter. Modellen har använts för att ta fram kostnadsnivåns elasticitet med avseende på ett antal ingående parametrar. Resultatet visar att utrymmesutnyttjandet är en av de allra viktigaste parametrarna. Det har elasticitetstalet 0,5 (10 % högre utrymmesutnyttjande sänker kostnaderna per personkilometer för tågtrafiken med 5 %).

Slutsatsen är att kostnadsnivån kan sänkas betydligt om tågen kan göras mindre, med bibehållet antal platser. Eftersom högre utrymmesutnyttjande kan misstänkas påverka komforten negativt har detta studerats ingående. Ett flertal stated preference intervjuer med tågresenärer har genomförts. Olika slags standard kan uppväga varandra, så av bland annat den orsaken har värdet av ett större antal fordons- och trafikeringsattribut undersökts. En del värderingar fanns redovisade i tidigare studier men för att få aktuella värderingar av relevanta attribut har ett stort antal egna stated preference studier genomförts.



Figur 0.2Sv Ökat utrymmesutnyttjande – att använda mindre tågstorlek för samma sittplatsutrymme. Observera att det korta motorvagnståget är bredare. Därigenom möjliggörs komfortabel 2+3-möblering.

De två första studierna (1992) undersökte främst utrymmesrelaterade komfortattribut som benutrymme, fällbara ryggstöd och antalet stolar i bredd. Värdet av hela inredningskoncept har undersökts i nya och ombyggda tåg, t.ex. i tyska och svenska InterRegiovagnar. Egna resultat och andras forskning antydde att värdet av flera komfort/ service åtgärder samtidigt inte kan summeras. Därför undersöktes 1995/96 hur värderingarna påverkas av olika sätt att gruppera och presentera tågattribut.

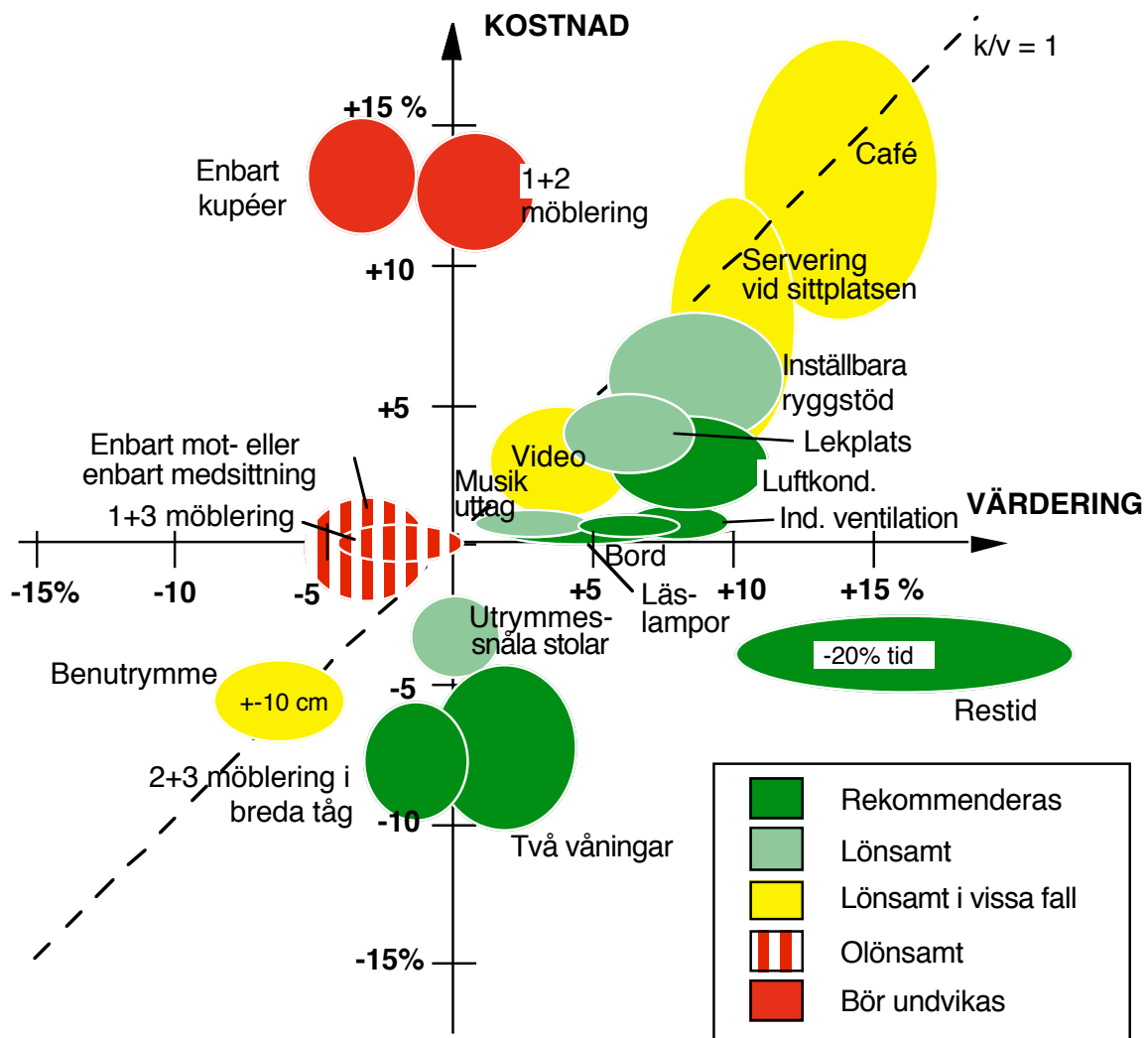
1994 gavs en unik möjlighet att undersöka värdet av tåg- kontra busstrafik. Bussar med mycket hög inredningsstandard; "tåginredning" trafikerade parallellt och samordnat med tågtrafiken, Kustpilen i Blekinge.

Ett antal mindre studier har genomförts för att undersöka värdet av t.ex. nattåg och dagtåg, tågupér, åka tåg i tunnel och specialbyggda provvagnar såsom BrainTrain och InterRegio Max.

En sammanfattning av resultaten från genomförda studier redovisas tillsammans med beräkningar av kostnaderna för olika åtgärder. Därigenom har grova nytto/ kostnadsbedömningar kunnat göras. Värderingar och kostnader för olika åtgärder eller attribut presenteras sammanfattat i figur 0.4Sv:

Många åtgärder värderas positivt. Betydelsen av att använda begreppen värde, värdering och även betalningsvilja betyder inte alltid att resenärerna verkligen skulle vara beredda att betala ännu högre biljettpriiser. I svenska tåg är nämligen flera av de studerade åtgärderna redan genomförda, det vill säga attributen har redan "hög nivå": De flesta svenska tågen har till exempel relativt bekväma stolar med fällbara ryggstöd, tillräckligt benutrymme, en blandning av med- och motsittning, individuella läslampor och bord vid sittplatserna samt kafé eller bistro.

Därför kan värderingarna i många fall förstås som de negativa värden som uppstår om tågens komfort och övriga standard försämras.



Figur 0.4Sv X/Y diagram som visar värderingar av olika egenskaper eller åtgärder på x-axeln och den marginella kostnaden för dessa på y-axeln: Alla värderingar och kostnader anges i procent av biljettpreis respektive kostnad. Ytornas storlek är till för att antyda osäkerheten i uppskattningarna

För att tolka resultaten av undersökningarna är det viktigt att ha god kunskap i hur människor gör värderingar och fattar beslut. En genomgång har därför gjorts av beteendevetenskapliga forskningsresultat om hur bedömningar och beslut görs. Denna genomgång visar att de genom stated preference experiment framkomna värderingarna bör diskuteras. Särskilt uppmärksammas vad som kan ligga bakom de till synes höga värderingarna av sekundära attribut avseende komfort och service ombord.

Problemen är av två slag och kan illustreras med ett exempel: Det från SP-intervjuer estimerade värdet av "något lägre buller" är närmare 10% av taxan och värdet av "något mindre skakningar och vibrationer" cirka 10%. Då frågar man sig intuitivt:

- Är det verkligen lika viktigt att sänka bullernivån som att sänka biljettpriset 10% ?
- Är värdet av att både sänka buller- och skaknivån samtidigt lika med summan; 20% ?

Utifrån erfarenheter från tidigare undersökningar och nya idéer genomfördes våren 1998 en avslutande stated preference undersökning där drygt 20 tidtabells-, komfort- och serviceattribut ingick. Dessa var grupperade i paket på en övergripande nivå. Denna nivå

genomfördes med parvisa val. På en undre nivå fördelades värdet av de tre paketen på enskilda attribut. Detta gjordes dels med Best/Worst conjoint och dels med en ännu enklare metod; en lista där man fick markera viktigaste attribut. Resultaten från denna avslutande studie jämfördes med resultaten från tidigare studier och överensstämmelsen var relativt god. De minskningar i värde som den s.k. "paketeffekten" ger upphov till var mindre i denna studie än vad den varit i flera tidigare studier.

Projektets slutsatser

De viktigaste slutsatserna från SP-studierna ur metodologisk synpunkt är:

- Man bör utvärdera hela "paket" av komfort- och serviceåtgärder för att få det sammanlagda värdet och därmed reducera risken för övervärderingar. Sedan gör man i ett ytterligare steg en uppdelning av värdet av dessa paket på delåtgärder genom de attribut som paketen innehåller.
- De värderingar man får fram i stated preference experiment samvarierar i hög grad med restider och biljettpriser. De som har långa restider och/eller höga biljettpriser har oftast högre värderingar i absoluta monetära termer.
- Smakvariationer mellan olika individer i värderingsstudier bör uppmärksammas då de misstänks påverka riktigheten av de framkomna vikterna för olika attribut. Detta gäller troligen särskilt i så kallade "unlabelled" stated preference designer.

De viktigaste slutsatserna med avseende på järnvägens utbud av tågtrafik och tåg samt dessas kostnader är:

- Tågtrafik kan produceras betydligt billigare än idag. Om alla de förändringar som diskuteras i denna studie genomförs kan kostnaden sänkas ner till halva nivån i jämförelse med konventionell loktågstrafik på en litet äldre, vanligt förekommande järnväg.
- Tåg värderas högre än buss även när de flesta vanligen förekommande skillnaderna mellan buss- och tågtrafik neutraliserats. Skillnaden i värdering är dock lägre än kostnadsskillnaden mellan buss- och tågtrafik.
- De viktigaste åtgärderna för att sänka tågtrafikens kostnader är att ta fram fordon med bättre, mer effektivt utrymmesutnyttjande och att höja medelhastigheten. Därmed kan både personal och fordon utnyttjas bättre. Mindre tåg leder till lägre investerings-, underhålls- och energikostnader.
- Kortare restider värderas positivt av resenärerna samtidigt som kortare omloppstider sänker kostnaderna för tågtrafiken. Om denna kostnadssänkning kommer resenärerna till del genom sänkta biljettpriser blir resenärernas nytta av högre hastigheter tvåfaldig.
- Tågresenärerna sätter värde på inte bara tidtabellsfaktorer utan också en mängd komfort-, service- och kvalitetsegenskaper hos tågen. Sådana s.k. sekundära attribut får höga värderingar i SP-intervjuer med befintliga resenärer, men man bör vara medveten om att betalningsviljan för ett paket av flera åtgärder ofta blir mindre än summan av de enskilda värderingarna.

-
- Resenärer som reser till arbetet med tåg – dagliga regionala resenärer – har höga värderingar av sittplatskomfort, högre än många andra resenärsgupper särskilt sådana som uppger att de sällan åker tåg.
 - Ovanstående slutsats samt det ekonomiskt fördelaktiga i att ha en gemensam tågtyp för flera marknadssegment talar för att det borde vara fördelaktigt med ett *standard-tåg* för stora delar av den regionala och interregionala tågsemarknaden. Det finns ett stort behov av en tågtyp som passar för såväl snabb regional som interregional trafik.
 - Dubbeldäckade tåg eller breda tåg med fem platser i bredd är effektiva sätt att sänka kostnadsnivån utan att resenärernas värdering påverkas mer än marginellt i jämförelse med dagens tåg. För dubbeldäckare är resenärernas värdering neutral eller svagt positiv medan för fem platser i bredd är värderingen svagt negativ; i medeltal ett par procent av biljettpriset. Dubbeldäckare är effektivare för långa loktåg medan breda tåg är effektiva även för korta motorvagnståg.
 - Det finns åtskilliga komfort- och serviceåtgärder som kostar mindre än vad de värderas till och vars värde bör kunna kompensera eventuella försämringar av utrymmesstandarden.

Frågor som inte studerats tillräckligt är bland andra hur icke-tågresenärer påverkas av olika åtgärder och hur efterfrågan på tågresor påverkas av tågtrafikens standard.

En annorlunda ansats med en ny strukturering av utbudets egenskaper och de för resenärerna intressanta attributen kan bidra till en ännu bättre analys av intressanta åtgärder.

Järnvägsgruppen KTH kommer i projektet "TrainLab" att fortsätta att forska om resandemiljön och tillsammans med designers och tågtilverkare ta fram tekniska lösningar som ger *maximal komfortupplevelse på minimalt utrymme*. Vidare kommer resultaten att implementeras i de trafikeringsmodeller som utvecklas vid avdelningen för Trafik & Transportplanering.

A Introduction

1. Background and purpose

1.1 Society's aims for rail transport

Different interested parties regard the railways, their function and their objectives from different angles and with different background knowledge. Society wants the railways to help to realise political objectives which, among other things, take account of the priorities set by different stakeholders. Society's aims are expressed in the form of decisions relating to transport policies.

The situation for the railways is different in different countries and this section is outgoing from Sweden.

Transport policy background

The overall target for transport policies, which was approved by the Swedish parliament in 1998, is formulated as follows¹:

– to offer the people of Sweden and trade and industry throughout the country a good, environmentally-sound and safe supply of transport which is socio-economically efficient and sustainable in the long term.

In 1989, SJ was divided into a business-oriented company, which was expected to generate a profit, and the Swedish National Rail Administration, which was expected to work to realise socio-economic objectives. This division is regarded as a good way of realising parliament's objectives.

Railways as a means to improve environment and traffic safety and reduce congestion.

One of the political objectives is that the railway should play a part in reducing environmental damage. The idea is that the railways' market share should increase, thereby reducing the share of transport work accounted for by road and air traffic, with less environmental impacts as the result. One environmental objective could be to increase the type of rail traffic for which the net effect is beneficial to the environment.

In socio-economic analysis often the reduced costs for traffic accidents are well as important as the calculated benefits for the environment.

In central Europe one of the main objectives for the political interest in railways is to reduce congestion in the road network.

¹ Statens Offentliga Utredningar, *Ny kurs i trafikpolitiken*, (Swedish transport policy, in Swedish), SOU 1997:35

Improved accessibility, regional balance and welfare

One objective could be for rail travel to increase. The Swedish government inquiry “The train’s coming”² states the following as one of the criteria for “success for the railways”:

- *The railways should be an attractive transport alternative for such a large percentage of the population that it can capture significant market shares in the passenger transport sector.*

The most common criterion for successful rail transport is an increase in travelling and higher market shares. This objective should perhaps be seen first and foremost as a means of increasing the railway’s economies of scale. An increase in travel could, however, be seen as a positive development as it would signify an increase in accessibility. Greater accessibility means that people can now work in other places or travel during their leisure time and make contacts and experience new things. From the angle of welfare theory, it is also a good thing if people value their journeys positively, as they offer more comfort, for example.

The transport policy objective of creating regional balance could mean operating rail traffic (or supporting traffic with other modes of transport) in parts of the country where profitability is lower.

Society, represented by politicians, also monitors the needs of special groups of citizens using political decisions. These groups include the elderly, the disabled, students and other people who have to or wish to use public transport instead of cars. For this reason, there are, for example, rules governing the adaptation of vehicles for the disabled and public transport which is partly paid for by taxation.

Socio-economically profitable traffic

With the optimisation of the socio-economic benefits as the starting point, it is possible to specify other requirements for the transport system than those which result from optimisation based on business economics. In a project relating to pricing, Jansson et al. found, among other things, that an economic deficit for SJ may be socio-economically profitable.

Cost responsibility

One transport policy objective is that the different types of traffic should bear their own marginal costs. As far as the operators (SJ and its competitors) are concerned, it is a question of ensuring that operations at least break even and produce some profit in terms of business economics. The cost of the external effects, such as the environmental impact, will be covered by internalising this cost in the track charges the operator pays to the state. The Swedish state and the county transport companies purchase some passenger traffic from SJ and other operators. This is justified politically, but it does not change the operators’ business economy targets.

The principal rule as far as the Swedish National Rail Administration is concerned is to prioritise investments and maintenance programmes on the basis of their socio-economic profitability.

² Statens Offentliga Utredningar, *Tåget Kommer* ("The train is coming", in Swedish), SOU 1994:19

1.2 The development of rail transport

Passenger rail services have reached a cross-roads; develop or slowly disappear. Other modes of transport, not least the automobile, are attractive and often cheaper to use than passenger trains, when marginal costs are compared. If the train is not developed from an attractiveness and cost angle, it will lose out in the general competition between several forms of travel. The EU's white paper on revitalising the railways³ states:

"The railways could do much to sustain mobility in the next century. However, while unease is growing about the negative effects of transport, rail's market share still declines. The main reason is dissatisfaction with the price and quality of rail transport, despite encouraging examples of new services. Rail is felt not to respond to market changes or customers' needs, as other modes do."

A number of predictions come to similar conclusions. It is feasible to increase train travel and to improve the market share of trains substantially, provided that good conditions are created for traffic, including a modern rail infrastructure.

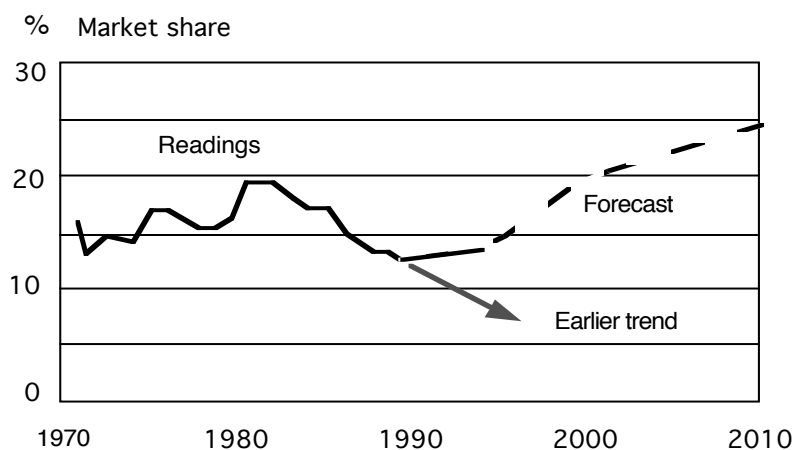


Figure 1.1 Railway's market share of domestic long-distance travel, readings and forecast. The forecast is based on a substantially upgraded infrastructure and traffic. The recent trend 1990-1999 has been in between the earlier trend and the forecast. (Source: SJ).

The Swedish government has started to develop the infrastructure. However, it is still not certain that travelling will increase as much as forecasted. The most serious threat is that high ticket prices will prevent travel from expanding. The threat stems from the high cost level of railway traffic – it is expensive to produce train services with today's means. Ticket prices are high because the cost of producing passenger rail services is high.

³ European Union, *White Paper - A strategy for revitalising the Community's railways*, Catalogue No CB-COM-96-421/424-EN-C, ISBN No 92-78-07964-2, July 1996

Railway traffic may not become sizeable enough due to the fact that the traffic must generate a profit for the operator. The travel standard then becomes inferior to the forecast models, which keep travelling down.



Figure 1.2 X2000 services have caused increases in ridership

Travel statistics confirm that high quality rail services lead to an increase in market shares, but also that high ticket prices and services which are not developed do not take market shares. In Sweden, the "Kustpilen" train, the "X2000" services and the new rail operations on Svealandsbanan (Svealand Line) have caused market shares to increase substantially. For the regional Kustpilen train, the market share has increased from less than 5% before the new train service (1991) to about 15% (1996)⁴ – an increase of 200%, because modern trainsets with an improved timetable were introduced. The introduction of the X2000 has led to an increase in the train/air market share from about 42% (1990) to about 57% (1996)⁵. High-speed InterRegio services on the converted Svealandsbanan have increased the number of journeys more than five times⁶, compared with the previous rail service on the old line.

In France, the TGV led to an increase in the share of the Paris-Lyon market from 21% (1980) to 48% (1988)⁷. However, the trends for the passenger market share are not positive in overall terms. Swedish national rail travel has not increased during the past ten years and the long-distance market share for trains versus buses, cars and air is around 13% (1998).

⁴ Lindh, C, Kottenhoff, K., The value and effects of introducing high standard train and bus concepts in Blekinge, Sweden, *Transport Policy*, 1995 Volume 2 Number 4, and updates from SJ

⁵ Nelldal, B-L., The experience of the SJ X2000 tilting train and its effect on the market, *Proc. Instn Mech Engrs*, Vol 212 part F, 1998

⁶ SJ, figures 1998

⁷ Sofretu, Systra Sofrerail, *Impact of TGV on Passenger Market*, 1995

1.3 Different requirements for rail transport

This section describes requirements for rail transport outgoing from the situation in Sweden.

- The Swedish National Rail Administration has sectorial responsibility for the railways. In this capacity, it has formulated strategic requirements for the development of the railways to enable transport policy objectives to be realised.
- Travellers, which means citizens in their capacity as rail passengers or potential rail passengers, want rail services to be accessible, offer sufficient quality and, at the same time, offer low or affordable ticket prices.
- Industry and the commercial sector want rail transport which functions effectively to obtain access to labour, for business trips and to transport the products industry produces.
- The rail operators, the companies which run the rail traffic, base their operations primarily on business economy criteria. They need to produce traffic which generates more income than expense.
- The track administrator – in Sweden, the same organisation (the Swedish National Rail Administration) which has sectorial responsibility – must supply an effective railway network; in other words, an effective network which makes efficient, competitive transport possible.

The requirements and objectives of the above-mentioned stakeholders/interested parties are described in more detail below. In addition to these stakeholders, the following organisations, which have some kind of relationship with rail traffic, are also mentioned briefly.

- Transport principal. The county transport authorities plan public transport on behalf of the citizens and work to realise political objectives. These objectives can include good economy, as well as fairness/equality, regional balance and a good environment.
- The rail supply industry wants to produce competitive railway material, for example attractive and effective rolling stock. These products should be sold on a world market.
- The academic world, universities and colleges, is interested in the railways for many different reasons. These can include questioning or “supportive” research, the research and development of sub-components or general models and methods, where the railway is only regarded as an application.

1.3.1 The Rail Administrator’s interpretation of political objectives

In its trunk network plan 1994-2003⁸, the Swedish National Rail Administration devotes a complete chapter to the objectives for the rail sector. In this plan, the transport policy objectives have been summarised as follows. The policy should:

- improve the environment

⁸ Banverket (Swedish Rail Administration), *Stamnätspan 1994-2003*, (Plan for Swedish main lines 1994-2003)

- improve accessibility
- increase efficiency
- enhance safety
- improve the regional balance

The railway can play an important role in realising the overall transport policy objectives. According to the Swedish National Rail Administration, the best way of realising these objectives is to sharpen the railway's competitive edge and help to reduce the environmental impact. As a result, the objectives for the rail sector are as follows:

to offer:	-- shorter travelling times
	-- increased frequency
	-- improved regularity
with	-- high comfort
	-- a high level of safety
	-- a good environment
at	-- a reduced cost

Figure 1.3 shows how increasing the railway's market share can help to realise political objectives.

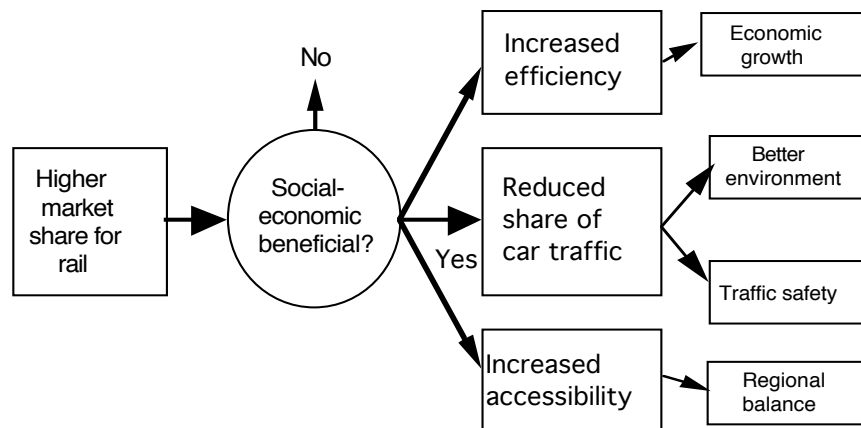


Figure 1.3 Diagram showing one possible way of relating different transport policy objectives

As long as an increase in rail transport is socio-economically defensible, it should be implemented. A reduction in the amount of road and air transport could help to improve the environment and enhance traffic safety. An increase in rail transport which is socio-economically profitable will improve society's efficiency and the geographical accessibility of its citizens.

1.3.2 Travellers' requirements

The general public wants the opportunity to move between different activities for both work and leisure purposes. For many people, travelling also has a value per se. When people's private economy improves, a relatively large percentage of the money is used for travelling.

The expansion in the use of cars demonstrates the characteristics which the vast majority of people appreciate. They include high geographical accessibility and flexibility in terms of time, combined with a moderately high marginal cost. Air and bus transport have also expanded, as they have qualities which are appreciated on certain markets.

The competitiveness of the railways can be improved by reducing costs and ticket prices and improving travelling standards. Good railway accessibility is elementary for train journeys to be perceived as an alternative.

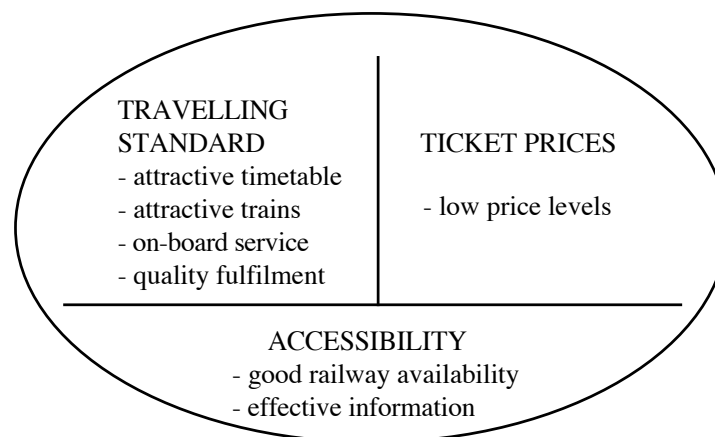


Figure 1.4 The competitiveness of the railways can be improved by raising travelling standards and reducing prices. Good railway accessibility is a precondition.

For a large group of current and potential travellers, “ordinary people“, it is important for ticket prices to be reduced in relation to the current level. For other groups, first and foremost business travellers, it is more important to develop the service or product than to reduce prices for the traveller's perception of trains to be enhanced. For the second of these groups, the current operators (in Sweden; SJ) have a strategy (such as the X2000 product), which has resulted in an increase in travelling, but, when it comes to the people who are sensitive to prices, the relationship between ticket prices and services should be further improved.

At intermediate distances, 100-600 km, travelling by train as an average costs more than travelling by bus but less than travelling by air, outgoing from the cost levels in Sweden. A rough estimate reveals that bus, train and air fares have the following relationship:

<u>Bus</u>	<u>Two people in a car</u>	<u>Train</u>	<u>Plane</u>
SEK 0.5/km	SEK 0.5/km	SEK 1/km	SEK 2/km

People estimate their marginal costs for car driving at fully SEK 1/km⁹. The private car is then often cheaper than going by train if two or more people travel in one car. It can therefore be concluded that trains will have difficulty attracting groups with less purchasing power, unless there are price levels that are lower than the present ones. There is a special section (8.1) about the importance of competitive ticket prices.

One of the aims of this thesis is further to improve our knowledge of the demands travellers impose on price and travelling standards in the form of comfort, service and quality fulfilment and the way they balance these requirements.

1.3.3 Industrial and commercial interest in rail transport

Industry and the commercial sector want effective freight transport at competitive prices, but they are also interested in effective passenger transport for business trips and an effective labour market. The train is an interesting alternative for one-day business trips, as long as the travelling time is no more than three to four hours¹⁰. Travelling to work should take no more than an hour or so. Fast regional trains can make it possible to travel 100-150 km to get to work, thereby improving the opportunities for trade and industry to recruit and retain workers.

The suppliers of railway equipment are particularly interested in seeing the railway sector develop and their products becoming competitive. This involves both the competition within the actual rail industry, as well as the opportunity the rail industry as a whole has to offer vehicles and rail transport services which can compete effectively with other means of transport such as buses, cars and aircraft.

1.3.4 The task of the regional transport principal

In Sweden, there are regional transport principals who are responsible for public transport by bus, train and boat and some special transport services. These transport principals commission traffic on behalf of the citizens. They are controlled by regionally-appointed politicians.

These transport principals work according to socio-economic principles, in combination with other political priorities relating to travelling to work and school, travel for the disabled and supplying transport for people who do not travel by car for environmental or other reasons.

Local and regional train concepts are designed and evaluated in comparison first and foremost with bus traffic concepts. For this reason, the transport principals are often obliged to weigh up train traffic with its costs and standards against bus traffic with its lower costs and greater flexibility but, in many cases, longer travelling times and lower comfort.

⁹ This price level is found to be perceived by Segerman and by others: Segerman, L., *Resvanor i den nya Svealandsbanans sträckning. Allmänhetens kunskaper om och värderingar av olika trafikutbud.*, Examensarbete 97-51, KTH traffic and Transport Planning, 1997

¹⁰ Nelldal, B-L. et.al., *The possibilities for train traffic on the future Swedish travel market* (in Swedish), TRITA-IP FR 96-11, KTH traffic and Transport Planning, 1996

1.3.5 The operator's objectives and situation

At the present time, the business economy objective is only realised in the case of traffic on the largest lines. This is an important problem, as long as the preconditions for rail companies are not changed. The problem is that there are many rail lines and rail connections which are not profitable in business economy terms.

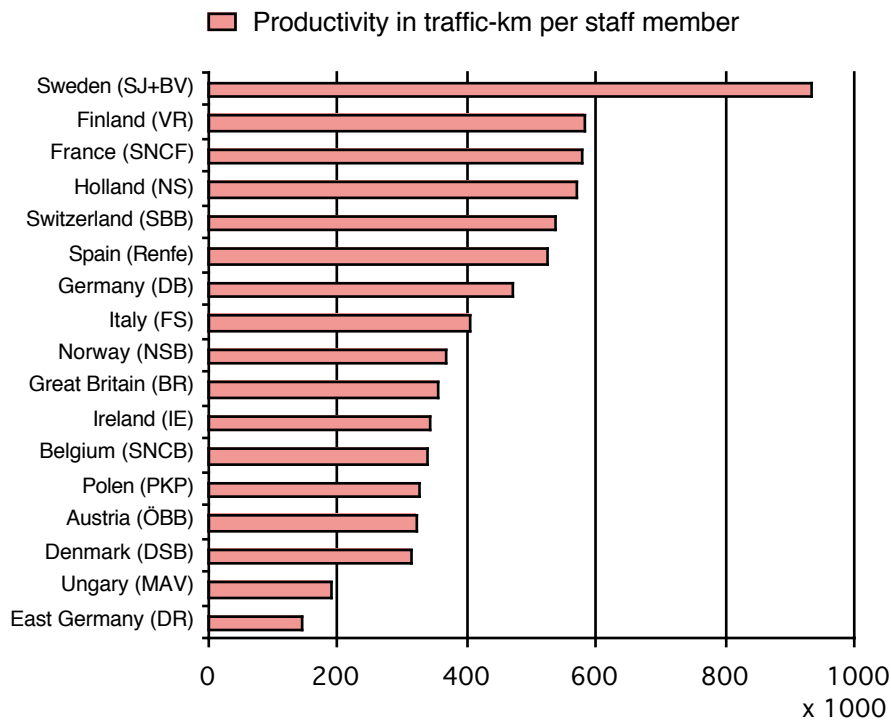


Figure 1.5 Productivity figures for various European railways 1991¹¹. (Traffic-km = pass.km + ton-km)

The above diagram shows the rail productivity; passenger plus freight, at the time when my research began. Productivity is not fully correlated with business economy, and the diagram above is just used to show that it is likely that the business economy of European railways were not very good. The problematic economic situation should not be exclusive for Sweden.

On a number of lines, the (Swedish) state and regional transport authorities purchase parts or all of the traffic that is produced on behalf of the citizens. From the operator's angle, it may be necessary to find ways of reducing the cost and increasing revenue for rail transport on a small and intermediate scale.

¹¹ Jackson, C.; Swedes ahead in European rail productivity, *Railway Gazette International*, pp.479-481, July 1992

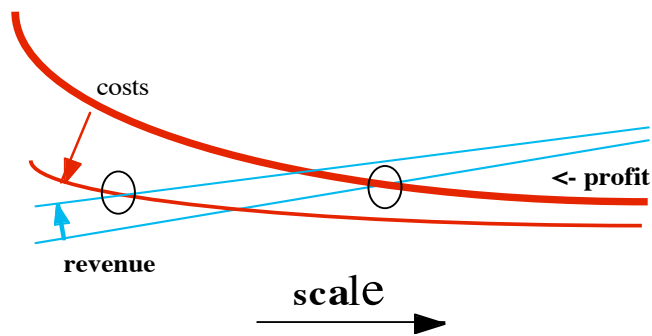


Figure 1.6 On a larger scale, the costs generally decrease as the income for each transport assignment rises. It is therefore most important to reduce costs and increase revenue on a smaller scale.

According to the diagram, it should be possible to move the limit for the scale on which profitability can be obtained (a long way) downwards, which should benefit the market coverage and competitive strength of the railways.

1.4 Role of research

Research can be related to the railways in many different ways. What is generally known as railway research in Sweden and internationally consists for the most part of technical research and development projects. At the ERRI, European Institute for Railway Research, and the regular international conferences on railway research, the WCRR, World Congress on Railway Research, most of the projects relate to the technical development of railway sub-systems.

In other scientific disciplines, the railway is dealt with from historical, social science or economic aspects, for example. This kind of research is rarely designed to strengthen the railways. Some research in the academic world has strong intra-scientific aims. It may, for example, be a question of developing economic theories and models which are studied almost exclusively by other researchers in the same discipline.

“The Railway Group of KTH” was set up to boost railway research in Sweden, as a result of the many changes in transport policies relating to the railways. KTH’s railway research is co-ordinated via a joint general programme in which several institutes/departments contribute their skills and expertise. The Railway Group’s research has a system approach.

Railway research and education is regarded as essential for both the future development of rail services and to enable the rail industry to develop competitive products. The knowledge which is acquired from railway research can improve socio-economics as a result of both the gains reported by the Rail Administration (economic growth, environment, safety and regional balance) caused by an increase in market shares and directly via cost reductions and an increase in people’s willingness to pay.

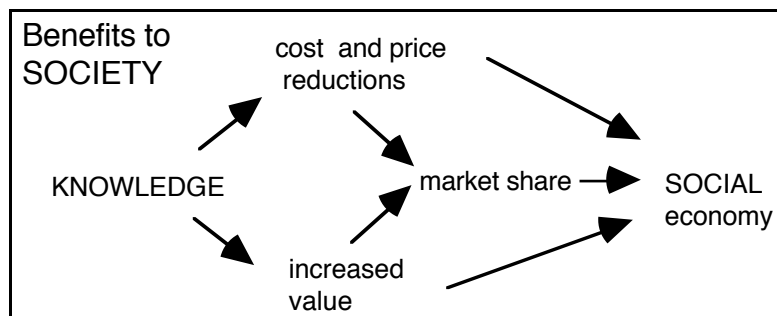


Figure 1.7 The knowledge generated by research can help reduce costs and prices and increase people’s willingness to pay. This will affect the number of travellers and the economy of rail transport.

The knowledge acquired from research can help to increase the value travellers ascribe to travelling by train, while reducing the cost of travelling. If the value increases and the cost is reduced, the consumer surplus rises and with it the welfare of travellers.

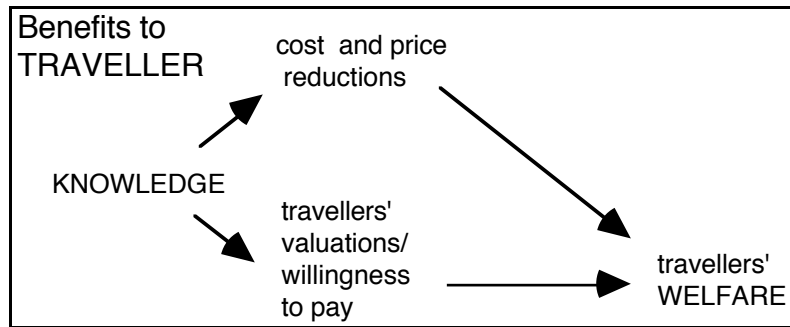


Figure 1.8 Travellers will benefit from lower costs and from ascribing a higher value to travelling by train..

The knowledge acquired from railway research can help the operators to improve their business economics by presenting measures for reducing costs and by demonstrating means of increasing travellers' willingness to pay.

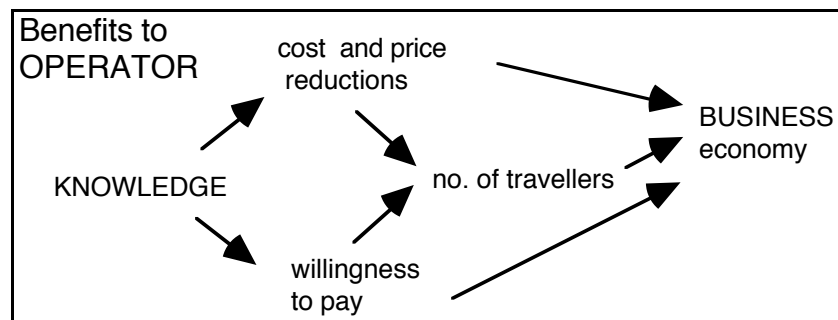


Figure 1.9 The knowledge generated by research can help reduce costs and prices and increase travellers' willingness to pay. This will influence the number of travellers and the business economics of rail transport.

The three preceding figures, which demonstrate the potential benefits to society, travellers and train operators, are summarised in figure 1.10.

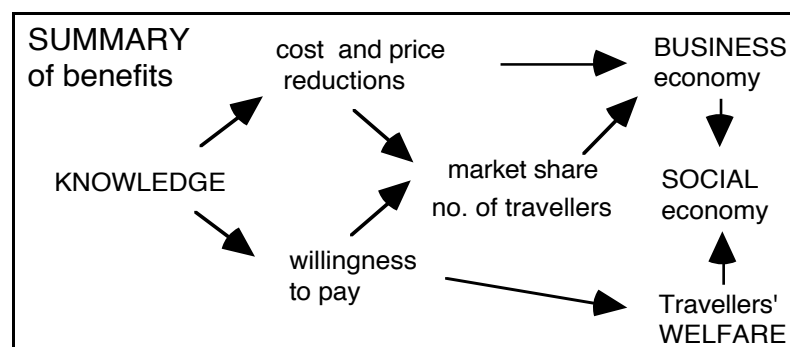


Figure 1.10 The knowledge generated by research can help increase social economy, travellers' welfare and business economics.

A larger market share for the railways will not necessarily lead to improved social or business economy. However, there is a correlation which is often (assumed to be) positive.

1.4.1 The Railway Group's objectives

The Railway Group at KTH applies a system approach with the overall target of sharpening the railways' competitive edge. A more operational objective for the research that is being conducted by the railway group is "trains at half price". Is it possible to increase the difference between cost and willingness to pay so that people can travel by train at half the price? There is no question that there are different ways of realising this objective on different markets. It is a question of increasing the difference between the market value and the price of tickets. Different travellers have different priorities and the conditions differ for different geographical areas and traffic assignments.

The starting point is that it should be possible to combine a number of changes to produce significant results.

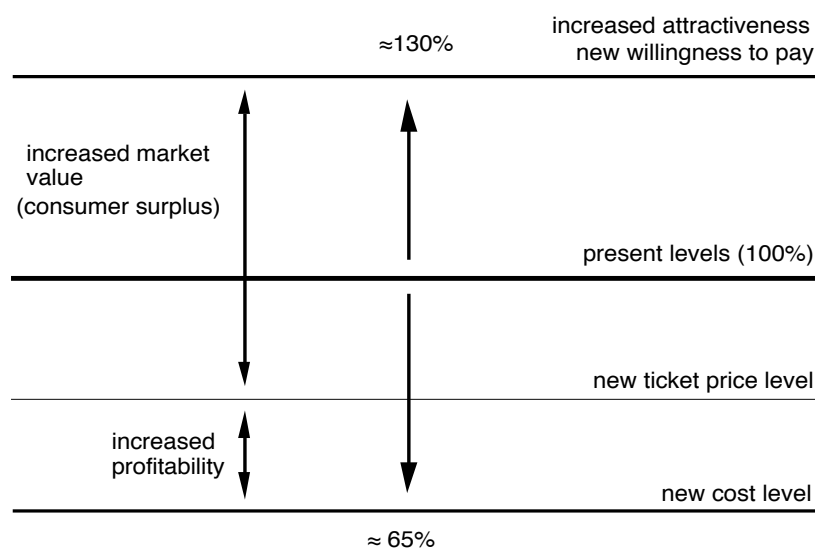


Figure 1.11 "Trains at half price" should be interpreted as a cost level reduction and an increase in people's willingness to pay due to enhanced attractiveness. In the above example, 65% divided by 130% equals exactly "half price".

Some of the cost-savings could be used to reduce ticket prices and some could be used to improve the operator's income and profitability. The improvement in people's willingness to pay would obviously make it possible to increase ticket prices, but the suggestion is that it should instead be used to help increase market value (consumer surplus) and the market share of passenger rail services.

The main question then is: how can we increase the attractiveness – the rate of travel and the value of train riding – and simultaneously reduce the cost?

1.5 Aims of this research

The overall aim of this thesis is to supply knowledge which will make it possible to strengthen the position of the railways as a means of transport using self-financing measures. Self-financing means that the relationship between benefit and cost is favourable and the benefit is of a business- and/or socio-economic nature.

The decisions relating to transport policies which are currently in force (in Sweden) are based on the assumption that rail traffic is to be run on the basis of business economics, thereby enabling it to compete with other modes of transport. This presupposes that *travellers* choose to travel by train and that the *operator* can make his operations financially viable.

In more precise terms, this projects aims to:

- structure the range of passenger rail services, primarily the characteristics of rail vehicles, from a technical angle. A good structure creates the potential for further analysis
- structure train attributes from the travellers' viewpoint,
- develop methods for describing and measuring the efficiency of the services,
- examine a number of different methods for (traveller) evaluations of the characteristics of these services,
- use methods for efficiency and attractiveness to identify interesting characteristics and measures,
- provide examples of suitable and unsuitable vehicle systems and concepts and
- comment on the potential and shortcomings of current methods for evaluating characteristics and concepts, as well as the opportunity to use these valuations in forecasting models.

Attractiveness is a fairly comprehensive concept. To make the potential attractiveness more easily comprehensible, as well as being modulated and understood in greater depth, the attractiveness theories and methods are presented, discussed and in some respects questioned. This can be seen as a contribution to the development of theories and models, but the main aim is to obtain reliable valuation figures.

There have been many studies of people's willingness to pay for reduced travelling time, as well as some studies of other factors. However, studies which investigate many train-related comfort and on-board service attributes and take account of the "package effect" are rare or in the possession of rail companies. In the same way, the cost of train services has been calculated, but a systematic study of various generalised measures for reducing the cost level, including the importance of the use of space, has not been found. The analysis of use of space in this project, its importance in terms of cost levels and the passenger's valuations is believed to be unique.

Theses are often written for the academic world and this one is no exception – at least to some extent. However, a more important target group is the railway sector and society; strategic persons and planners inside and outside the railway industry. As a result, the text

sometimes attempts to explain academically-established facts or theories. The purpose in this respect is to compile relevant facts and theories together with explanations and interpretations as a way of promoting understanding. In some cases, this may have led to oversimplifications from a more strict academic point of view.

1.5.1 Premises and hypotheses in this project

The trains of today are too expensive to permit the same low ticket prices as are offered by bus services. Also car travel is often experienced as cheaper, at least when two persons or more travel together.

It is possible to increase the competitiveness of passenger trains by combining cost reductions with an increased willingness to pay.

- It is possible to find a simple and reliable method to investigate the measures which will increase the competitiveness of rail passenger transport in the travel market.
- The conversion of measures in the train system to economic figures can be made fairly simplistic.
- Ordinary stated preference (SP) methodology can be used to investigate willingness to pay, but some difficulties and shortcomings in the most frequently-used methods may be overcome by adding alternative SP methods.
- Cost/benefit comparisons will clearly indicate the measures which will increase the competitiveness of passenger trains.
- Train design and performance play an important role in the competitiveness of passenger rail services. Many features contribute. They are to be found in areas such as train configuration, interior use of space, performance and general design.
- One of the most important factors, beside increased average speeds, is to use train space efficiently.

2. Methods and definitions

This research project is applied research; in other words “a systematic and methodical search for new knowledge and new ideas with a predetermined application in sight” (Nilstun¹²). The project attempts to focus on factors which are relevant to the future attractiveness and effectiveness of rail traffic. It should be possible to use the knowledge and information that is acquired to develop more competitive passengers services. As is usual when it comes to science, a simplification of the real-life situation is used – models which should be easy to understand and methods which should be easy to use.

The overall research design is exploratory. The main problem is an unstructured one. Passenger trains have difficulty competing with other modes of transport and thereby contributing to societal goals such as a better environment and economy. How can competitiveness of passenger rail services be improved?

This chapter discusses

- methods and criteria at various levels,
- definitions (limitations) of what the thesis omits,
- definitions and methodological aspects of the attractiveness and effectiveness approach and
- working methods and the collection of information and data.

¹² Nilstun, Tore, *Praktisk Vetenskapsteori*, (Practical Theory of Science, in Swedish), Studentlitteratur ISBN 91-44-25421-0, Lund 1988

2.1 Methods for measuring competitiveness

This thesis evaluates measures that can make trains more attractive, effective and efficient. Both train services and passenger demands are studied. To do this, a number of methods or models are used. Some of them have lured me to a greater and greater degree. Since many of the evaluation results are based on stated preference methodology, this methodology has been studied in greater depth, especially from a psychological viewpoint based on people's judgements and choices. So there are methodology issues that require special chapters in the thesis. In this chapter (2), only an outline is given.

An appropriate level of evaluation

The evaluation of trains and services is made at an intermediate level, in accordance with a paper by Holvad et al. (1997)¹³ entitled *Evaluation of rail services*. The authors divide the possible levels into financial appraisal, cost-benefit appraisal and multicriteria appraisal, where the number of impacts is illustrated by the following figure.

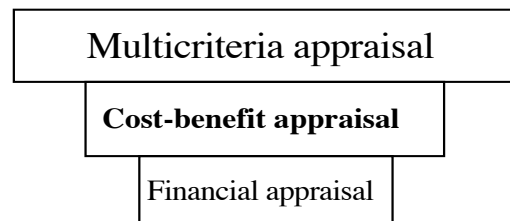


Figure 2.1 The level of appraisal/evaluation and number of impacts (from Holvad et al.)

The level of appraisal used here is mainly the cost-benefit level which takes account of more impacts than – at least a short form of – financial appraisal, supplemented by some other criteria. There are real impacts which play an important part in the evaluation of (some) rail projects, which could be included in a multicriteria analysis, but which are not included in this thesis. Some impacts are hard to quantify in monetary terms but the kind of measures investigated here are not so extensive that they cannot be approximately quantified.

Practical and efficient methods

One aim has been to find and use methods which are practical to use even for those who are not experts in statistical modelling. The methods should also be efficient. That means that they should have relatively high and reasonably correct "output" in relation to the efforts of the investigator (researcher, engineer...) and the respondents.

Effectiveness and attractiveness

In this thesis, the terms *effectiveness* and *attractiveness* have been chosen to represent two angles from which rail services can be studied. The term effectiveness means "the power or capacity to produce a desired result", while attractiveness means "the power or quality

¹³ Holvad, T, Cole, S, O'Higgins, T, Gommers, M, Evaluation of train services, *Trafikdage Aalborg August 1997, report 1*, pp 195-205

of attracting". In this chapter, these terms will be discussed and various definitions will be presented. How effectiveness and attractiveness can be linked and traded off is a central part of the thesis.

2.1.1 Competitiveness

Competing means striving against (others) for victory. "Others" is put in parentheses because victory and thereby competitiveness can have various meanings. Firstly, the meaning of competing against others will be examined.

Competitors offer bus and air travel. In this respect, high competitiveness means having a large market share on the travelling market.

In the case of the private car, there is no single competitor to rail. Instead, the railway has to compete in a society which has already been converted for the easy use of cars, including many commercial interests. The individual is influenced by this society, but he/she still can, in many cases, make his/her own choice between car or rail (or bus or air). In the case of the private car, the competitors to rail are the many rail customers themselves.

Another more self-reliant interpretation can be made. In the case of passenger rail, competitiveness can mean making a large percentage of rail services beneficial from a business economy point of view. The "other" to strive against here is "red figures" in the books.

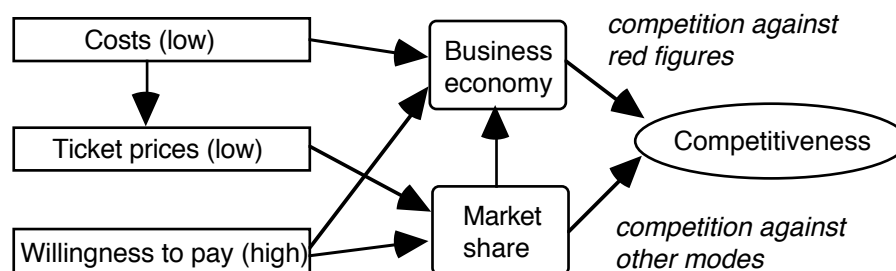


Figure 2.2 Competitiveness of two types is achieved by cutting costs and increasing willingness to pay.

In a situation in which profitability is insufficient, lower cost rather than a reduction in ticket prices may be necessary in order to make a profit. In the same way, greater attractiveness and willingness to pay can be used to increase revenues by raising ticket prices. At a sufficiently high profitability and efficiency level, the operator can stop raising ticket prices. The raised attractiveness will then attract more passengers. This will thus increase the number of travellers and the railways should significantly improve their market share.

In this thesis, increased competitiveness is achieved when willingness to pay (wtp) is increased and/or costs are decreased. Competitiveness in terms of other modes is thereby positively influenced if ticket prices are reduced, or at least increased less than wtp. The railway company will benefit more from the opportunity to lower costs or raise revenue.

The latter can be achieved by higher ticket prices, made possible by higher wtp or more passengers, when prices are kept at a lower level.

Anyhow, higher market share is the most used indicator for passenger rail's competitiveness.

2.1.2 Methods for evaluating supply and effectiveness

Functional structures

One important issue is to create a structure of the supply that can be used in further analyses of measures. The structure is made by classifying passenger rail vehicles and their features.

Another important step in the analysis is to investigate the cost structure for passenger rail services, with special emphasis on the role of the vehicles. An economic model has been constructed and it has been used to investigate the importance of various measures. How great an influence do various measures have on costs?

What is effectiveness, efficacy and efficiency?

Measures for effectiveness can include cost effectiveness, productivity and profitability. The German language has two words: "Effektivität" and "Effizienz". In English, there are three words¹⁴ representing three levels:

1. Effectiveness: is this the right thing to be doing?
2. Efficacy: do the means work?
3. Efficiency: are minimum resources used (for a given output)?

The difference between level 1 and 3 is further described by Vieregg¹⁵:

- "Effektivität" and "effectiveness" is a pure output view. The words at this level show the influence or effects of measures. Comparisons of the actual and the desirable values are relevant.
- "Effizienz" and "efficiency" describe the relationship between input and output. These words correspond to the Swedish word "verkningsgrad". It is, for example, possible to measure the efficiency of an engine.

¹⁴ Wiley, *Rational analysis for a problematic world*, Ch4, 1989

¹⁵ Vieregg, Martin, *Effizienzsteigerung im Schienenpersonenfernverkehr*, Akad. Verlag München 1995, ISBN 3-929115-51-4

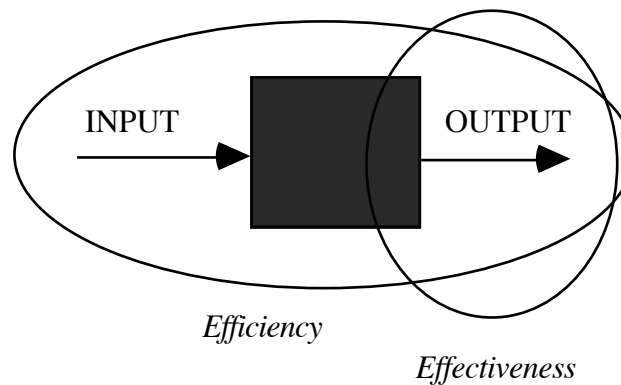
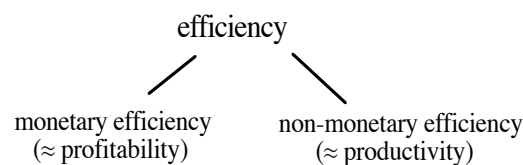


Figure 2.3 The terms efficiency and effectiveness

Example: Trains with good performance have high effectiveness, while high efficiency also requires the relatively low use of resources.

In Swedish, there is just one word for "effectiveness" and related "eff" words.

Efficiency can be divided into a monetary and a non-monetary part.



Monetary efficiency means much the same thing as profitability, where both input and output are specified in monetary terms. Productivity, on the other hand, means the "output" for the investment volume of each factor. For example, the output may be passenger kilometres and the input may be the number of employees. Productivity criteria of this kind can be used for comparisons of concepts or companies.

Absolute and relative efficiency

Absolute efficiency has the same measurement dimension at input and output. Business profitability is one example. It is less obvious if socio-economic profitability can be measured absolutely. This is often assessed in a relative manner – here called *relative efficiency*.

The following matrices shows how various efficiency criteria can be classified in terms of absolute and relative efficiency in one dimension and absolute and relative comparison in the other.

Table 2.1 Various types of efficiency

	Absolute efficiency	Relative efficiency
Absolute comparisons equal magnitudes (e.g. income / cost)	Profitability from a business economy angle Technical efficiency	Change in profitability from a business economy angle Socio-economic profitability (cost/benefit)
Relative comparisons different quantities (e.g. production / cost)	Productivity Key ratios	Assessment of measures: business/socio-economically most effective measures (cost efficiency)

The difference between the two fields "change in profitability" and "assessment of measures" is that, in the first case, the advantage of doing anything at all is investigated, while the other case, assessment of measures, relates to reaching a goal, perhaps a certain level, at the lowest possible cost.

Productivity can be measured in for example passenger-kilometres/SEK and an example of key ratio can be kWh/passenger-kilometre.

In this thesis, most assessments are made in the upper right quadrant: relative and absolute comparisons. Valuations, in monetary terms, of (marginal) measures are compared to marginal costs; a restricted cost-benefit analysis.

Bench marking

A restricted application of bench marking have been made in this project, by measuring comfort related properties during study trips with modern European trains and by studying railway literature. Some of these data are presented in chapter 3.

2.1.3 Methods for evaluating attractiveness

Attractiveness can be studied and described in many ways. Many of these descriptions include statistical models for predicting travel volumes or, less ambitiously, market share. These models presume that a more attractive transport system results in more travelling.

In this thesis stated preference (SP) techniques are used to estimate the relative strength of various attractiveness-related measures. In most stated preference models, it is assumed that people maximise their own utility or at least behave *as though* they do so "in average". The SP-results are however not meant to be used directly in prediction models.

Definitions of attractiveness concepts

The term *attractiveness* has the following synonyms¹⁶: appeal, charm, attraction, pull, draw, glamour, magnetism, fascination, lure, enchantment, allure, allurement, charisma and witchery.

Preference means: favourable, preferential bias *or* the act of choosing. Synonyms for the first explanation are: favour, favouritism and partiality. For the second explanation:

¹⁶ Casio electronic treasures (1985), IC card ES-600

election, choice and selection. Ben-Akiva et al.¹⁷ describe preferences as a representation of "the desirability of alternative choices".

Valuation also has two meanings. A measure of the qualities that determine merit, desirability, usefulness or importance *or* the act or result of judging the worth or value of something or someone. Synonyms are: value, account and worth. In this thesis, the word valuation is most frequently used as a measure of value or utility in economic terms which is calculated and estimated using statistical tools from interviews with travellers.

Evaluation has a broader meaning including the judgement process and other results of this process than just a figure representing economic value. Synonyms are judgement, assessment and appraisal.

Utility is a word which has rather exact and somewhat different meanings in economic and psychological theory. The concept of utility from a psychological meaning is mentioned in section 6.2. An ordinary wordbook defines it as "the quality of being suitable or adaptable to an end", with synonyms as use, advantage, benefit, profit and usefulness. From an economic viewpoint the concept of utility is strongly related to the inherent qualities of alternatives that can be chosen. It "explains" the choices that are made.

More definitions of words used in the analysis of attractiveness are presented in section 6.1.2 about judgements and choices.

Methodological issues in terms of attractiveness

Stated preference (SP) methodology has been used to evaluate attractiveness. It produces travellers' weights for various attributes or measures. These weights can be recalculated into monetary valuations. This possibility to present values for various measures on an absolute scale is the main reason for choosing SP methodology.

The method has some shortcomings. The Department of Traffic Planning at KTH has conducted a number of studies to investigate methodological issues regarding SP interviewing. The issues which have been studied include:

- Interviews using paper questionnaires versus computers.
- Self-administered computer interviews versus interviews with interviewer support.
- Adapted or non-adapted levels for time and price factors.

In short the findings from these studies are that computer interviewing with small self-administered computers work technically fine. The price and time levels used should be adapted for each respondent.

This thesis is part of the general project entitled "Efficient Passenger Rail Services for the Future¹⁸", in which one aim is to analyse the following method issues.

¹⁷ Ben-Akiva, M., Walker, J., Bernardino, A., T., Gopinath, D., A., Morikawa, T., Polydoropoulou, A., *Integration of choice and latent variable models*, Draft revised May 1998, MIT, for presentation at AMA ART Forum '98, Keystone Colorado

¹⁸ Prestudy: Railway group KTH, Andersson, E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik.*, in Swedish – full English version is underway, 1999), KTH Railway group report 9702, 1997. Summary report in English: *Efficient trains for future passenger services – a study on improving ratio between customers value and operating cost*, KTH Railway group report 9802, 1998.

- Package effects. The results of different SP studies reveal that many factors receive high evaluations, but that there is a package effect which says that the combined value of a number of measures is less than the sum of the component parts. How is willingness to pay for improvements affected when several measures are implemented? (Section 6.4 of this thesis)
- The dependence of evaluations on different travelling times and price levels. The way in which valuations are presented – in the form of Swedish kronor (SEK) or a percentage of the fare or as SEK per hour of travelling time – is not unimportant. The socio-economic significance differs and the forecasting models react differently, depending on the way the evaluations are represented. It appears that this problem has not been analysed on any large scale. Existing interview data – our own and that of others – is used for some in-depth analyses using logit models which include time and price dependence. I have chosen to present the passenger's valuations in relation to the travellers' relative ticket price, i.e. in per cent of the price. This choice will be motivated in section 6.5.
- Best/worst conjoint. This is a new SP method which is based on the respondent giving his/her direct opinion of different attributes instead of choosing between alternatives. This method provides information not only about the *benefit* of the various levels of different attributes, as conventional SP does, but also about the *significance* of different attributes in relation to one another. (Section 6.6.) The Best/Worst method has been used in some of the studies.
- Comparisons with qualitative studies which are better in some respects than quantitative studies like SP. For example, qualitative studies provide information about factors and aspects which the interviewer may not have thought of. So qualitative studies are a means of extending our knowledge of the travellers' situation and they can also act as an extremely interesting complement to quantitative SP methods. (A few results are presented in Section 8.2)
- Evaluations of the services by people who do not travel by train. If the aim is not simply to retain current rail passengers, it is important to define the evaluations of travelling by train which are made by car and rail passengers and non-travellers. This has to be dealt with in subsequent studies.

In all probability, the natural thing would be for individual evaluations of an attribute to differ, distributed according to some distribution function. This presumption is discussed a little in this thesis and it will be further considered in subsequent work.

2.1.4 How to trade-off effectiveness and attractiveness ?

More efficient services may result in lower fares, which is attractive in its own right. A more attractive service may generate more travel customers and/or higher revenue.

In order to make the appropriate trade-offs between enhancing attractiveness and keeping costs down, it must be possible to link the conditions of the service with individual

¹⁹ Prestudy: Railway group KTH, Andersson, E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik.*, in Swedish – full English version is underway, 1999), KTH Railway group report 9702, 1997. Summary report in English: *Efficient trains for future passenger services – a study on improving ratio between customers value and operating cost*, KTH Railway group report 9802, 1998.

perceptions. There must be relationships between qualities, or features, and the traveller's opinion of them.

The services offered are shown to the left in figure 2.4. They can be described by features or characteristics. The interesting features include travelling time/speed and frequency, as well as many vehicle qualities like train configuration, the use of space, design and service systems. Correlated to these supply features are the passengers' evaluations, shown to the right in the figure. Passengers make evaluations and the evaluation attributes have been grouped under timetable, comfort, service and quality fulfilment.

Another way of describing figure 2.4 is to say that the left side is the supply side, dealing with the effectiveness or efficiency with which train services are produced. The right side is then the demand or attractiveness side. The following text briefly describes research results from both sides, beginning with attractiveness.

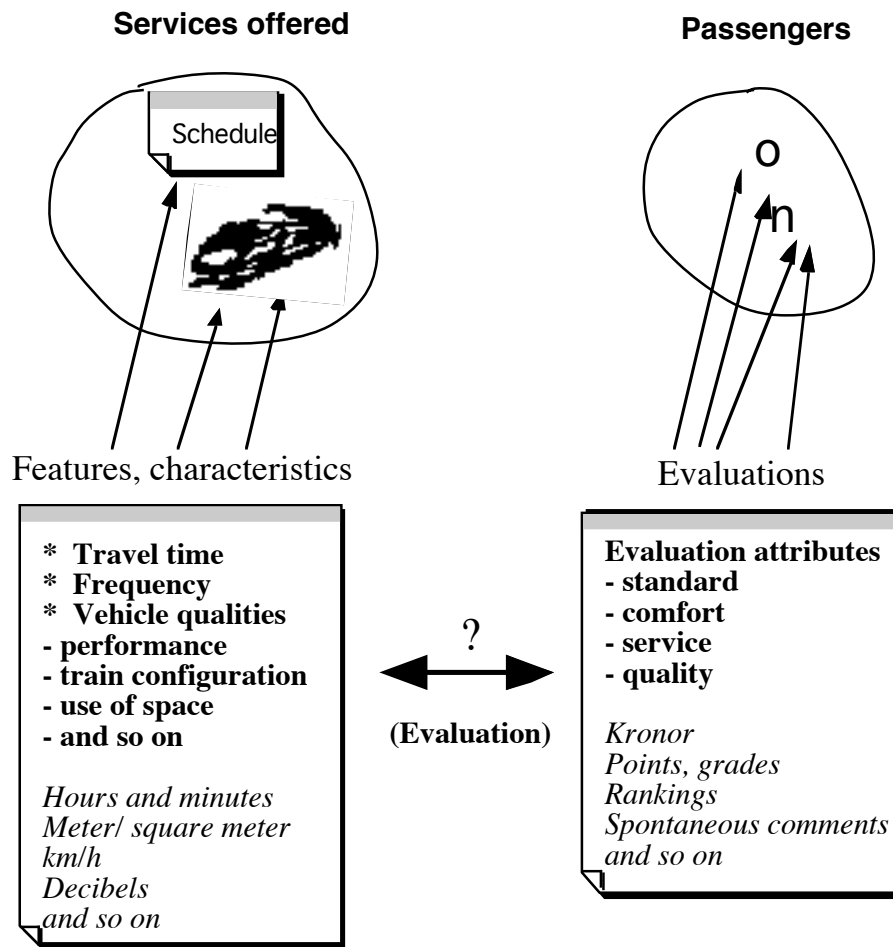


Figure 2.4 Correlation between features of train services and train travellers' evaluations²⁰.

It is very interesting for the railway industry, as well as for other industries, to find the right balance between product standard level or quality and the user's preferences and valuations. There may be many ways or methods for finding this balance, but there is one discipline that has been specially developed to handle balances or "trade-offs" – economic science. It is natural to make comparisons in economic terms and units.

In this project, valuations of attributes in economic terms are put into a cost-benefit comparison.

²⁰ Kottenhoff, K., *Framtida Persontåg – fordonsegenskaper för ökad attraktivitet och effektivitet*, (Future Passenger Trains – Vehicle concepts for increased attractiveness and effectiveness, in Swedish), Licentiate thesis, Traffic & Transport Planning KTH, TRITA-IP FR 94-3, 1994

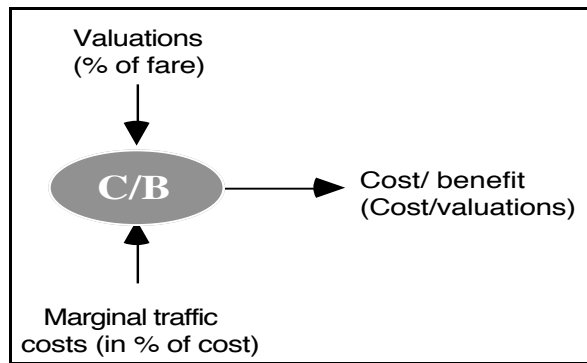


Figure 2.5 The passengers' valuations of various attributes can be compared with the marginal costs of related measures.

The method for cost/benefit comparisons used in this project is described in Chapter 9. It makes comparisons of relative changes in passengers' valuation and operators' costs.

The values of various attributes can also be fed into socio-economic models to make an overall evaluation of various strategies.

A more complete model should also include the effect of demand changes – more passengers will generate higher revenue.

2.3 Working method

This project is interdisciplinary in character and the work has therefore been done using a number of different methods from various scientific disciplines. Both engineering science and economic methods and market surveys are included, together with a review of relevant psychological knowledge.

In addition to literature studies and methodology courses, the work on attractiveness has included a number of sub-projects based on on-board interviews with train and bus passengers. The attractiveness section also includes a review of scientific articles relating to assessment and choice. In addition to literature studies and interviews with professional railway experts, the work on services has included study trips. During these trips, a large number of relevant comfort parameters in non-Swedish trains were documented using measuring instruments transported by me.

The following mind map presents some of the most important working procedures in this thesis.

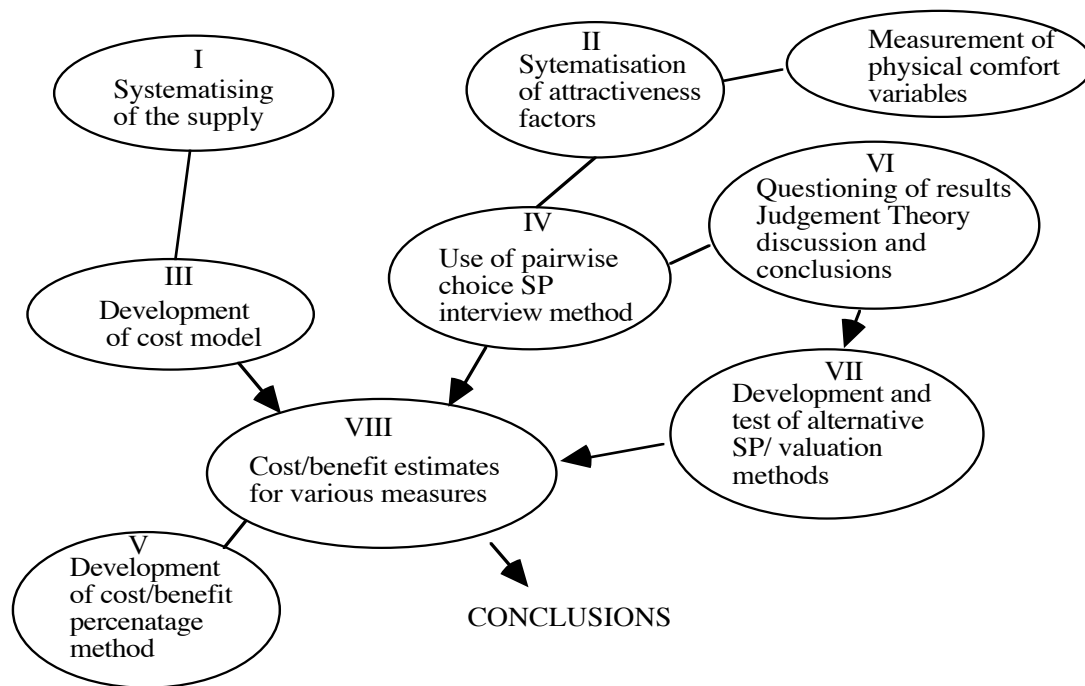


Figure 2.6 A mind map illustrating various parts of this project.

The project started in 1991 with a search to identify relevant problems while working on the competitiveness of passenger rail traffic. It was deemed necessary to structure both passenger train supply factors (I in figure 2.6)) and attractiveness factors (II). After some consideration, an economic dimension was chosen as the link between the supply side and the attractiveness side.

The cost of rolling stock and passenger train operation is central and an economic model was developed (III). It was used to calculate the price level for producing seat and passenger kilometres but also to investigate the relative cost of various measures. It is worth mentioning that the inputs of "real" cost figures to such calculations are not official, at least not from the Swedish operator, SJ. Therefore other ways have been used, see section 4.2.

When making cost estimates, it was of interest to investigate passengers' valuations for various measures. A number of interviews with train passengers were conducted in 1992-1998 using stated preference pairwise choices on portable computers (IV).

An easy-to-use cost/benefit percentage method were developed (V). The costs and valuations were used in cost/benefit comparisons (VIII). They show the marginal *relative cost in relation to the relative valuation* for each measure.

It was noted that packages of measures would not have the resulting additive value of all the individual measures. This was one of the reasons for going more deeply into judgement and choice theory (VI). Package effects have been investigated and alternative SP methods have been tested (VII). The alternative methods make it possible to make corrections for at least part of the package effect and the resulting wtp evaluations are used in the final cost/benefit appraisal.

The results of the SP studies have been questioned (VI), especially because the evaluations sometimes appear to be too high to believe intuitively. This is the main reason for learning about and taking account of judgement and choice theory. It is hoped that the inclusion of section 6.2 – Psychological knowledge of judgements and choices – will enhance our understanding of the complexity and potential when evaluating train concepts.

2.3.1 Own studies

Within the framework of this thesis, a number of sub-projects have been run, some of which took the form of MSc degree thesis projects. Most of these sub-projects have been presented in separate reports. Many of them have included interviews with rail passengers. During study trips, a number of comfort-related physical properties in passenger trains were measured.

The author has either conducted or been the supervisor in the following sub-projects, which are associated with the main project.

1. Evaluation of space standard in long-distance trains (Ostkustbanan), October 1992.
2. Evaluation of comfort in the new vehicles on the Roslagen Line, December 1992.
2. Changing trains, supervision (Pia Carlsson, MSc thesis), 1994.
3. Evaluation of InterRegio, Norwegian ICE and X10, Göteborg 1993.
4. Trains or buses with train interiors – a comparison in Blekinge between trains (Kustpilen) and spacious buses (Kustbussen), 1994.
5. Travelling by train in tunnels and over bridges, SP study, November 1995.
6. Reduction in valuations when evaluating train concepts – study of comfort, service and timetable packages using the Stated Preferences method, supervision of Lotta Schmidt (MSc thesis, 1995-96).

7. Passenger rail traffic on a small scale – where do we draw the line?, 1996.
8. Passengers' valuation of night train services (for the Botniabanan study), SP study, March 1996.
9. Svealandsbanan, (Lars Segerman, MSc thesis) 1997.
10. Are wide trains profitable – an evaluation of different seating arrangements using four methods, supervision (Pär Båge, MSc thesis) 1997.
11. Evaluation of BrainTrain, 1996/97.
12. SP interviews within the project entitled "Establishing new rail connections – like the Svealand Line", 1997, 1998.
13. Rail interviews on the Internet, (Karin Törnström, MSc thesis) 1998.
14. What does the general public know about travelling by train? A questionnaire study in Stockholm and Dresden, (Marcus Schubert, MSc thesis) 1998.
15. Evaluation of a large number of timetable, comfort and on-board service attributes, spring 1998.
16. Evaluation of InterRegioMax, a test coach with more seats, May-June 1998.
17. Evaluation of Bombardier double deck trainset, Nov.-Dec.1998.

Several of these sub-projects included interviews using the Stated Preference technique. During the interviews, a number of pocket computers (approx. 500 g) of the Poquet brand and the slightly larger HP Omnibook (1.3 kg) were used. The software comes from the Hague Consulting Group and comprises the MINT interview program and ALOGIT for evaluating the SP data. SPSS has been used for response statistics.

Interviews with rail passengers

Most of the information about people's evaluation of train services stem from interviews with existing rail passengers. They have been interviewed while travelling by train. The interview situation is good – people have time and they are close to the object(s) of the interview. The drawback is that existing passengers may be biased in favour of the train, compared with the average population.

The main tool for investigating passenger preferences and evaluations is stated preference interviewing. One of the standard measures included in stated preference interviews is a change in ticket price levels. For this reason, trade-offs between various measures and ticket prices can and have been made. The output is taste-weights, valuations or willingness to pay for various attributes or measures.

These taste-weights can be used in further modelling of the choice of travel mode, for example, but combinations with other data are needed. The willingness-to-pay figures can be used as an indication of the social value of improving trains and train services, at least for existing rail passengers.

To obtain a better understanding of passenger attitudes and preferences, the quantitative SP interviews have been supplemented with qualitative open-ended questions. One type is "What do you associate with the term "Kustpilen"? "

Stated preference and related methodology is discussed in Chapter 6.

Measuring the physical properties of rail vehicles

A number of small measurement instruments have been used primarily to measure comfort-related properties such as the distance between seats, noise, lighting and vibration. One of these instruments, a small vibration meter, was constructed specifically for this project. The instruments are as follows:

- Metal tape-measures and ultrasound-based distance meters, Accutape S
- Noise meters, made in-house and Brüel & Kjaer 2221
- Vibration meters, made in-house with filter curves calibrated at KTH. Shortly described in section 3.4.4.
- Acceleration meter clinometer from Silva (A sort of water level for sailing boats that measures inclination).

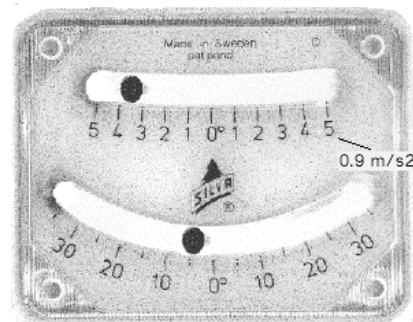


Figure 2.7 Clinometer from Silva

2.3.2 Other sources from which knowledge has been acquired

Research reports and analyses

Reports; the analyses and research reports which have been used can be found in footnotes and in the list of references.

Database searches

A database search which was made at the start of the project (1991) revealed that much of the work that is done on rail traffic and vehicles relates to a specific line or geographical area and is therefore of less interest. Nor does it appear that “rail vehicle design for market needs” is a common research subject.

On the other hand, the direct searches that have been conducted on the Internet in recent years and the searches of library databases via the Internet have produced a number of useful references, especially in relation to models for evaluating and identifying the demand for train services. The VTI’s Roadline database and the library database at the School of Economics in Stockholm have proved particularly useful.

Trade press

The most rewarding publications when it comes to obtaining information about vehicle development from a market angle have been: the *International Rail Journal (IRJ)*, *Railway Gazette International (RG)* and *Passenger Rail Management (PRm)*. These publications also deal with other issues of interest to the strategic development of the railways.

Eisenbahntechnische Rundschau (ETR), in which we have published two articles in German on the project in question, is a more technology/science-oriented publication.

Interviews

The following people have been interviewed using questions agreed upon in advance. They are listed according to their companies and then alphabetically. The main subject(s) studied are also listed.

Person(s)	Company	Subject
Jan Alexandersson	SJ, Passenger Traffic division	Vehicle development, needs
Lennart Gunnarsson	SJ, Machine division	Vehicle development, analyses
Karl-David Selin	SJ, Passenger traffic	Passenger traffic, strategies
Per Leander	SJ, Machine division	Vehicle analyses
Sven Malmberg	SJ, Passenger traffic	Traffic, quality etc.
Lars Tuveson	SJ, Passenger traffic	SJ's vehicles
Eriksson, Jönsson, Appelgren	TGOJ Malmö	Passenger vehicles
Heinz Kurz	DB Deutsche Bahn, Frankfurt	German vehicle development
Bo Östlund	Swedish National Rail Admin.	Travel forecasts
Juhan Janusson	Own consultant, formerly SJ	Travel market
Gösta Knall	FJT, formerly SJ	History of express trains etc.
Bengt Sonesson	Consultant (formerly SJ)	Traffic operation strategies
Tommy Gärling	Göteborg University	Evaluations/travel standard
Erik Bache, Henrik Sylvan	DSB staff	Danish rail traffic/strategies
Paul Böyum	NSB staff	Norwegian vehicle strategies
Hugo Surace, Fabio Buffa	FS (Italy)	Passenger train traffic/strategies
van der Sluis, Nieuwenhof	NS (Netherlands)	Market development/plans
Zoebeli	SBB (Switzerland)	International passenger traffic
Mr Smith (from BR)	ERRI (international)	Rail engineering research

Study trips

A two-week study trip was conducted in the spring of 1992 to study European passenger rail traffic in general and modern express trains in particular. The trip involved visits to Denmark, the Netherlands, Belgium, France, Spain, Italy, Switzerland and Germany. In 1993, this trip was supplemented by a short trip to Germany and the UK. During these trips, test journeys were made on most of the European express and high-speed trains (TGV, AVE, ICE, IC225, IC/3, Pendolino and Talgo). On all the train journeys, comfort-related vehicle parameters were measured using the measurement instruments described

above. The second trip also included a study trip together with SJ to two manufacturers, Waggonbau Görlitz and Talbot in Aachen, both of whom build double-decker trains.

Together with other members of the Railway Group at the Department of Traffic and Transport Planning, a few study trips have been made. They have included visits by rail researchers to the universities in Hannover (1994 and 1995), Braunschweig (1995), University in Delft (1995), EPFL in Laussane (1996) and Deutsche Bahn (DB) in Minden (1995) and Frankfurt (1996), SBB in Bern (1996) and FS in Rome (1992 and 1996).

In addition, a number of short study trips have been made in Sweden, Norway, Finland and the rest of Western Europe, often in connection with some other business, during which the range of train services has been studied.

Important trade fairs and conferences

The study trip in 1992 included a visit to a high speed train trade fair in Brussels, "Eurailspeed", at which most of the European trains were on display. In November 1994, a large part of my project was presented on a poster at the World Congress on Railway Research (WCRR) in Paris. The theme of this presentation was "Train Interiors and the Value of Space". The poster won the award for the best poster. At the WCRR in 1997 in Florence, the project was once again presented on a poster. In January 1998, the project was presented to the US TRB's "Committee on InterCity Rail Passenger Systems".

2.3.3 Publications

The work has been presented in working reports at the department, at conferences and in scientific papers.

KTH working reports

- KTH Meddelande 85, TRITA 93-10-93: *Marknadseffekter av satsning på ett nytt tågssystem- "Kustpilen" Karlskrona - Malmö, samt värdet av och kostnaden för tåg respektive buss med tåginredning*, written together with Christer Lindh, 1994
- KTH Meddelande 86, TRITA 93-11-96: *Evaluation of passenger car interiors: German InterRegio-cars, Norwegian InterCityExpress and regional X10-trains*, 1993
- KTH AR 94-11: *Tågresenärers värdering av inredning och utrymme i fjärrtåg och lokaltåg*, 1994
- KTH AR 94-13: *European high-speed trains 1993 - a personal report on comfort and facts*, 1994
- KTH AR 94-14: *Train interiors and the value of space*, 1994
- KTH AR 95-34: *Utvärdering av tyska och svenska interregionvagnar (1993/1995)*, 1995
- KTH AR 96-45: *Persontågstrafik i mindre skala - var går gränsen?*, 1996
- KTH AR 98-68: *Utvärdering av SJ's experimentvagn B20. Resenärers kvalitativa och kvantitativa preferenser av högkapacitetsvagn "IRmax" på olika linjer*, 1998

KTH Research reports

- KTH FR 94-3: *Framtida persontåg - fordonsegenskaper för ökad attraktivitet och effektivitet*, (licentiate thesis), 1994
- KTH FR 96-11: *Tågtrafikens möjligheter på den framtida persontransportmarknaden - Sammanfattning och slutsatser av hittillsvarande FoU inom Järnvägsgruppen vid avd Trafik- och Transportplanering KTH*, written together with Bo-Lennart Nelldal, Gunnar Lind, Stina Rosenlind and Gerhard Troche, 1996

KTH Railway Group reports

- Järnvägsgruppens publikation 9702: *Effektiva Tågssystem för framtida persontrafik - Analys av förutsättningar och möjligheter för attraktiv tågtrafik*, chapter 2 written by me, 1997
- Järnvägsgruppens publikation 9711: *Marknad, konkurrenskraft och trafikproduktion. Projekt mål, effektivitet och optimering*, 1997

KFB reports

- KFB rapport 1994:14: *Tåg eller buss med "tåginredning"? - en jämförelse i Blekinge mellan tåg (Kustpilen) och rymliga bussar (Kustbussar)*

Conference papers and posters

- KFB/VTI Transport Forum/forskardagar 1993: *Ansätser för att strukurrera och utvärdera olika tågsystems attraktivitet och effektivitet*
- KFB/VTI Transport Forum/forskardagar 1994: *En jämförelse mellan europeiska höghastighetståg*
- World Congress on Railway Research (WCRR'94): *Train interiors and the value of space*, poster (winner of best poster award) and text in conference documentation, Paris 1994.
- KFB/VTI Transport Forum/forskardagar 1995: *Effektivitet för dubbeldäckade/breda tåg*
- KFB/VTI Transport Forum/forskardagar 1996: *Persontåg i liten skala - var går gränsen?*
- Ålborg transport research conference 1996, *Attraktiva och effektiva persontåg*
- 23rd European Transport Forum (PTRC) 1995, *The value and cost for trains and buses (long distance coaches) with train "interiors"*.
- KFB/VTI Transport Forum/forskardagar 1997: *Attraktiva och effektiva tågkoncept*
- KFB/VTI Transport Forum/forskardagar 1997: *SP-värderingars beroende av reslängd och biljettpris*
- World Congress on Railway Research (WCRR'97): *Improving effectiveness and attractiveness for passenger trains*, poster and text in conference document, Florenz 1997
- KFB/VTI Transport Forum/forskardagar 1999: *Breda tåg för olika marknader - ekonomi och passagerarkomfort*, presented together with Bo-Lennart Nelldal

Scientific papers

- Transport Policy Vol2 No4, pp 235-241: *The value and effects of introducing high standard train and bus concepts in Blekinge, Sweden*, written together with Christer Lindh, 1995/96
- TRB: Transportation Research Record 1623, Public Transit; Rail, pp 144-151, *Passenger Train Design for Increased Competitiveness*, printed September 1998

Other publications

- Seminar about Fordon-Bana-Transportkvalitet (Vehicle-Track-Transport quality) Oct-92: *Buller, sidaccelerationer och vibrationer hos några europeiska tåg - stickprovsmätningar*, (Noise, lateral accelerations and vibrations for some European trains, in Swedish), not published.
- Passenger Rail Management, April 1995: *Evaluating train interiors and space*
- Eisenbahntechnische Rundschau (ETR) 7-8/96 (45)1996, *Innengestaltung von Reisezugwagagen – Kundenpräferenzen und Wirtschaftlichkeit*, written together with Gerhard Troche
- Eisenbahntechnische Rundschau (ETR), 1-2/99 (Jan/Feb. 1999), *Effiziente Zugkonzepte für den InterRegioVerkehr* - written together with Bo-Lennart Nelldal and Gerhard Troche, 1999

2.4 Delimitations

The project mainly addresses interregional passenger rail traffic and the vehicles used in these services. It focuses on vehicle qualities from the market and cost points of view. One central aspect is the attractiveness of passenger rail vehicles. This section states some delimitations.

This project as a whole does not aim to:

- estimate the demand for rail travel,
- assess the environmental and safety effects of rail traffic,
- treat geographical aspects on railway services, as different rail routes/rail networks and
- address short term production planning and vehicle maintenance.

In travel demand modelling similar methods are used and the results from my work may be developed further and used in demand modelling, but the aim at this stage just defines the benefit and cost of various measures. Environmental and safety effects are also left out because these issues are complicated and should be treated more seriously than could have been done in this thesis. The reason for not dealing with specific routes is to find more general results. The potential of efficient production planning and vehicle maintenance and also a lot of other activities related to passenger rail services are out of my competence.

The following areas, which are associated with this thesis, are being covered by other projects at the Department of Traffic Planning at KTH:

- Optimal traffic organisation (Gunnar Lind and Stina Rosenlind)
- Railway engineering (Professor Evert Anderson and colleagues, Railway Group of KTH)
- Different sub-projects within the "Efficient Passenger Rail Services for the Future" project at KTH
- Night trains. (Studied by Gerhard Troche²¹)

²¹ Troche, G., *Efficient sleeper train traffic – problems and prospects*, (in Swedish), KTH Traffic & Transport Planning, TRITA-IP AR 98-67, 1998

2.5 Layout of the report

This report is divided into four parts entitled A-D. Each part contains one or more chapters, which have been numbered 1-11.

Part A is an introduction. It has two chapters which deal with the background to the project and its purpose and present a brief description of the methods which have been used. A more detailed description and discussion of the different methods can be found in each chapter.

Part B deals with the range of services/trains and their cost. In Chapter 3, the range of rail vehicles is structured and the relevant aspects are described briefly. Chapter 4 contains a review of the average cost levels for purchasing and operating passenger trains.

Part C deals with travellers' evaluations. In modern demand models, the evaluations of individuals are used as parameters and, for this reason, a short review of demand modelling is given in Chapter 5. Chapter 6 takes a far more in-depth look at the way individuals evaluate attributes, such as different properties in trains. Chapter 6 is based on psychological knowledge of evaluations and choices and on practices within stated preference studies and the author's own studies of aspects associated with the stated preference method. One reason for this chapter being quite long is that doubts were raised about too high valuation figures for train related attributes. Parts of chapter 6 was then written with the prospect of finding explanations from the psychological research about judgement and choice. Chapter 7 presents the results of individual studies including SP interviewing within the framework of the main project. These results could have been presented as appendices, but the decision has instead been made to summarise them in English as a chapter in the actual body of the thesis. In Chapter 8, these results are summarised and compared with the results of other studies.

Part D focuses on cost-benefit analysis. The cost-valuation analyses in Chapter 10 are divided up according to the range structure presented in Section 6.8. Part D also contains a discussion of the results that have been obtained and the conclusions which should be drawn.

B. Passenger rail supply and costs

3. Structuring the vehicle supply

This chapter covers a number of characteristics of rail vehicles which affect the efficiency and attractiveness of trains. Many of the characteristics that have been included are designed to cover the standard factors mentioned in section 6.8 relating to the market. Many of these factors also influence the efficiency or cost of rail traffic. The selection has been made in order to include factors which are usually taken into account in different studies of attractiveness, i.e. travelling standard (timetable, comfort, service and quality), and efficiency, i.e. the cost situation. It's inevitable that the choice of factors to include in a compilation like this is somewhat ad hoc and also that the compilation may be too detailed in some respects and too approximate in others.

The chosen factors are classified and discussed in this chapter. The main division of vehicle characteristics, is presented in the next section. The following sections present the content under each heading. About a few aspects, some specific findings from this project are presented.

Division of vehicle characteristics

To make the structure of vehicle characteristics easy to comprehend, these characteristics have been divided up in a specific way. The main division is as follows: Exterior train configuration, interior use of space, design, performance, auxiliary systems and technical quality.

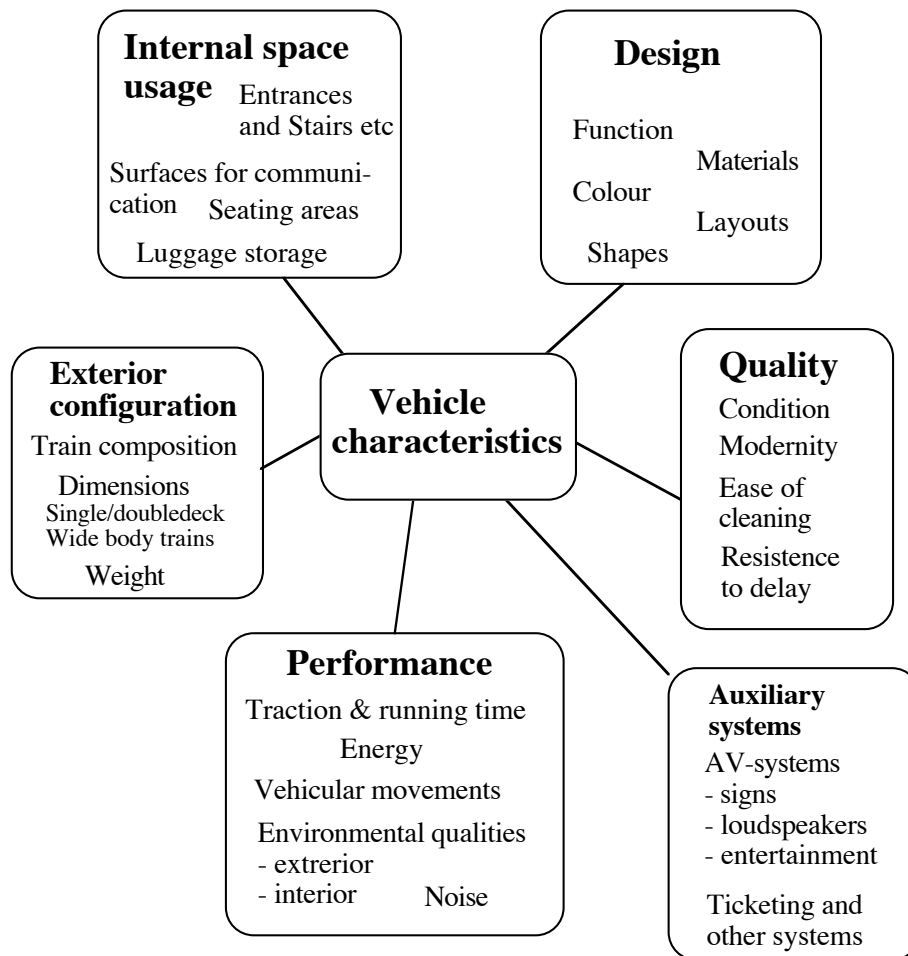


Figure 3.1 Main division of different vehicle characteristics in this project.

The above division will be defined more precisely in the sections following. Each section is fairly comprehensive. The sections include both reports of facts and analyses of different characteristics. The results of these analyses can be used as a basis for the reader to make his own assessments but also for additional analyses of benefit/cost characteristics, for example.

3.1 Exterior train configuration

Exterior train configuration includes aspects such as main measurements, i.e. the length, width and height of the train, as well as its weight (mass). The composition of the train, i.e. the number of passenger cars and possibly locomotives, as well as whether or not the vehicles are double-deckers, is also included here.

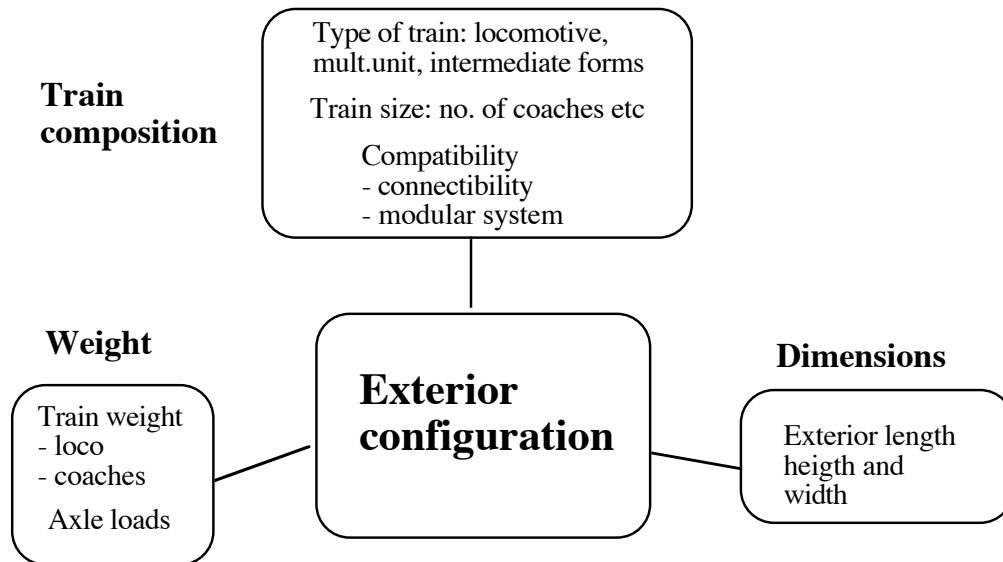


Figure 3.2 Division of factors relating to the exterior configuration of trains.

Trains can be made up of locomotives, coaches of different types and motorised units in different train compositions. The way in which trains can be put together or composed is one of the main issues in this project.

The exterior dimensions of a vehicle are important, as there are limitations when it comes to the areas in which they can be used – the vehicle must comply with the prescribed loading gauge related to the infrastructure. The dimensions of course also affect the weight, air resistance and energy consumption of the vehicle either directly or indirectly.

3.1.1 Train composition

Train types - proposed division structure

Passenger trains are traditionally divided into locomotive trains and multiple unit trains, but the division is not sufficient. Figure 3.3 is an attempt to systematise different passenger train systems. Freight trains have been included because so-called *mixed trains*, which are both freight and passenger trains, are sometimes used.

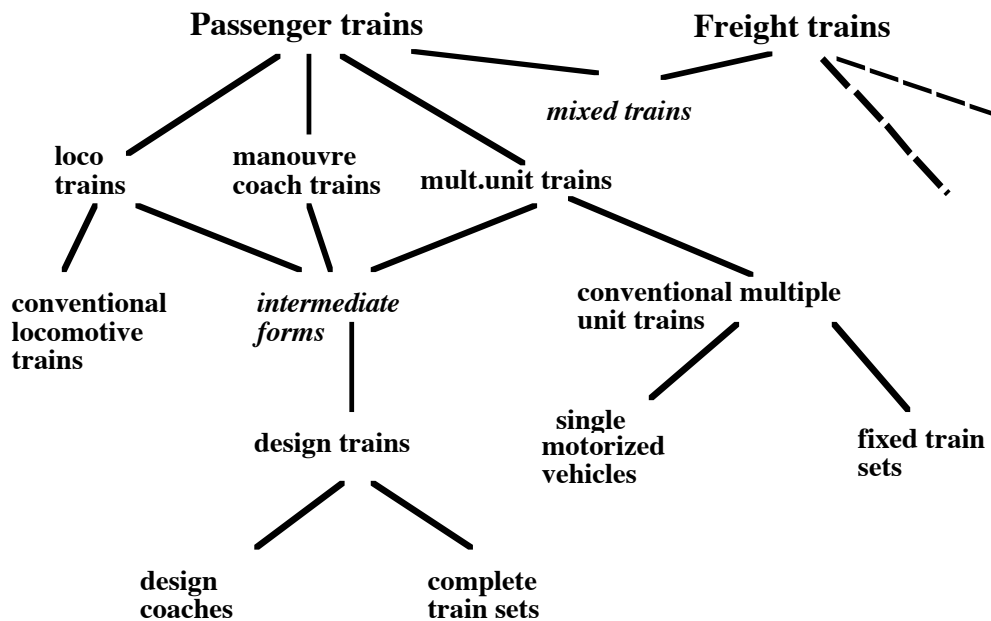


Figure 3.3 Proposed categorisation of passenger trains of different types. The division into locomotive trains and multiple unit trains is not sufficient for all the train system versions which are currently in use.

Some categories are new. They have been introduced to explain the difference between the different types of trains which are in use.

Table 3.1 A few proposed definitions for the categorisation of passenger train types.

Design train	A type of train which has been technically designed and developed with a uniform design, i.e. cross section, function and colour scheme. One example of this type of train is the Talgo unit when it is pulled by it's designed locomotive.
Design coaches Design cars	Coaches/cars which have been given a technical design and colour scheme which matches. Examples of these coaches include the Talgo unit (when it is pulled by a different locomotive) and S-Bahn cars in the Ruhr area.
Complete design	Complete trains, i.e. coaches and locomotives, which have been given a function, design and colour scheme which match. These trains include the X2000, the TGV and so on.

One term which it may be practical to retain is the *conventional locomotive train*. This consists of a locomotive which can be connected to most of the freight and passenger cars operated by the railway companies in any country, as well as vehicles which can be connected in virtually any order in technical terms. Most Swedish passenger trains (1991) (and freight trains) can be included in this category: they include InterCity trains.

The other type of train could be defined in a correspondingly simple manner as the *conventional multiple unit train*. This is a passenger train in which one or more of the

passenger vehicles are powered, where powered and non-powered cars look similar and where both types are used for passengers. These cars are not designed to be connected to vehicles of other types and they are more or less permanently joined together.

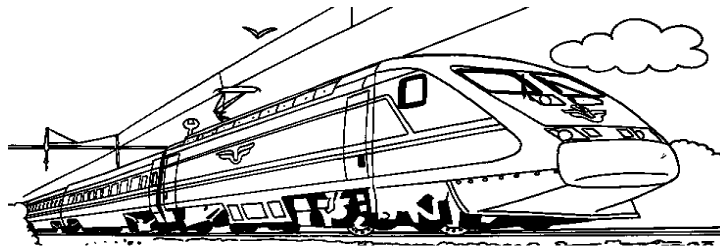


Figure 3.4 The Swedish X2 (X2000) trainset is an example of intermediate train type; a "design train".

It is possible to attempt to place existing train concepts on a scale starting with locomotive trains and ending with multiple unit trains, but there are special systems which make the results less than uniform. In spite of this, an attempt to divide up European high speed trains using two dimensions now follows.

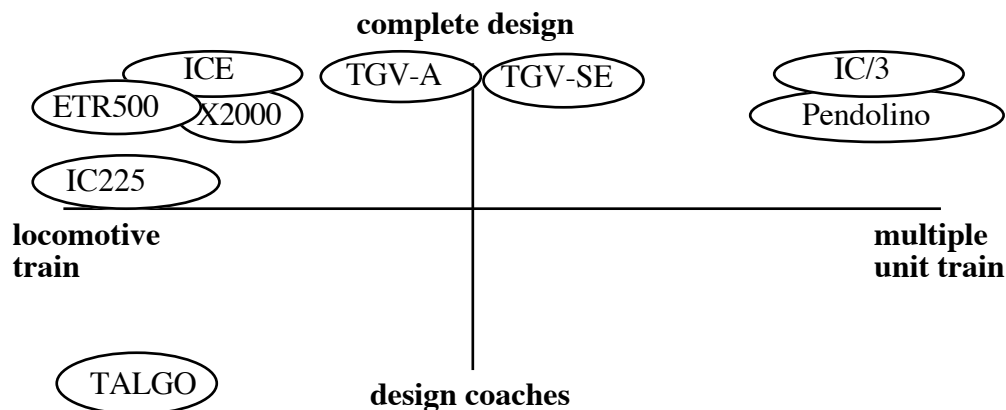


Figure 3.5 Division of European express and high-speed trains..

The four train types at the top on the left, not the TGV, consist of one or two locomotives (power units) and four-axle intermediate cars. The TGV, IC/3 and Talgo are permanent train units with bogies/axles between relatively short cars. The TGV-SE has propulsion equipment not just in the locomotive but also in the first coach bogies next to the locomotives, which the TGV-A does not need. The IC/3 and Pendolino have several axles powered, while the Talgo is a unit of multiple cars without propulsion which can be pulled by standard or specially-designed locomotives.

For those readers interested in the development of high speed trains I can recommend the books "The world high speed train race" by Hughes²².and "High Speed Trains"²³.

²² Hughes,M., *The world high speed train race*, (Swedish translation: Högfartståg, Frank Stenvalls förlag), 1988/1990

The exterior train configuration of a number of modern European fast and high speed trains are shown below. Many of them can be classified as design trains.

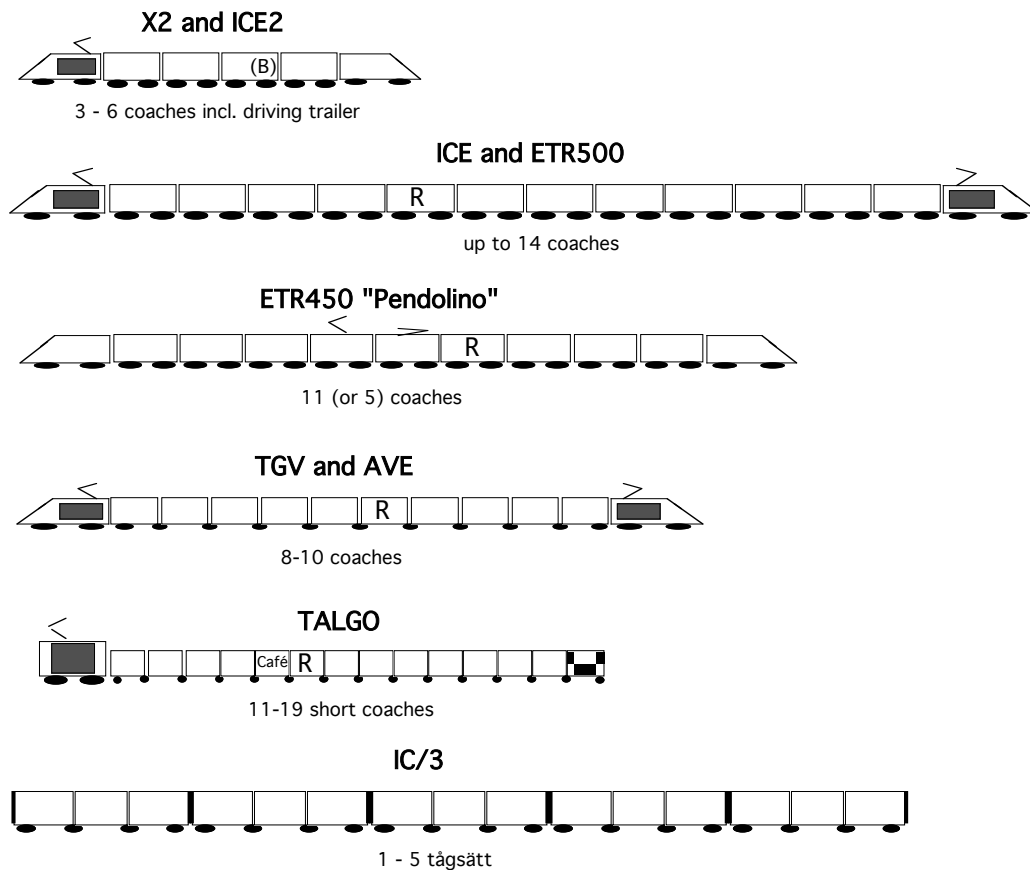


Figure 3.6 Exterior train configuration and size of different European express trains.

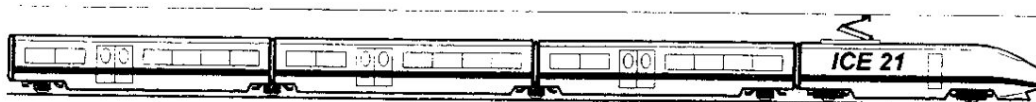


Figure 3.7 German outline of a future high speed concept; a loco-hauled "complete design" train²⁴.

²³ Whitelegg, Hultén, Flink (edit), *High Speed Trains - Fast tracks to the future*, Stockholm School of Economics, Leading Edge Press & Publishing, ISBN 0-948135-45-X, 1993

²⁴ Technologiträger ICE21, Forschungsinformation Bahntechnik, *Eisenbahntechnische Rundschau* (ETR), ETR 44 (1995) H.1-2, page 228, figure 2, Jan/Feb. 1995

Train size

The size of a train should be determined by many different factors. They include: the number of passengers, train frequency requirements and restrictions relating to track capacity.

The sizes of European fast/ high speed trains are illustrated in the following table.

Table 3.2 Size of European fast/ high speed trains²⁵.

Train type	Number of cars	Number of locomotives	Length (approx.)
X2 (X2000)	(4-) 6	1	165 m (max)
IC/3 (Denmark)	3 per train unit(set)	0	60 m
ICE-1 (Germany)	9 - 14	2	410 m (max)
ICE-2 (Germany)	6	1	≈175 m
TGV-SE/ Thalys/ TGV Duplex ²⁶	8	2	200 m
TGV-A	10	2	240 m
AVE & TGV-R & 2N	8	2	200 m
Eurostar	18	2	393 m
Talgo Pendular	11-19	1 (in addition)	145-250 m +loco.
ETR450/460 Pendolino	11/9	0	290/240 m
S220 (Finnish Pendolino)	6	0	159 m
ETR500 TAV (Italy)	8 - 14	2	400 m (max)
IC225 (UK)	10	1	250 m
BM71 (Norway)	3	0	82 m

The table shows that the existing high speed trains are quite large.

In the KTH project "Efficient Passenger Train Systems"²⁷ the design, use and profitability of smaller trainsets have been preliminary studied. The conclusion so far is that small trains in frequent services can be justified. As small units as one vehicle trainsets, designed for about 250 km/h, should be further considered. The capacity of a four axle wide body high speed EMU could be about 90 seats. See also section 4.4.4.

²⁵ Various sources e.g.: La carte d'identité des matériels exposés, *La Vie du Rail*, No 2514, pp 16-20, October 1995

²⁶ Bilevel version TGV 2N

²⁷ Railway group KTH, Andersson,E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik*. (Efficient Passenger Rail Services for the Future, in Swedish – English version is underway, 1999), KTH Railway group report 9702, 1997



Figure 3.8 Wide body four axle EMU.

Compatibility/ Connectability

In Europe, manual screw couplings combined with buffers for the transfer of propulsion forces are generally used for conventional trains. The brakes are operated by a compressed air system throughout the train. The widespread use of this system enables virtually all railway vehicles to be connected to one another. The cars are “modules“ in a system in which the various parts can be combined with virtually complete freedom. Thus far the situation is positive.

Some railway vehicles, such as motorised cars and ore wagons, have an automatic coupling. The advantage of an automatic coupling is that it is faster to both connect and disconnect trains and that less staff is required. An automatic coupling of this type will probably be essential in future trains which are going to be split up at intermediate stations.

One interesting innovation can be found in the Danish IC/3 train. It has an automatic coupling and a new type of gangway between different train units. This gangway consists of large rubber bellows which act as a pedestrian connection and climate protection. When two train units are connected, these bellows make it possible to walk on the inside. According to information from SJ, it takes approximately two minutes to connect two IC/3 trains. By way of comparison, it takes approximately ten minutes to disconnect a standard passenger coach from one train and connect it to another train using a shunting engine.

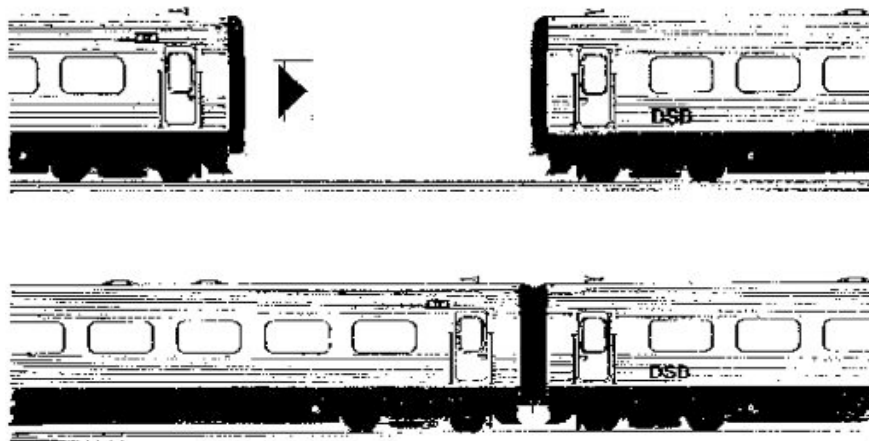


Figure 3.9 Two IC/3 trainsets connecting, which takes a few minutes.

The inflatable rubber intercommunication gangway developed for IC/3 is also used in e.g. Belgian AM96 coaches²⁸. These form EMU trainsets with some similarity to the modular train system outlined in the following section.

²⁸ AM96 continous SNCB upgrade, *Passenger Rail Managemant*, p.6, February/march 1996

Other benefits from having good connectability by effective gangways is that:

- passengers can be easier distributed to free places in the train,
- catering areas can be saved and
- number of on-board staff can be reduced.

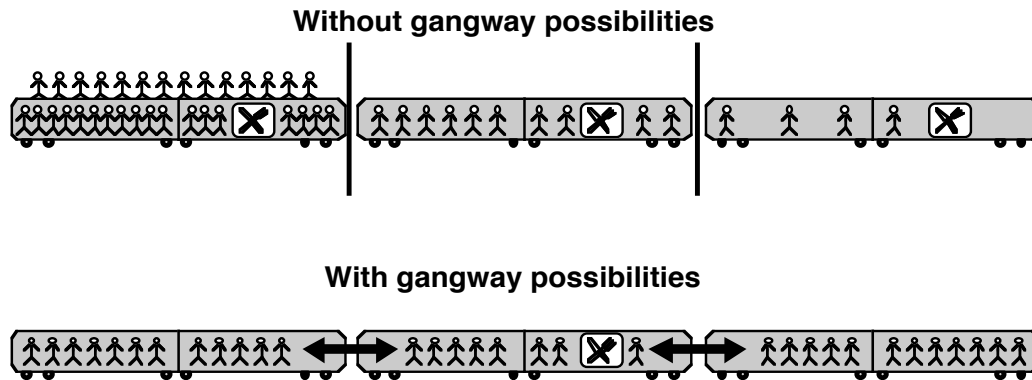


Figure 3.10 Positive effects of gangway possibilities between train units

A proposal for the division of connectability into seven levels, where level 1 represents the highest degree of connectability, is shown below. In this case, connectability relates to the opportunity to connect units to many other vehicles, not to the speed or the ease of connection (“no complexity”).

Table 3.3 Proposed division of connectability

Level of connectability	Linking cars/ units
1.	Screw coupling, buffers and standard brake system and transition
1a	Like 1 but with a different brake system
1b	Like 1 but with extra cables for auxiliary power or signal transfer
1c	Like 1 but a non-standard gangway between cars
2	Central coupling according to some standard - “all with all”
3	Central coupling of some standard type, without extra cables or hoses between cars
3a	Like 3 but with extra cables or hoses to connect
4	Special coupling for certain train (vehicle) types
4a	Like 4 and with special gangway (like the IC/3 or its equivalent)
5.	Semi-permanently connected cars - “short coupling” (variable number of cars)
6.	Permanently-connected cars - e.g. “married” pairs of cars (fixed number of cars)
7.	Trains with “felles bogies”, Jacob bogies (like the TGV, IC/3)

Most multiple unit trains or intermediate forms are of type 4-7.

Modular train system

The traditional loco-hauled train has some advantages over the size-locked multiple unit train. Essentially all the vehicles may be linked to all the others in order to put together a train of just the right size and function. An interesting solution is building a new modular system consisting of various coaches, locomotives and multiple units.

In this case, modular system means *a system of vehicle units which can be connected to create trains which are feasible for use as passenger trains in specific cases*. It goes without saying that the factor known as connectability, which has already been dealt with, is important, but there are also other important factors, such as compatible multiple operation (propulsion, braking etc.) and sufficiently uniform design. An illustration of the types of vehicle which could be used in a modular system follows below.

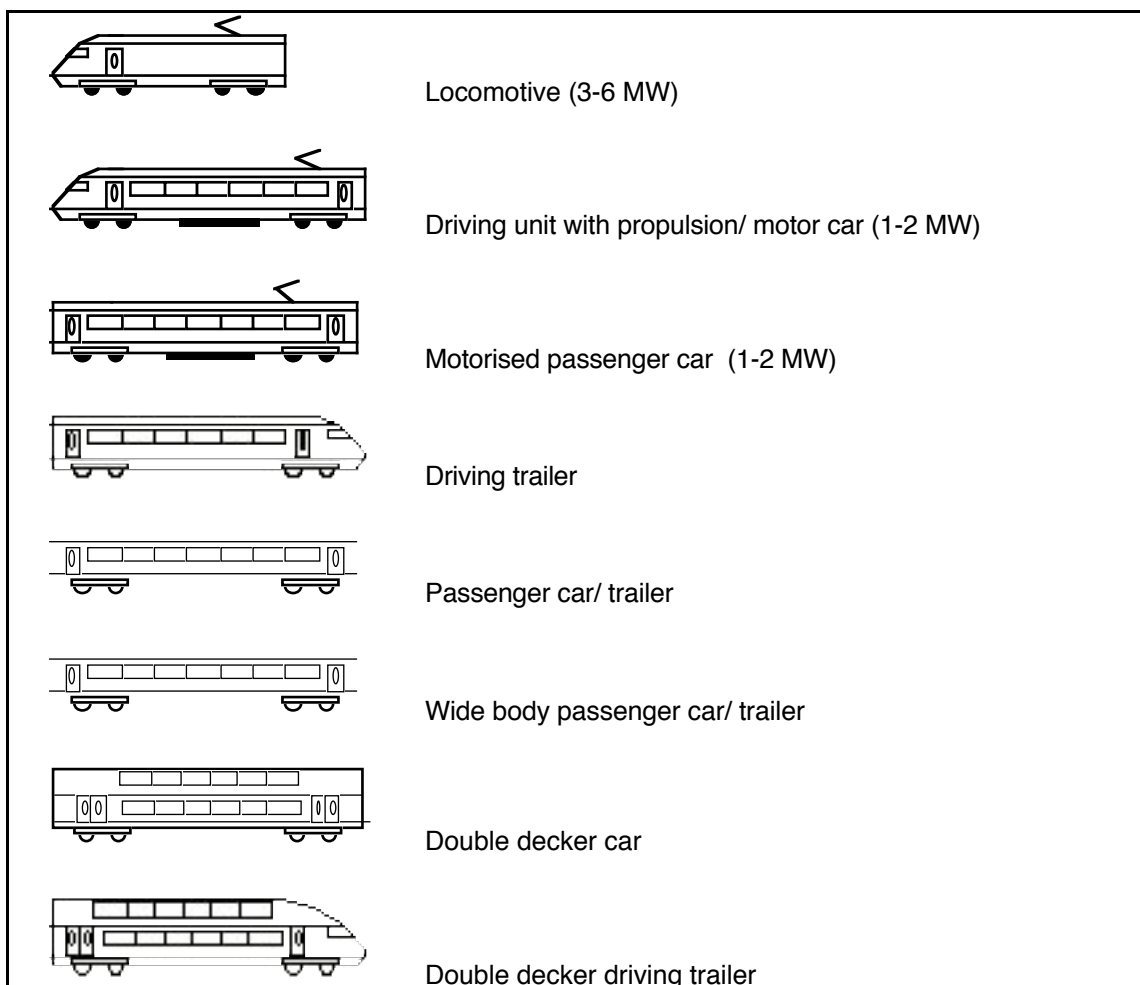


Figure 3.11 Examples of vehicle units in a modular system..

Using the different modules (vehicle units), it is possible to put together short and long trains of varying capacity. The smallest train consists of a motorised unit and a driving trailer. It has 140 seats.



Figure 3.12 A strong Swiss motor coach hauling passenger coaches.

A very large train consists, for example, of 12 double-decker coaches with a locomotive at each end. This train may have as many as 1500 seats. Coupling of vehicles should be a quick thing handled easily by regular train staff. The IC/3 front is the most intelligent device so far!

In order to haul long trains it may be economically sane to use a locomotive. The most modern loco of today owns up to about 6 MW (6.000 kW) of power and manages to get up over 200 km/h. But it is a waste not to put passengers in the propulsion unit of short trains. – There is a need for a strong motor-coach. In Switzerland, for example, electric motor coaches of 2 MW are pulling regular coaches. At the other end of the train one may have a driving trailer, or in the case of a longer train, an additional locomotive or motor-coach.

All the vehicles can be connected to (almost) all the others. The principal benefit of a modular system is that it creates an opportunity to make the production of train traffic more efficient. It also offers greater flexibility when conditions change, compared with conventional multiple unit trains, for example. This flexibility is characterised by the following factors:

- It is possible to create trains of exactly the right size for different journey types.
- It is possible to follow weekly and seasonal variations by varying the number of vehicles.
- It is possible to follow long-term demand changes by purchasing (or selling) some additional vehicles.
- It is possible to vary the comfort and service offered by the train by connecting different types of vehicles.

There are also disadvantages to the modular system described above. It can help to preserve old-fashioned technology, if modular systems with a screw coupling were to be built, for example. It can make it difficult to create a design which is cohesive and/or attractive to customers. The smallest trains could be more expensive, compared with trains with a propulsion system which has been designed specifically for them.

Compact express trains and cruise trains

Using the market dimension (7.1) and the problems which have been described in this project as the starting point, the following train types are proposed for further consideration:

* *Compact express trains* which are generally used for day trips with a journey lasting between one and three hours

* *Cruise trains* for longer trips where the train is unable to compete on the basis of speed

The compact express train needs to have many seats in its total area in order to maintain low costs for people who commute by train. This should not, however, have a negative effect on legroom or the opportunity to work on board the train. Savings should instead be made on other types of space. Like a cruise liner, the cruise train has special areas for a cafeteria, restaurant, bar and/or cinema, for example. It should be easy to move about on board this train. The studies in this project have, however, revealed that the requirements imposed on the size of seats are no more rigorous for leisure travellers than for people travelling to work - rather the reverse.

The compact express train and cruise train can consist of entirely different vehicles, but it would also be possible to create them from different units in a modular system like the one described above.

3.1.2 Train weight

Trains are generally heavier than cars, buses and aircraft, when measured in relation to passenger area. The reasons for this include the fact that train vehicles have to be connected together and have to withstand the forces which are then created and that passengers have to be able to survive in the event of a collision.

A typical four-axle locomotive weighs 80 tonnes and a passenger coach weighs 40 tonnes, rounded up to the nearest 10 tonnes. A long-distance train weighs in the order of one tonne per seat. An interesting international comparison of specific weights and space utilisation key ratios and associated design issues was presented by Gärtner²⁹.

Trains' specific weight can be compared with a country bus which typically weighs in the order of 250 kilos per seat. The difference in weight in terms of useful passenger area is not as great. A locomotive train (five coaches) weighs approximately 650 kg/m², while a normal long-distance bus weighs 400 kilograms/m². The differences are illustrated by the following figure.

²⁹ Gärtner, H., Passenger trains in Europe (in German), *ZEV+DET Glas. Ann*, 118 (1994) Nr. 11/12, pp-490-497, Nov./Dec. 1994

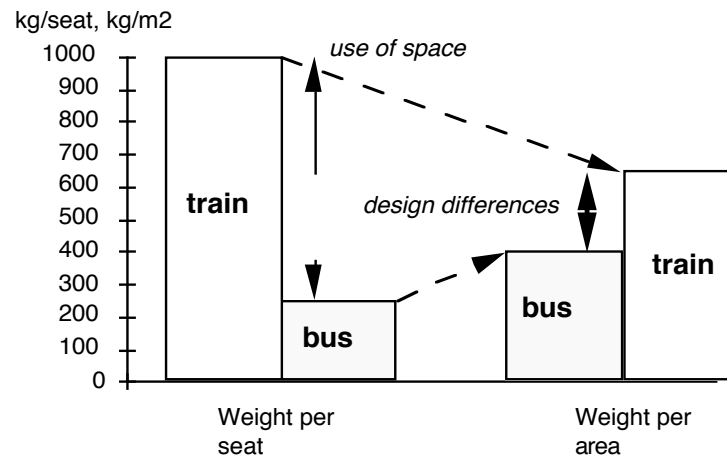


Figure 3.13 The weight of passenger trains in relation to long distance buses (coaches). The weight of the train is based on a loco-hauled train with five Swedish passenger coaches (45 tonnes, just over 3 metres wide, 26 metres long).

Conclusion: the main problem when it comes to weight is mainly not the weight as such but how the vehicle with its weight and area is utilised.

3.1.3 Exterior dimensions

To begin with we look at what dimensions which constitute the limits for how tall and wide a vehicle can or may be built.

Length

Most modern passenger cars are around 26m long and they rest on two-axle bogies. Coach bodies that rest on Jacobean bogies cannot be made of equal length, because then they may not fit into the infrastructure's inside limitations.

Loading profile:

The loading-gauge limits the width and height of railway cars and their load that one is allowed to transport on railway. It is somewhat different on different railways. In Sweden and Norway a greater width, 3.40 m, is permitted above 1.20 m over r.u.e. (rail upper edge), while many of the countries in Continental Europe – Denmark and southwards – allow 3.15 m from 0.43 m to a height of ca 3.5 m. The permissible height is 4.65 m (except in e.g. Norway and on Malmbanan, "the Orelane", where 4.35 and 4.30 m respectively are permitted). It has anyhow been decided to enlarge the loading profile because of the importance for rail freight economy.

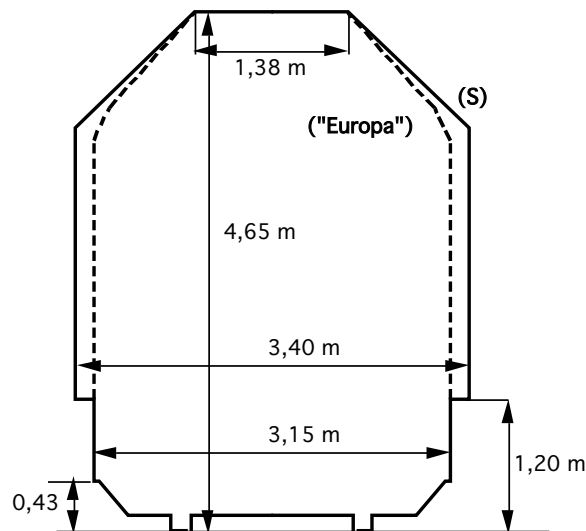


Figure 3.14 Swedish loading gauge³⁰ and European ³¹(dotted) .

The permitted vehicle gauge is smaller than the loading gauge. The normative vehicle is the starting-point one has in Sweden for dimensioning of rolling stock. It is an unsuspended vehicle with two-axle bogies with the car body on fixed revolving-centres. The vehicle is 24 m long with 18 m bogie distance.

Width:

For two reasons, one that the loading gauge must not be exceeded in curves, where parts of the body cause a wider sweep, and two a dependency on the margin of the suspension-movement, the entire cargo-profile cannot as a rule be used as vehicle-width. The same reservation applies to cars with a body tilt. When dimensioning vehicles one may start thinking in terms of a "tunnel" of certain dimensions, which UIC is known to do, or in terms of a normative vehicle that can be in service on the railway-net in question.

In Sweden most passenger-coaches are about 3.1 metre wide externally. The coaches from the 60s, which are 24 metre long, use almost the entire width permitted; they are 3.14 m wide.

Extra wide trains

In Continental Europe the passenger-coaches are 2.8-2.9 metres wide but many new vehicles are wider. According to UIC (the International Union of Railways) regulations passenger coaches of 26 m length are allowed to be 2.80-2.85 m wide. Shinkansen in Japan has even wider trains; 3.4 metres. The advantage, among others, is that this allows five seats side to side. The Danish State Railways has developed and introduced local trains that are 3,6 metres wide and facilitate six seats aside.

NSB in Norway has a sleeper coach in service that is 3.24 m wide and 27 m long.

³⁰ *SJ frakthandbok* 1986-11, figure F25

³¹ UIC 505 [N11] leaflet

There are even examples on wide body trains in European continental countries, where UIC regulation are often used:

Table 3.4 Examples of existing train types with wider bodies.

Denmark	S-banetåg ³²	3.60 m
Denmark	IC/3	3.10 m
Germany	ICE	3.07 m
Holland	SM90 (wide body) ³³	3.20 m
Japan	Shinkansen	3.38-3.40 m

The reasons for wide car bodies are not always to increase capacity. In the German ICE trains, increased comfort – wider interior dimensions – was the reason.

Adtranz in 1998 developing an EMU vehicle platform for 3.45 metre wide trains for Scandinavian markets. It is intended for fast regional services and is planned for 2+3 seating in second class and 2+2 (or 2+1) seating in first class³⁴.

DB (Deutsche Bahn) is now investigating even wider trains; new generation trains about 3.30 metre wide³⁵.

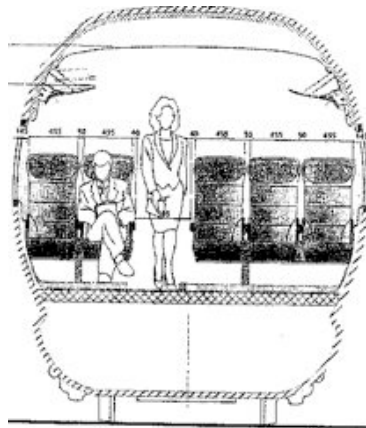


Figure 3.15 An outline for 3.3 m wide future German ICE trains (reference; see text).

³² DSB's first S-tog delivered, *Passenger Rail Management*, p.5, February/march 1996 (Brochures and other sources also used)

³³ Blair, I.F., SM90 aims to keep life costs low, *Railway Gazette International*, pp.548-550, August 1991, and

Stelwagen, T.J., NS builds to handle traffic boom, *Railway Gazette International*, pp.548-550, August 1993

³⁴ Adtranz, information material

³⁵ Kurz, H.R., Reemtsema, K.-D.; Anforderungen an die Technologieentwicklung des Systems Eisenbahn aus der Sicht eines zukunftsorientierten Fahrplans (Demands on technological development of the railway system from the standpoint of a future-oriented timetable, in German), *Eisenbahntechnische Rundschau* 46, (1997), p.422, H.7/8 Juli/August, 1997

Height

Ordinary passenger-coaches are often 4+ metres high. UIC-coaches are 4.05 metres high. Swedish coaches of the 1980s are 4.40 m. The floor-level is at ca 1.2 m over the rail. The profile allows a 4.65 m height. New double-deckers are often about 4.60 m high, and that height is probably needful for a comfortable double-decker.

Fast trains (which are not double-deckers) are lower than regular Swedish passenger-coaches; X2 is 3.80 m, ICE is 3.84, and the coaches of TGV-A is 3.48 m. Also in Japan the vehicle height of new fast trains is fairly low.

Carbody tilt limits the possibilities to build wide vehicles, while the body runs the risk of coming outside of the profile when it leans. In particular it limits the possibilities of constructing a double-decker with body tilting.

Trains with two levels – double deckers

There are several reasons that speak for double-deckers and of course also some that do not:

- + Up to about 50% higher capacity; furnishable space per metre of length.
- Interior stairs are needed.
- + It is feasible to make a horizontal instep to the lower level.
- The ticket collector cannot pass through the entire coach in one go.
- Difficulties with food trolleys (can be solved).
- The carbody tilt becomes unfeasible since the upper level becomes too narrow.
- + Environment reason – lower consumption of energy per passenger.
- + It is possible to use the upper and the lower level for separate purposes.

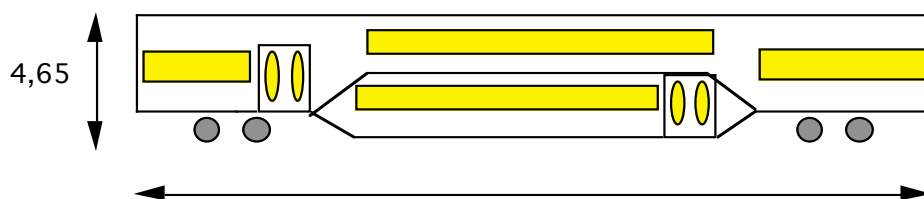


Figure 3.16 An example of a two-storied coach. The doors are often located like the left door. By instead situating at least one door in the lower level a level boarding entrance with ramps can be achieved.

The main reason for including double deckers in this study is the potential of lower cost per furnished area. A very critical index then is how much extra furnishable floor space there is in comparison to a comparable single decker.

Example of double decked trains in Europe

There are many examples of double decked trains in Belgium, Holland, France, Germany, Italy, Spain and Switzerland. The trains are used mostly for commuting and often have 3+2 furnishings, but there are exceptions.

New double decked TGV-trains *TGV-2N* have 520 seats in eight intermediate coaches in lieu of 386 seats in a single-decked TGV-SE. They run up to 300 km/h.

One of the most interesting ventures is made by the Swiss train-companies, which bet heavily on double-decked Inter-city-trains for 200 km/h. The trains have complete upper apartments with transit between coaches on the upper level. The S-Bahn-trains around Zurich consist for ten years now of double-decked "design-trains".

A double-decker design is being used in modern German-Swiss night-trains.

A two-axle, double-decked railbus with two levels straight through, was presented in Germany in the spring of 1994. The idea for the coach was first sketched on a napkin by the head for the German railways Hans Dürr³⁶. It has the following data³⁷:

Length:	16 m
Height:	4.6 m
Kerb weight:	22 ton
Number of axles:	2
Maximum speed:	100 km/h
Number of seats:	100 (77 - 118)



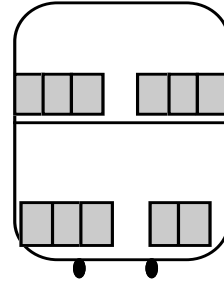
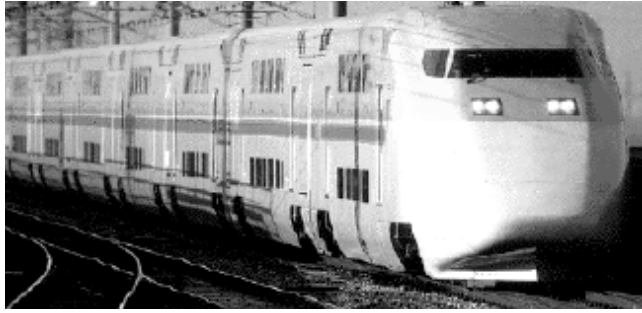
Figure 3.17 DWA double decked railbus prototype

In Japan the Shinkansen series 100 has two cars per train set that are double-decked. These have first class "Green Car" in the upper apartment. In the lower apartment there is in one of the cars a deli-shop and conference-cabins. Two high capacity Shinkansen, intended for business-commuting, have been brought forth by JR East. In some of these cars seats 3+3 are offered³⁸.

³⁶ From serviette to prototype in 6 months, *International Railway Journal*, p.33, June 1994

³⁷ Brochure from DWA 1994, articles in IRJ June 94 plus Stadtverkehr 6/94.

³⁸ Doppelstöckiger Shinkansen, *Eisenbahntechnische Rundschau*, 43(1994) H.10, p.628, October 1994



Figures 3.18 Photo and cross section of double decked Shinkansen.

Conclusions regarding vehicle exterior dimensions:

Increased width as well as height renders the opportunity to get an increase of the interior area. It ought to be feasible to offer a service with 3.3 – 3.5 m wide coaches in Scandinavia and hopefully even in parts of Germany.

3.2 Use of interior space

This section deals with physical factors which are to some extent associated with travellers' experience and the "benefit" of the train, as well as factors relating to train economy.

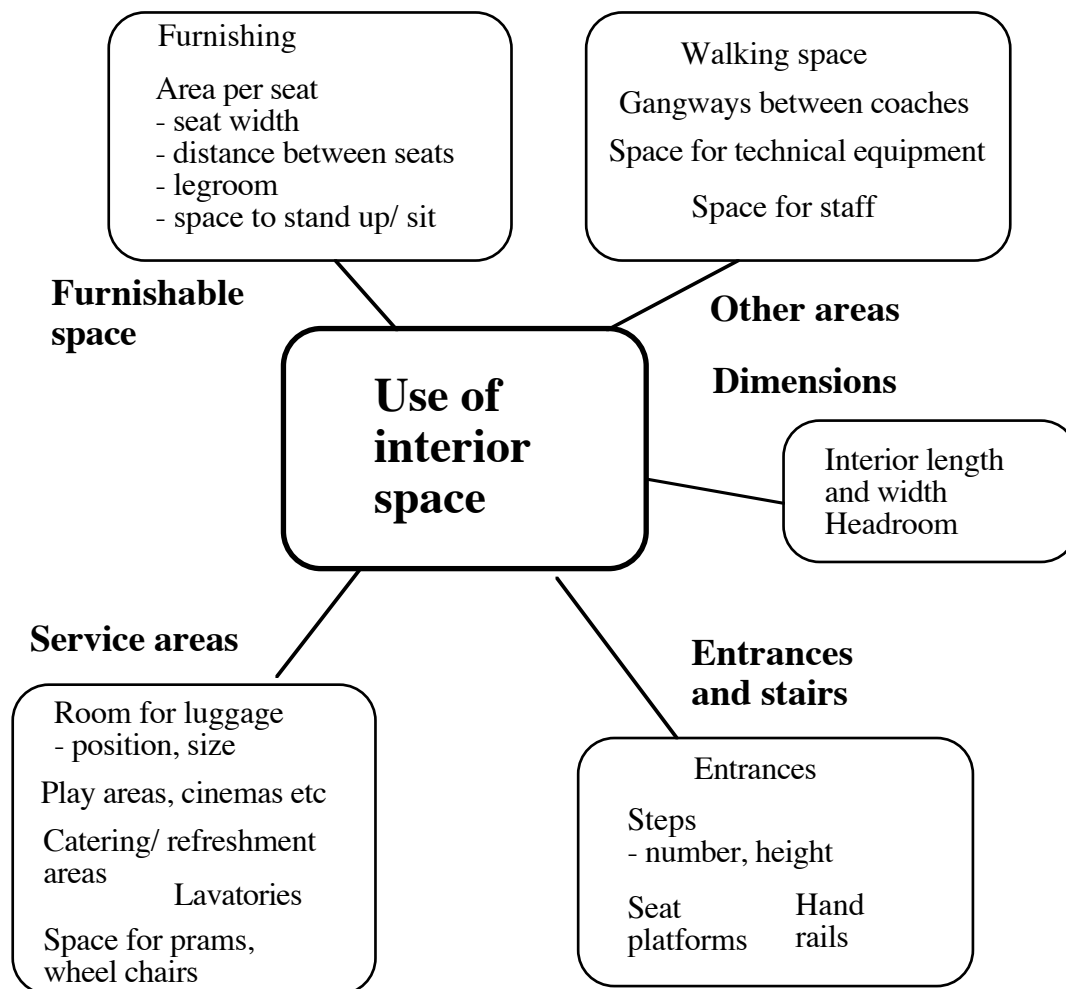


Figure 3.19 Factors relating to the use of interior space in passenger coaches.

The purpose of systematising the use of interior space is to show and compare the way this space is used in current vehicles and to obtain measurements which are easy to use in comparisons of (cost)effectiveness and standard.

The dimensions relate to the main interior measurements, the length and width between the inner walls and inner height.

Differences in level and stairs can cause problems for some travellers and this can result in boarding and disembarkation taking longer time. Data relating to these factors is therefore important. This data also includes entering the vehicles, including the number of entrances and their location.

Seat design has an important effect on comfort and on the economy of rail traffic. A simple seat is inexpensive to produce, or to offer to customers, but it may also help to scare away customers, thereby reducing the company's income.

The use of floor space affects the economy of rail vehicles and their characteristics, i.e. the usefulness of trains in different types of traffic. This space can initially be divided into *furnishable space, service space and other space*.

3.2.1 Interior dimensions

The interior length multiplied by the width represents the maximum space available for use. In certain comparisons, this data may be relevant - for local trains which are planning to carry standing passengers, for example. The length should then be measured where the inner wall at the end of the coach finishes; in other words, the length of the gangway between two cars should not be included (unless it can be furnished, as is the case in an articulated long-distance bus).

Many passenger cars are slightly arched and, as a result, the width of the coach should be measured at approximately "elbow height" - 0.6 to 1.0 metre above the floor, for example. A large width is required at this height, as this is where the trunk and arms of a seated passenger are located. This fact is used by the KTH Railway Group's proposal for wide body EMUs.

The interior width is often 0.2 - 0.3 m less than the exterior width, as a result of the thickness of the walls. This thickness is in turn due, among other things, to strength requirements, insulation and heating systems. In long-distance buses, low windows sometimes extend the width available for use.

Table 3.5 Examples of interior widths in passenger rolling stock

Coach type	Approximate interior widths
Y1 (UIC-gauge)	2,76 m
X10/X12 EMUs	2,93 m
X2 ("X2000")	2,78 m
Swedish 1960s coaches	2,94 m
Swedish 1980s coaches	2,84 m
UIC passenger coaches	2,65 - 2,70 m

UIC coaches are usually furnished with 2+2 seats side by side. To fit 2+3 seats side by side using the same seat and aisle width, the width of the coach would have to be increased by 0.5 m. In round figures, this would result in an interior width of 3.15 metres, which is 0.15 m more than the width of current Swedish passenger coaches. (Using somewhat narrower seats, even UIC coaches can be furnished with 3+2 seats side by side.)

There are some international rolling stock developments (besides wide or double deck train concepts) where an increase of space utilisation is in focus. The most striking

example regards trains for London's underground³⁹. The new "Space Train" is an articulated concept with small diameter wheels where the usable length has been increased. The number of passengers per train is estimated to increase by 45%.

Furnishable length in double-deckers

A number of double-deckers have been compared with Swedish passenger coaches in terms of their furnishable length by measuring drawings. The results are as follows.

Table 3.6 Furnishable length in relation to car length in a Swedish passenger coach and in double decker cars

Car type	Furnishable length/ car length
Swedish passenger coach	≈ 75 %
Old German double decked 2-car-sets ⁴⁰	135 %
Modern German double-decker Dbz750	113 %
Zürich S-Bahn (Schindler)	109 %
Switzerland Bahn 2000, dd car (large upper deck)	107 %
Dutch intermediate car (IRM-1)	106 %
French intermediate car (suburban train)	120 %

As the above table shows, a double-decker has a furnishable length which is almost 1.5 times as large as that of a 1980s Swedish passenger coach. Müller⁴¹, working for Waggonbau Görlitz which produce double deckers, claims 60% higher "seating length per coach length", while Fischer⁴² at DB claims that it is possible to increase number of seats per metre by 43% compared with a single deck German comparable coach. (Powered double decked coaches have less space furnishable space.) The length of lavatories and so on has been deducted and all the coaches in the comparison are approximately 26 metres long.

³⁹ Sempler, K., Mer plats i Londons tunnelbana, (More space in London's Underground, in Swedish), *Ny Teknik* 45/1998

⁴⁰ Müller, R., Der fünftausende Doppelstockwagen aus Görlitz (in German), *ZEV+DET Glas.* Ann.119 (1995) pp 203-209, Nr.6 Juni, 1995

⁴¹ Müller, R., Der fünftausende Doppelstockwagen aus Görlitz (in German), *ZEV+DET Glas.* Ann.119 (1995) pp 203-209, Nr.6 Juni, 1995

⁴² Fischer, H., Lineages of Double-Decker Coaches on Railways in Germany, *Railway Technical Research*, 2 (1995), pp 7-13, 1995

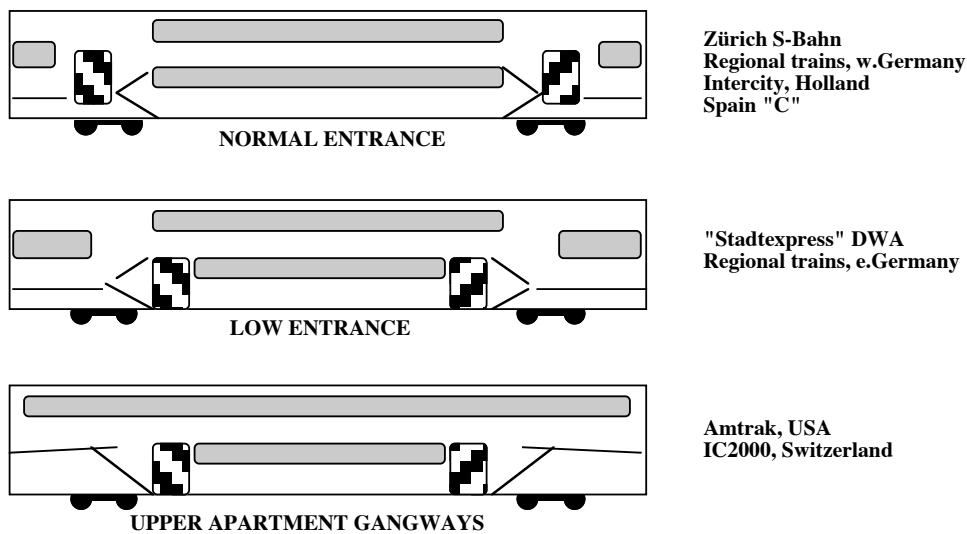


Figure 3.20 Various types of double decker designs.

There are some double-deckers with an unbroken upper deck, where the gangway between the different coaches is on the lower deck. These coaches are interesting in principle, as their upper decks offer the greatest comfort. One of them, the Swiss IC2000, is included in the above list. The equivalent furnishable length of this coach is almost 29 metres, more than two-thirds of which is on the upper deck.

Outlines for a double decked coach, made in this project, show that 50% more furnishable space should be possible. Figures from DB (the German Railway operator) indicate that the increase in usable space may only be 36%⁴³

In order to get as large an area that can be furnished as possible the two levels ought to take as much as possible of the train-length, and the bogie-distances should be big. Articulated designs with Jacobean bogies or similar could be one way to increase the area that can be furnished. The sketch below illustrates this design idea.

⁴³ Kurz, H.R., Reemtsema, K.-D.; Anforderungen an die Technologieentwicklung des Systems Eisenbahn aus der Sicht eines zukunftsorientierten Fahrplans (in German), *Eisenbahntechnische Rundschau* 46, (1997) H.7/8 Juli/August, 1997

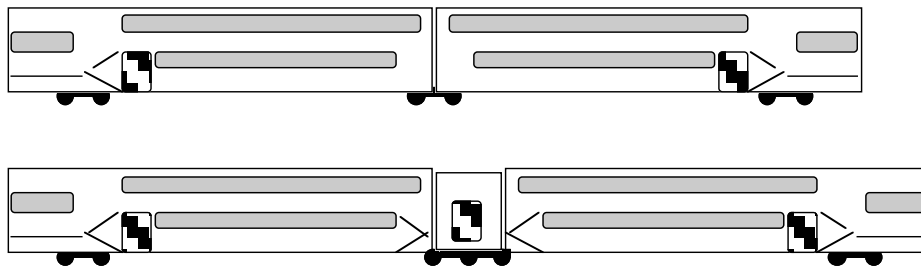


Figure 3.21 Two sketches for articulated double deckers. Similar solutions do exist (existed) in eastern Europe (Müller⁴⁴, Fischer⁴⁵).

Müller shows that such double decked concepts had up to six seats per metre but modern single coach designs, also with wider seat pitch than the old ones, have 4-5 seats per metre. These figures should be compared to existing single deckers with 3-4 seats per metre coach-length.

3.2.2 Furnishable space

People normally want to sit down when they travel by train but when trains are crowded, people have to stand. The standing facilities can vary in quality. The study about 3+2 seating, presented in section 7.10, revealed that a smaller part of the passengers prefers to stand instead of taking a less attractive seat.

There are transport modes where seating is not the only alternative. Shipping offers an example. Passengers on large ships are offered various alternatives to seating - walking indoors and on deck, shopping, standing in the bar, dancing and so on. The cost of different alternatives and people's valuations for them might be worth examining.

Seating in various countries

Train interiors have been designed differently by different railways. In Sweden large open salons with two plus two non-facing seats used to be standard from about 1960 to 1985 for long distance trains. In local and regional trains face-to-face seating have often been used. In other countries the opposite solutions have sometimes been chosen – facing seats for long distance and non-facing for regional trains. In Switzerland, face-to-face seating is standard while in Norway, another rocky country, almost all seats are non-facing.

⁴⁴ Müller, R., Der fünftausende Doppelstockwagen aus Görlitz (in German), *ZEV+DET Glas*. Ann.119 (1995) pp 203-209, Nr.6 Juni, 1995

⁴⁵ Fischer, H., Lineages of Double-Decker Coaches on Railways in Germany, *Railway Technical Research*, 2 (1995), pp 7-13, 1995



Figure 3.22 Norwegian ICE (express) train with non-facing (face-to-back) turnable seats.

There may be a number of reasons why different furnishing arrangements have been chosen for different trains. Some of them may be as follows:

- Tradition by the railway company or for the type of coach which is being replaced. This can be based on a specific desired standard in certain types of traffic and class.
- Beliefs that a certain furnishing arrangement produces more seats per coach.
- A certain type of furniture results in shorter passenger exchange times.
- The cost of different alternatives.



Figure 3.23 An example of an old fashioned face-to-face interior in a European country.

As the furnishing in given types of train in different places often offers only a few furnishing alternatives, it has generally been assumed that differentiation results in more problems than benefits. My opinion is that planners by the railway companies have often not used the best methods to evaluate the various passenger preferences, including their willingness-to-pay for appropriate seating arrangements.

In recent years, German Rail (DB) has introduced more varied furnishing in both its new high speed trains (ICE) and its interregional trains (InterRegio, IR). Both the 1st and 2nd class sections of the ICE have been furnished to suit customers with different tastes. Each coach has been divided into three parts, with about one-third of the seats in compartments, one third in saloons/groups of seats facing one another and saloons/seats behind one another.

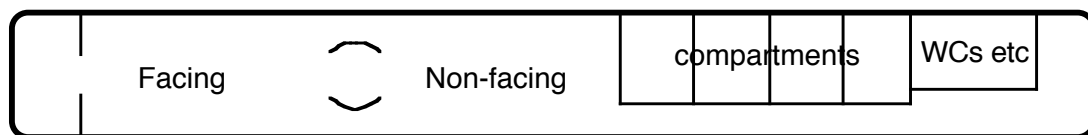


Figure 3.24 Division of interior space in German ICE coaches (not to scale).

Seat density for different coach types and furnishing arrangements

In order to calculate the cost of different types of train, it is necessary to know how much space different types of seat take up or, conversely, how many seats can be fitted in a specific furnishable area.

A comparison of density in existing Swedish coach types; first and second class, saloons and compartments, restaurant furnishing, couchettes and sleeping coaches is shown below. This comparison is based on the number of seats or beds per furnished length [seats/metre]. Needless to say, the values for non-Swedish coaches may deviate slightly from the Swedish ones.

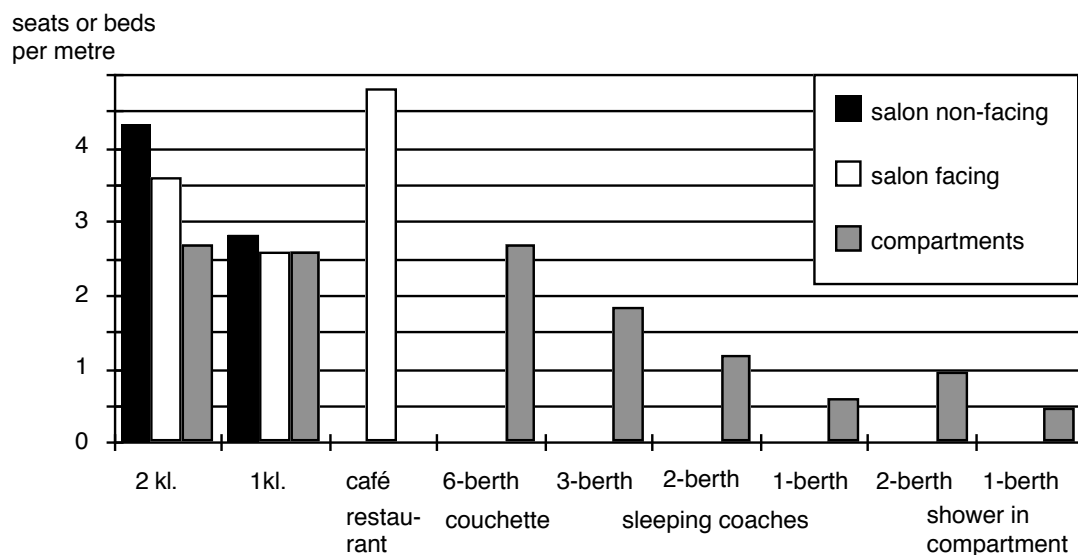


Figure 3.25 The area required for different furnishing arrangements expressed as seats per furnished train length in metres (Kottenhoff).

The above diagram demonstrates that in saloons non-facing seating produces the most seats per furnished train length. The most effective furnishing arrangement can be found in the restaurant coach. A table and four seats take up *less space* than four standard armchairs. From these figures we can not judge if face-to-face seating is effective or not:

When having a certain type of reclining seats it is not, on the other hand, the restaurant coach example shows very high seat density (despite there is a big table in each seat bay).

Sleeping cars have the lowest seat density. The use of space in couchettes compartments with six berths is almost 50% higher than that of sleeping cars with three berths. Single compartments with showers produce less than half a seat per metre or nine to ten berths per coach. It is, however, important to be aware of the fact that there are more effective sleeping coach designs outside Sweden, including “one and a half” and two level systems⁴⁶.

Modern second-class compartments have three seats side by side and the use of space is therefore no better here than in first-class coaches.



Figure 3.26 First class salon with the same seat type as in second class but separated by a "table". Swedish InterRegio coach rebuilt from InterCity 1980 coach.

With five seats side by side in standard seating coaches, it is possible to obtain about five seats per furnished length-metre.

⁴⁶ Troche, G., *Efficient sleeper train traffic – problems and prospects*, (in Swedish), KTH Traffic & Transport Planning, TRITA-IP AR 98-67, 1998

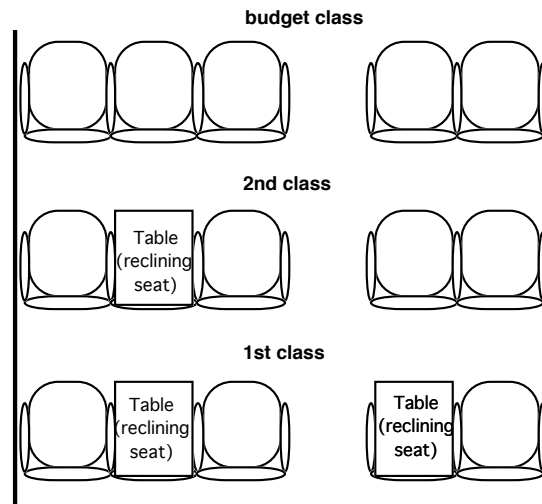


Figure 3.27 Design with flexible 2+3 seating

The furnishing with 2+3 seats can be flexible for various standard levels; first and second class and a budget class. When used as first class compartment, two of the backrests should be reclined and easily "converted" into two tables close to the remaining seats. In second class compartment this is done only with the mid seat, on the side with three seats.



Figure 3.28 Backrest that is convertible to a "table" beside you. This particular design is used in the Swedish family cars, for parents with babies. A modified design would be needed for use in ordinary flexible purpose cars.

Conclusions: Saloon coaches with non-facing seats are most effective in terms of space utilisation and can be made even more effective by having 2+3 seats abreast. Seats with tables and chairs, like those in the restaurant coach, might be worth considering as a complement in seating coaches.

Seat distribution - distance between seats ("cc")

Views on which seat distribution is most suitable appear to differ significantly between rail companies. Of the modern high speed trains, DB's ICE has the largest distribution between seats, about 100 cm in 2nd class, while BR's IC225 is at the other end of the scale with only about 77 cm in second class.

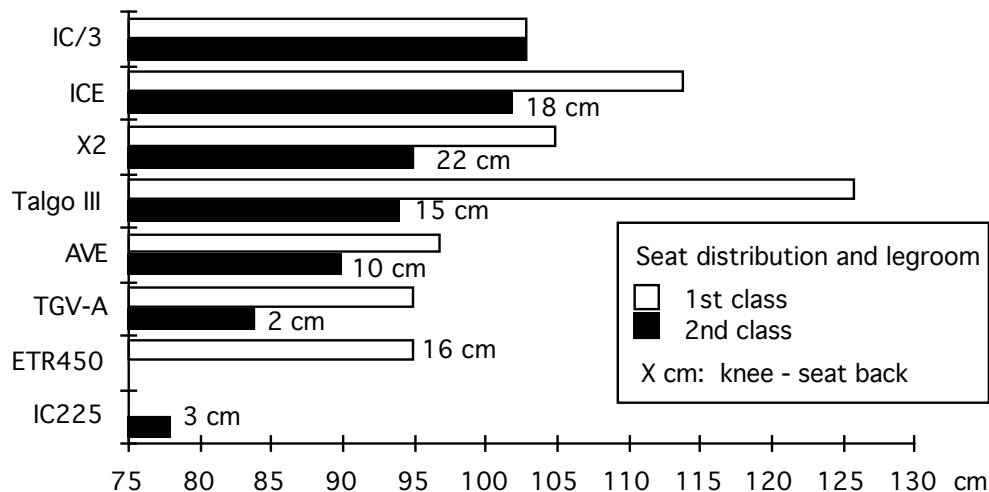


Figure 3.29 Values measured by me (mainly) relating to the division between seats, primarily non-facing (behind one another) and the distance measured between Kottenhoff's knees and the seat back in front of him. Some values, especially those in 1st class, could not be measured ⁴⁷.

When studying the above diagram, it is important not only to consider which train offers the greatest comfort but also to analyse the relationship between legroom – “knee distance” and seat distribution. It can be seen, for example, that the IC225 offers at least as much (little) space for the knees (3 cm) as the TGV-A (2 cm), even though the seats are closer together. X2 (X2000) seem to offer the largest legroom of these modern trains. The seat design differs on the different trains.

The different designs also give unlike possibilities to stretch one's legs, mostly depending on the shape of the lower part of the seatback in front of you.

Seat width

It is important to know the width of seats when making comparisons with others modes of transport and when considering whether to furnish a narrower (UIC) coach or to fit five seats side by side.

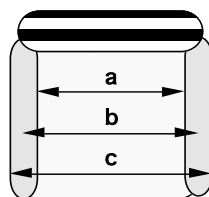


Figure 3.30 Different ways of measuring seat width.

The measurement **a** relates to the distance between armrests, while **b** relates to the distance between the central point on the armrest and this is the measurement which has been used in this project. **c** relates to the width of the seat, including two armrests, but this measurement may be misleading as two seats next to one another share the centre armrest. In Swedish passenger coaches, the measurement **b** is usually

⁴⁷ Measured on study trips in 1992 and 1993

- 53 cm in 2nd class and
- 65 cm in 1st class

In tourist buses and in (Swedish) domestic aircraft, this measurement is approximately 48 centimetres (or less)⁴⁸.



Figure 3.31 Some Swedish EMUs (X14) has 2+2 seating with 53 cm wide seats and 3+2 seating with 48 cm bus type seats. Both seat widths shown here.

3.2.3 Service areas

Luggage space and wardrobe facilities

In long-distance trains in Sweden, there are small, separate luggage facilities binding floor space. In addition, there are shelves for luggage and wardrobe facilities at the entrances to passenger coaches. The floor space in the wardrobe facilities can also be used for heavy luggage or for prams, for example.

Luggage takes up no extra floor space if it is placed above or under seats. The opportunity to put luggage under seats is not as well utilised as it might be. These facilities can be improved by changing the design of seats and improving the information about the luggage facilities that are available. Information stickers could, for example, be put up, as they are in the French Corail coaches.

The way luggage space should be designed and dimensioned is an important question when it comes to efficiency. Should it be designed to match the maximum load - the situation over Christmas, for example, when the trains are crowded and everyone is carrying Christmas gifts apart from their own belongings? Present-day SJ-coaches do not appear to be designed to deal with situations of this kind with their standard luggage facilities.

One solution would be to have *flex-areas* like DSB does in IC/3. These facilities are floor space which can be used for different things: luggage, bicycles, wheelchairs, prams and/or

⁴⁸ Hansson, L., *Utformning av sittplatser – Maximal komfort på minimalt utrymme*, (Design of seating – Mximal comfort in minimal space, in Swedish), KTH Railway Technology TRITA-FKT 1996:26, 1996

folding chairs, for example. However, problems can arise if these “needs” occur simultaneously.

Play areas

In Sweden and Norway, play areas which take up about a third of these “family cars” have been created. (In addition, there is a great deal of space for prams.) Fairly long trains are required for the number of passengers to justify this amount of space. Another alternative is to create a small play area like the one in the Danish IC/3. In this case, a group of four seats has been replaced by soft cushions and some toys.

Refreshment areas

Sweden has a large variety of refreshment space. It comprises everything from converted seating compartments to a full 26-metre restaurant coach. As has already been explained, the seating groups in Swedish restaurant cars are very effective in terms of space as there are almost five seats per furnishable metre.

The serving of refreshments at seats requires (at least) a kitchenette where the food can be stored and prepared for serving. The serving staff may also require staff facilities.



Figure 3.32 A small area is required for self service coffee in a Swedish X14 EMU.

The double decker has potential for long-distance transportation by it having room for different forms of service.

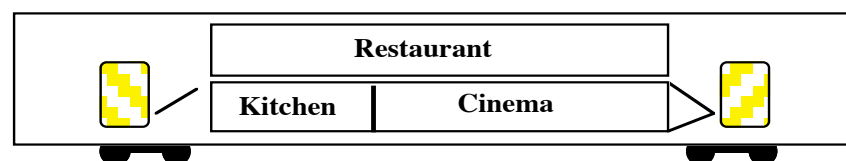


Figure 3.33 The double decker can be designed for different purposes on the two floors.

The point with the double decked concept is that rooms of full interior width can be allocated for special purposes, as for example kitchen or cinema.

Lavatories

In passenger coaches from there are often one large lavatory specially adapted for the disabled and one smaller lavatory in each coach. This means that there is one lavatory for every 25 to 40 seats. Some DMUs and EMUs have one lavatory for every 60-80 seats.

Lavatories of a high standard are appreciated by travellers, but they take up both space and need additional equipment. It may therefore be worth reconsidering the number of lavatories that are required and their size in future trains. A standard train lavatory takes up just over 1m², while a lavatory which is specially adapted for the disabled takes up just over 2m².

Other space

Other space at floor level on trains includes the following.

- Aisles and entrances. The size of aisles and entrances should be based on factors such as efficiency and attractiveness, as well as the needs of certain groups, such as the disabled.
- Gangways between cars.
- Staff facilities. On Swedish trains, there is usually at least one specially equipped coach with a guard's compartment. One alternative in order to save space could be to combine the staff's coach with the space used by the driver. This would require either multiple unit trains or cars which are pulled by a motorised coach or have a control coach with a driver's area.
- Space for technical equipment. For reasons of accessibility and climate, it is an advantage to have technical equipment at floor level. In order to utilise the space, it would be an advantage if as much equipment as possible could be positioned under floor level or in the roof of cars, for example.

3.2.4 Entrances

Among other things, the number of entrances influences the speed of boarding and disembarkation, the utilisation of space in the train and safety in the event of an accident (which will not be dealt with in this thesis).

When the Swedish 1980' passenger coach generation were planned, SJ considered having just one door at one end of each coach. This proposal met with resistance and was only implemented on couchettes and sleeping cars. In the 1990s, the motorised X12 coach, which is designed for long regional/short long-distance journeys, has been equipped with a door in the centre of the coach. The IC/3 has just two doors for every three cars.

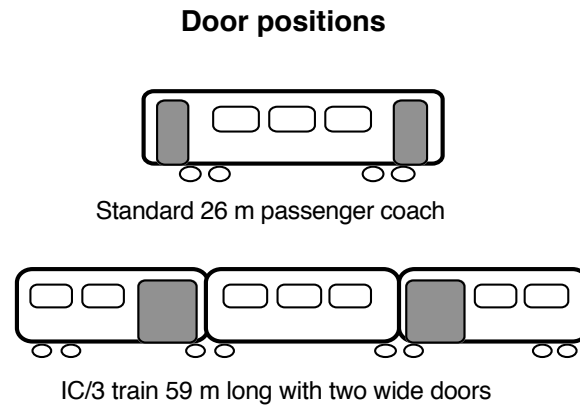


Figure 3.34 Examples of different door positions. Note that the intermediate trailer in IC/3 has no own entrance at all.

The total door width can be compared with the length of the vehicle. The ratio for a standard passenger coach is $2 \times 0.75 \text{ m} / 26 \text{ m} = 0.06$. The ratio for the IC/3 is $2 \times 1.4 \text{ m} / 59 \text{ m} = 0.05$. The ratio for the IC/3 is somewhat lower. One of my students conducted a small study of boarding and disembarkation times on different Swedish trains. This study is only presented in this dissertation. The times were taken at Hässleholm and Norrköping on two weekdays in January 1994. The student made the following comments.

“The cars on the Y2 (=IC/3) trains appear to be larger and roomier inside than other saloon cars. As a result, travellers are distributed more rapidly in these cars and the waiting time when boarding is shorter. I do not therefore regard the width of the doors as the only reason for speedier boarding. When it comes to disembarking, the width of the doors is not used as efficiently as it is during boarding. In my view, this type of train is by far the best alternative for (long-distance) commuters. Reducing the number of doors does not appear to have any negative effect as long as the doors are sufficiently wide.

The advantages I see in the Y2 trains cannot be seen in the X12 trains. The doors are not particularly wide and the interior is no roomier than it is in any other train. Neither in Norrköping nor in Hässleholm did it happen a single time that the doors closed directly after the last passenger. The trains always hold at the platform for a time whether they were delayed or not.

“I have never seen any of these types of train before. My spontaneous reaction to the Y2 trains was that they did not lose time by having just two doors, while the X12 trains did.”

The student’s comments indicate that the time taken at each station depends on many factors other than the number of doors; these factors include the area inside the entrance (vestibule and connection to the saloons).

It took approximately two seconds per disembarking passenger and door for the 80s and 60s passenger coaches and the X10 and X12 multiple unit trains. The time taken by each disembarking passenger, approximately 1.5 seconds, was somewhat shorter on the IC/3 trains. Having doors which are twice as wide does not appear to reduce time in half.

It also took approximately two seconds per boarding traveller and door for the 80s and 60s passenger coaches and the X10 and X12 multiple unit trains. The time taken by each boarding passenger on the IC/3 trains, just over one second, was somewhat shorter.

To make it possible to see the total time taken, the number of people debarking and boarding has been added together in a figure. When it comes to the Y2 train, one door has

been taken into account, while both doors were included for standard coaches (whenever data was available for two doors).

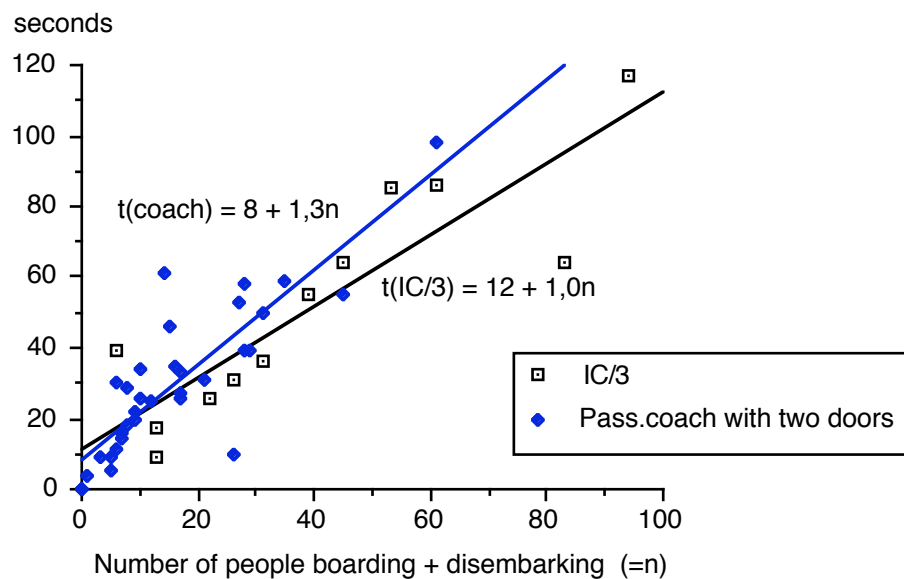


Figure 3.35 Diagram showing the total time taken for debarking and boarding when the IC/3 is compared with standard coaches

This figure indicates that the IC/3 is somewhat faster for the same number of passengers when there are more than approximately 15 people boarding + disembarking. The points on the diagram do, however, make other interpretations possible and the material is very sparse. Another equally good interpretation would be that no significant differences can be seen.

Position of entrances - at the ends of coaches or not

When it comes to standard passenger coaches, it is possible to consider positioning the entrances in some way other than the conventional method of having one door at each end of a coach:

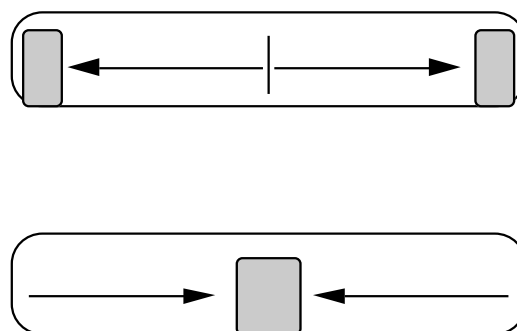


Figure 3.36 Different entrance positions: one at each end of the coach or one in the middle.

There are several good reasons for positioning *the entrances at the ends of the coaches*.

- The end of the coach can be designed as a crumple zone to reduce personal injuries in the event of train collisions.
- The vibration and noise levels at the ends of coaches are often higher than in the middle. It would therefore be a pity to put passengers in the less comfortable parts of the coach and have entrances in the most comfortable parts.

In spite of this, there are factors in favour of positioning the entrances in other places, such as *the centre of the coach*.

- It is easier to build an entrance that is specially adapted for the disabled, by lowering the floor of the coach in the centre, for example.
- It should be possible to manage with just one entrance per passenger coach if that entrance is placed in the centre. The distance to the entrance as far as passengers are concerned is no longer than if there are two entrances at each end of the coach.

It is difficult to make a general assessment of the best position for entrances, but the advantages and disadvantages should be carefully considered before a decision is made to put the entrance doors in the same position as before, simply as a matter of routine.

Please, also note that the drawing in figure 3.20 show different door arrangements for double decked coaches. Level entrances for about 0.5 m platform height are quite easy to arrange in a double decker.

Space utilisation in small trains

If the vehicle units are small, the utilisation of space will be less effective, as certain basic functions are required in every train. These functions can include:

- One or two driver's cabins, often covering the entire width of the vehicle.
- A sufficient number of entrances (at least one should be specially adapted for the disabled).
- Lavatory(ies) (at least one should be specially adapted for the disabled).
- Luggage space.
- Optional first class.
- Equipment cabinets and so on which are associated with the propulsion system.
- Possible play area for children.
- Catering area; restaurant, café/bistro or automatic dispensers.

If the vehicle units are somewhat larger, the above functions can be divided over a larger area and/or more cars.

3.2.5 Comparison of use of space in trains and buses

One way of gauging the utilisation of space can be to determine the percentage of the train length which is accounted for by seats. A comparison between different high-speed concepts shows that this percentage varies between about 50% for the French TGV-Atlantique to nearly 80% for corresponding double-decker units. The different configurations of high-speed trains, multiple unit sets or locomotive-hauled trains, cars with

ordinary or Jacob bogies, with or without a restaurant, single- or double-decker vehicles leads to various possible percentages of the train length being used for seats. The result of calculations for some of the trains can be seen in the following figure.

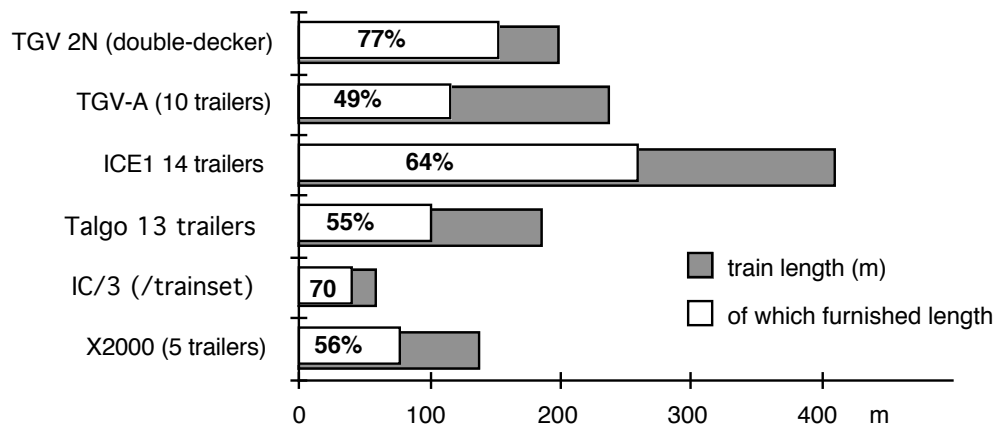


Figure 3.37 Comparing the furnished length with the total train length provides a rough gauge of space effectiveness. Furnished length is defined as the length ("space") used for "paying" seats.

As figure 3.37 shows, the Danish Flexliner IC/3 is the leader when it comes to single-decker trains because it does not have a separate buffet area and is a genuine multiple unit without a separate motor unit/ locomotive.

A 12-metre bus ("road coach") has a furnished length of about 10 m or about 80% of its total length. A SJ passenger coach (B4) and a standard long-distance bus are shown below. The railway vehicle has 46 seats and the road vehicle 48.

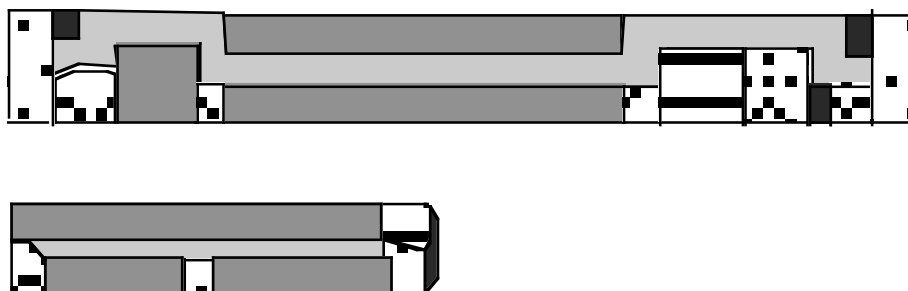


Figure 3.38 Space utilisation according to scale in a railway vehicle (B4) and a road coach. Explanations of area types are about the same as in figure 3.39.

The utilisation of space depends on how large a seat area each passenger is allowed and what space must be used for other purposes. The railway coach in figure 3.38 has unusually few seats. It has nonetheless been chosen to show that much of the space in trains is used for communication (aisles, entrances), staff, luggage and so on. In locomotive-hauled trains, locomotives and often restaurant coach areas are added.

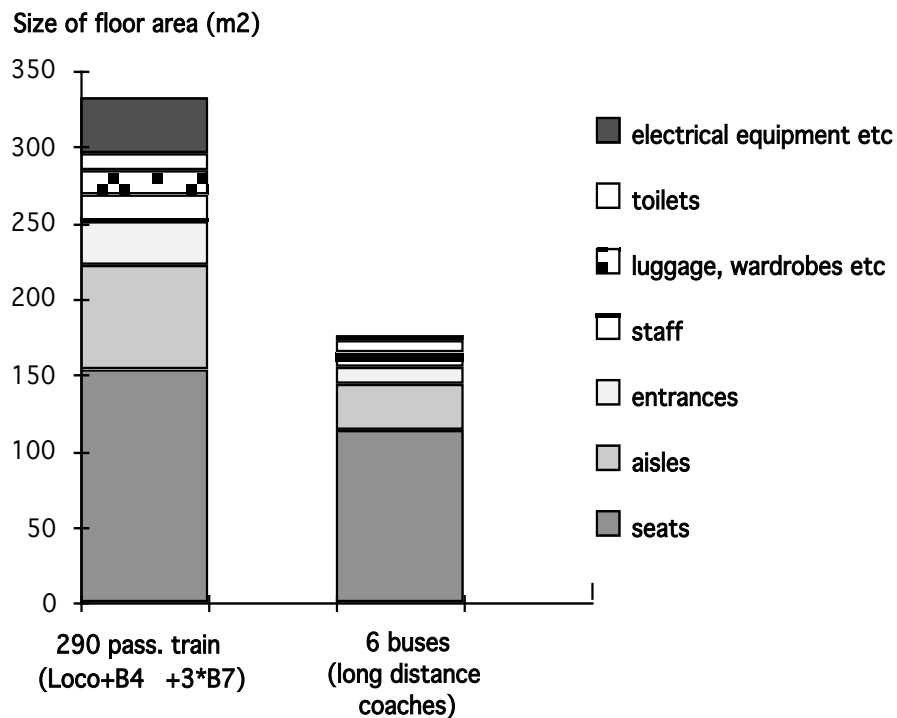


Figure 3.39 Interior floor area and its utilisation in a locomotive-hauled train with four cars compared with six long distance buses. Both units seat about 290 passengers.

From the diagram, it can be seen that the dissimilarity in seat area is only a minor part of the explanation of the major difference between trains and buses. Most of the difference depends on the difference in the size of areas for other purposes. As can be seen, the locomotive but no buffet or restaurant cars are included. Nor is there any first-class coach in the train in the example. Therefore, the difference in the utilisation of space between a conventional train and a motor coach is still greater than that shown in figure 3.39.

It is essential to distinguish between effective space utilisation with an unchanged, high level of attractiveness and the kind of measures which have a negative effect on attractiveness.

3.3 Design

Design has many aspects of importance. Good design is synonymous with good function, ease of maintenance, aesthetics, economy and so on. In this section, interest focuses on the importance of design primarily when it comes to the traveller's experience of the journey (attractiveness) and secondarily when it comes to the efficiency of the traffic company.

According to Berg/Pettersson/Zachau⁴⁹, "when we speak about design, we are actually speaking about man's need and ability to create order in his life. Design is both the process and the result of these efforts". The task of the designer, as he may see it, includes creating a synthesis of different, sometime contradictory, requirements. He seldom sees himself as someone who is expected to add a little spice to a product which is almost complete.

Examples of designer attitudes to trains

One example of a train in which large-scale design work has created a new product is the Danish IC/3. A journalist writing in *Dagens Nyheter* on May 22nd 1993 had the following to say, "The IC/3 trains are ugly. They look dreadful with their black rubber bellows at the front". This characteristic rubber front section is an example of the fact that function may take precedence over appearance, even when it comes to a designer. "When you understand the intelligent function of a design of this kind, its perceived value increases," Peters/Zachau write. The aforementioned journalist continued, "Inside, however, these trains are comfortable with large blue and red seats which are almost reminiscent of the X 2000".

The following sub-headings can be used under the general heading of design:

- Design shapes
- Colour scheme
- Function
- Choice of materials

⁴⁹ Berg, R, Pettersson, L, Zachau, H., *En gemensam resa mot bättre vetande om stadsbussar - ett projekt om design av morgondagens bussar*, (A concept for a new city bus (HUMBUS), in Swedish, TFK Report 1992:5, ISBN 91 8694 478 9, 1992

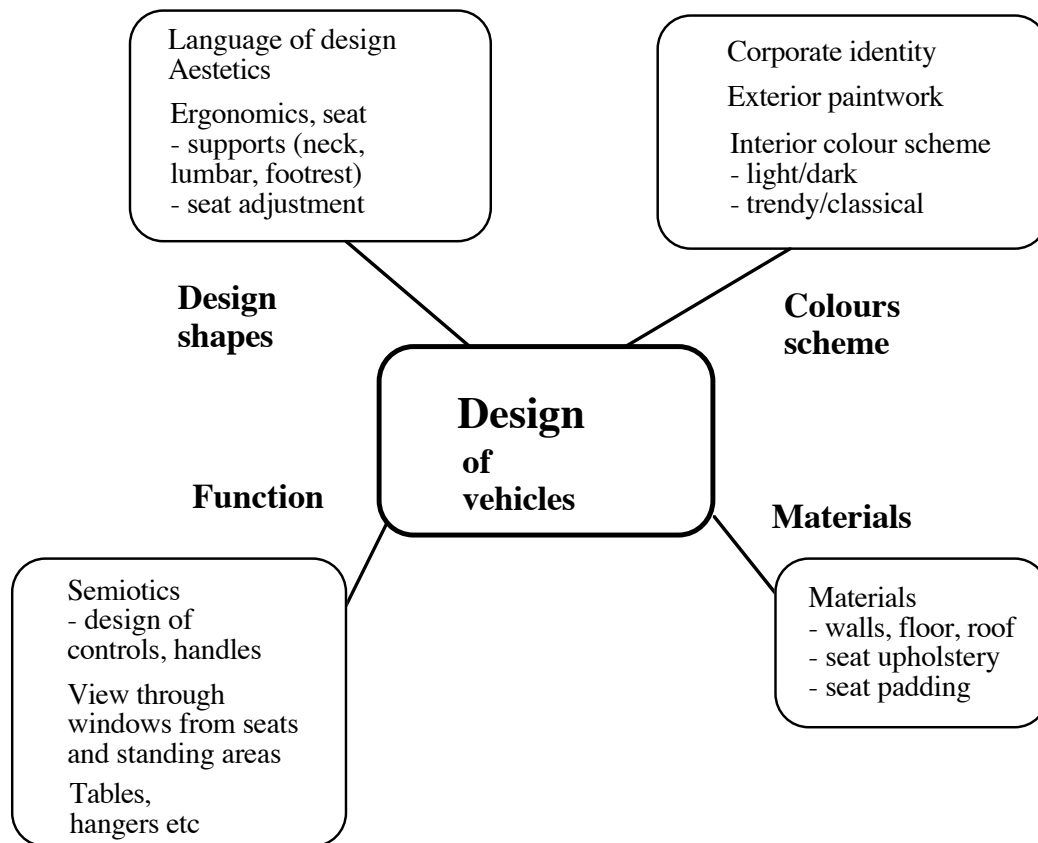


Figure 3.40 Factors which result from or are affected by vehicle design.

There are people who associate design first and foremost with colour schemes. Colour scheme is the first factor in the following presentation, not because of its importance but because it provides a somewhat better link between the different sections.

There has been a great co-ordinated research work about design of public transport systems, lead by KFB and TFK⁵⁰. This work includes many more aspects in the concept of design. Ljunggren et.al.⁵¹ has a comprehensive view. Their whole includes different levels where the concept of design (and other concepts) are useful: the traffic system (technical and organisational), the vehicles and stations, the separate vehicle systems (interiors, information system etc.), the products (for example the seat) and the components of those products (for example a grip). The same referred report also deals with our perceptions of these systems, but this problem does not fit into this section of the thesis.

3.3.1 Colour scheme

Colour schemes are naturally used to appeal to customers and staff. However, they frequently also perform the function of *informing*. Five different ways of informing people using *the exterior colour scheme on trains* now follow.

⁵⁰ TFK = Institutet för Transportforskning, an institute supported by the Swedish transport industry.

⁵¹ Ljunggren, S, Monö, R, Nordström, M, Svedmyr, Å, *Trevlig Resa - Våra sinnens perceptioner och deras effekter på beteende i kollektivtrafikens rumsliga miljö*, KFB Report 1997:43

1. Colour scheme based on a company to create a *corporate identity*. This method is being used in Sweden by the new SJ and by many county traffic companies. The traveller is told which company he/she is travelling with.
2. Colour scheme based on rail vehicle type. This type of colour scheme has been very frequently used by the railways. In Sweden, for example, rail buses in the 1950s were painted in a certain way, in yellow and orange.
3. Colour scheme based on the line on which the trains operate. Examples include Spain, where the new AVE express trains as well as locomotives to be used on the same line are painted using a specific colour scheme. In Japan, the term “line-oriented design” is used; this means that trains are designed for special lines. One example is the new Narita Express (*N'ex*), a train which operates between Tokyo and Narita Airport.
4. Colour scheme based on the type of rail traffic or “traffic function”. This model has currently been used in Germany. IC trains were painted in different shades of red. Red indicated the “top of the line”, “die Spitze”. The InterRegio trains were blue and regional trains were painted green. The S-trains were still orange. The colours represent the four temperaments; choleric, melancholic, phlegmatic and sanguine.

Colour schemes are changed from time to time. In Germany the colour schemes have been changed so often the latest years that three different colouring schemes, and ideas, exist in parallel.

3.3.2 Design (shape)

Vehicles are designed to be effective (low air resistance, for example) and thereby economical, to make them attractive and comprehensible. At the same time, the language of design should say something to train customers. This is the subject of discussion among designers: Rune Monö feels that the design should be “honest”, by using good semiotics, for example (see the next section on function), whereas Karl-Erik Lind⁵² believes that a product which is going to sell well needs some degree of “seduction”.

Seat design and seat adjustability

The term “adjustable seats” usually means that the individual can adjust the angle of the backrest and some other device, such as the headrest, himself. It is, however, never possible to adjust as many ergonomic factors as one can on a good driver’s seat or office chair. It is, for example, generally not possible to adjust the height, angle or length of the cushion. The lumbar support in the backrest cannot be adjusted either.

For reasons of space, among other things, different backrest angle designs have been used. The two most important types are those in which the backrest reclines -towards the seat behind - or the cushion rides forward - towards the seat in front.

To reduce the production cost of train traffic, each seat should require as little space “as possible”. The possible limit may sometimes coincide with sitting as one does on a cramped city bus - travellers’ knees touch the seats in front. However, this would result in the loss of passengers for many types of traffic, thereby reducing revenue. Good design

⁵² In a lecture at a design conference in Malmö the 28th of August 1990 arranged by the Swedish Transport Research Board and TFK.

work makes it possible to make seats more space-effective longitudinally than present-day train seats. The following parameters can be used:

- Thickness of backrest.
- Shape of backrest; contours in terms of height and width.
- Function of backrest angle.
- Backrestheight, shape, colour and material choice to create a feeling of space.
- Room for the legs under the seat in front.

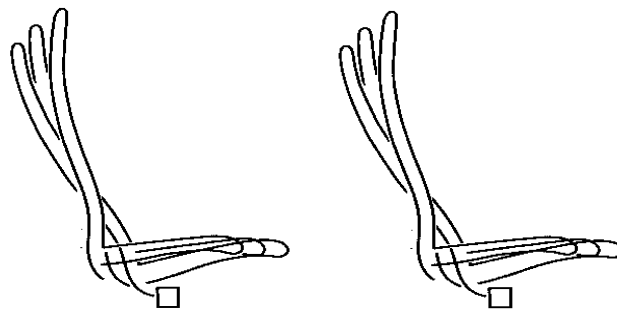


Figure 3.41 A seat which only takes up a little space longitudinally can be created using thin, contoured backs and a seat-angling mechanism which causes the cushion to move forwards when the backrest reclines⁵³

The X2000 has seats which function similar to the above manner. The deflection at the upper edge is no more than 85 mm when the backrest is fully reclined. However, this deflection also calls for sparse furnishing if face-to-face seating is used. In this case, the backrest angle requires almost 8% more distance between seats.

3.3.3 Function

Semiotics is a term which is used to explain how the design of a product (such as a control switch) is linked to its function. The old type of latch on the inside of a train lavatory door is an example of good semiotics. Everyone understood how it worked and they could rely that they would not be interrupted.

One way of reducing costs is to build vehicles in *modular fashion*. The term “modular design” can be used to describe a number of different technical solutions. For example, electrical and other equipment can be designed as modules which can easily be replaced. Or a coach can be divided longitudinally into a number of modules, several of which are often the same length.

⁵³ Ergonomidesigngruppen/TFB(KFB), *Design sv regionalståg* (Design of regional trains, in Swedish), TFB 1992:33; original drawing: Ergonomidesigngruppen, Stockholm.

Window pillars and view from windows

One particular problem is that some non-facing seats may end up next to window pillars, thereby preventing the passenger seeing out of a window. Multiple units and passenger coaches generally have wide window pillars, 50 cm or more. By way of comparison, it may be of interest to note that the window pillars in buses are often 10 cm or less.



Figure 3.42 To sit by a window pillar reduces sight out of a window. About half of this passengers' view is reduced – blind spot in the drawing below.

The following diagram illustrates the blind spots which result from building a train with wide window pillars and non-facing seats which do not match the window module. A comparison with a bus is also shown. In the case of the train, it is assumed that the windows are about 120 cm long and the window pillars 60 cm. In the case of the bus, it is assumed that the windows are about 140 cm long and the window pillars only 10 cm.

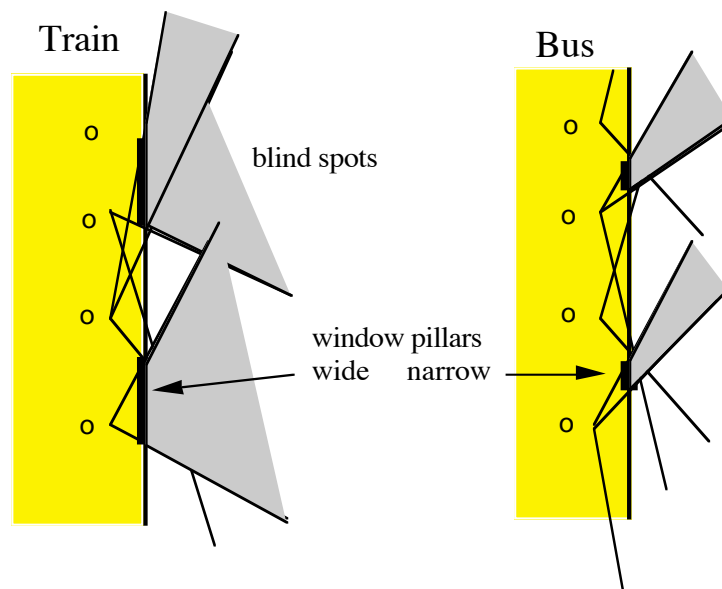


Figure 3.43 Illustration of blind spots from a number of different seats in trains and buses respectively, both furnished with seats behind one another (face-to-back). Narrow window pillars reduce the blind spots.

If it were possible to make the window pillars in trains as narrow as the ones in buses, it would be easy to give all the passengers in every coach a good view. This would probably also produce another effect; namely that the seats felt roomier.

If narrow window pillars are not possible, non-facing groups next to windows produce seats "by window". This presupposes that the distance between windows and seats is divided into modules. Larsvall⁵⁴ has illustrated what would happen if the furnishing in a modular coach with non-facing seats were changed.

- Reducing or increasing the distance between seats and retaining non-facing seats would *significantly* reduce the view for two rows in every ten.
- Face-to-face seating at modular distance would limit (with wide window pillars) the view for every other passenger.
- Reducing or increasing the distance between seats and having face-to-face seating would *significantly* reduce the view for two rows in every ten.

Territory or private zone

Monö⁵⁵ writes about the concept of territory. "Using conscious design, it is, for example, possible for pattern structures and the shades, values and division of colours to create a sense of greater space. Using design and shifts in colour, the territorial borders can be made clearer, thereby increasing the feeling of comfort and seclusion." A design based on light colours in a horizontally-oriented pattern expresses space.

The existence of a private zone is one of the important differences between private (car) and public transport. Armrests and/or small tables between seats are used to increase the feeling of privacy.

3.3.4 Materials

The choice of materials has an important role, not only for the technical quality and maintenance conditions, but also for the passengers' impression of the train. Swedish long-distance trains have a large percentage of natural material (wood) in their interior fittings. The idea in Sweden has been to offer a cosy internal environment that differs from buses and aircraft⁵⁶.

⁵⁴ Larsvall, J., *Projekt Regionaltåg, Inredning & Layout* (Interior and layout), Ergonomidesign-gruppen 890821, for TFB (KFB) Regional train project, 1989

⁵⁵ Monö, R., *Design for joint travelling*, (In Swedish; Design för gemensamma resor), TFK

⁵⁶ Lennart Nilsson, former chief designer at SJ, now (1999) by Adtranz.



Figure 3.44 Swedish "post-modern" interior with 3+1 seating and light wooden material (class B2)

3.4. Performance

Propulsion and speed is the first category of performance. It includes everything associated with propulsion/traction and braking, such as acceleration and deceleration levels and maximum speed. One measurement which relates to the fact that people do not want overly long travelling times is distance covered per time. It is, for example, possible to see how far a certain train travels in three hours on a given track.

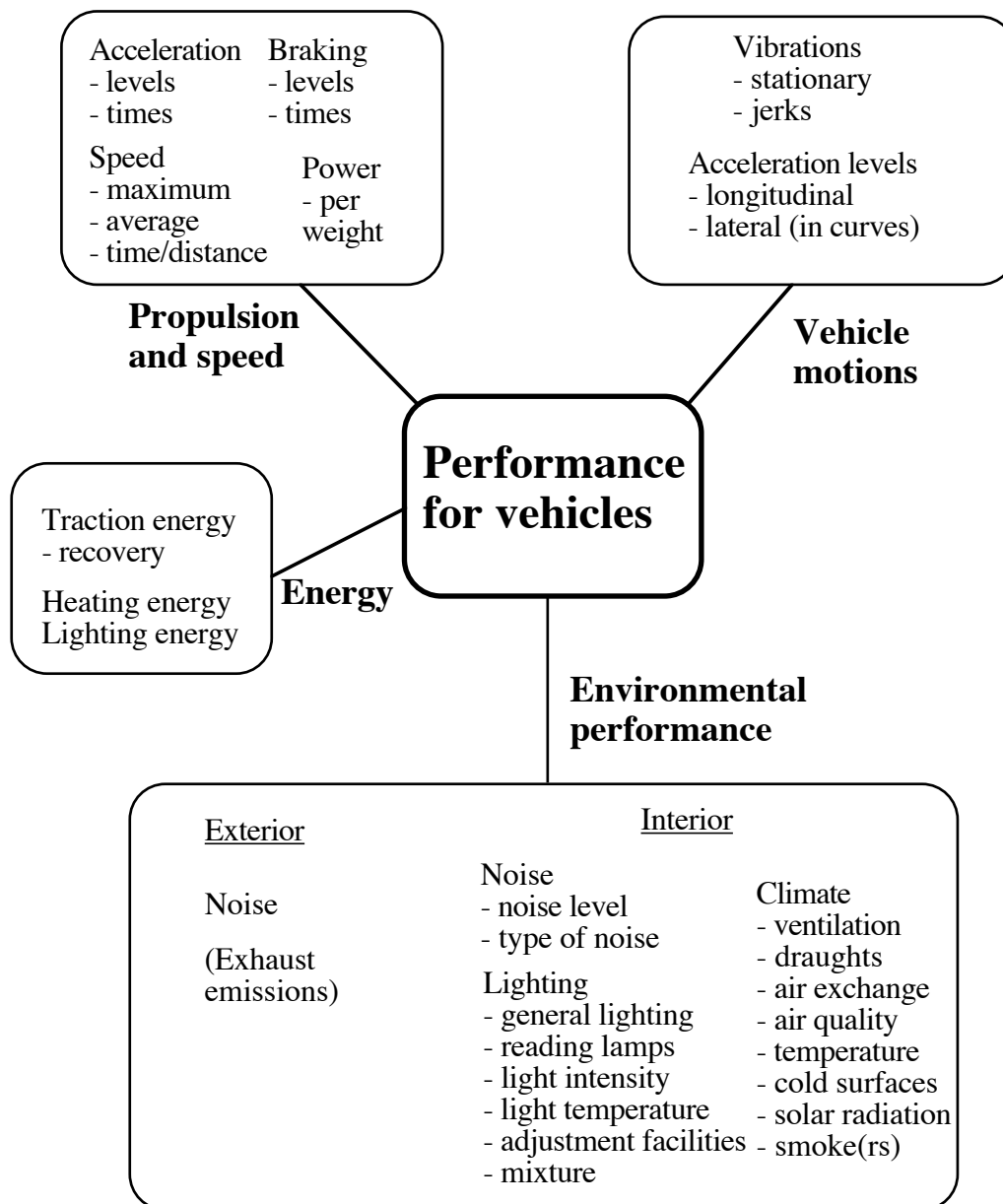


Figure 3.45 Example of factors which are included in “performance” in this report.

Energy performance includes the energy the train converts for propulsion (traction), any kinetic energy that is recovered during braking and energy for lighting and heating. Vehicle motions comprise vibrations and unexpected vehicle movements, as well as

acceleration, braking and lateral acceleration. Environmental performance is divided into exterior and interior factors.

3.4.1 Traction performance

The need for power increases almost with the cubic of the speed because $P=F \cdot v$ and F , the traction force needed, is to a great extent dependent on air resistance⁵⁷, which is proportional to v^2 and to the acceleration level needed.

$$P \approx (k \cdot v^2 + m \cdot a) \cdot v$$

Too low power reduces speed and acceleration performance.

The power use to be related to the weight and traditionally the power level has been up to around 10 kW/ton for ordinary passenger trains. X2 (X2000) has a continuous rating of somewhat more than 10 kW/ton. Trains for higher speeds need more.

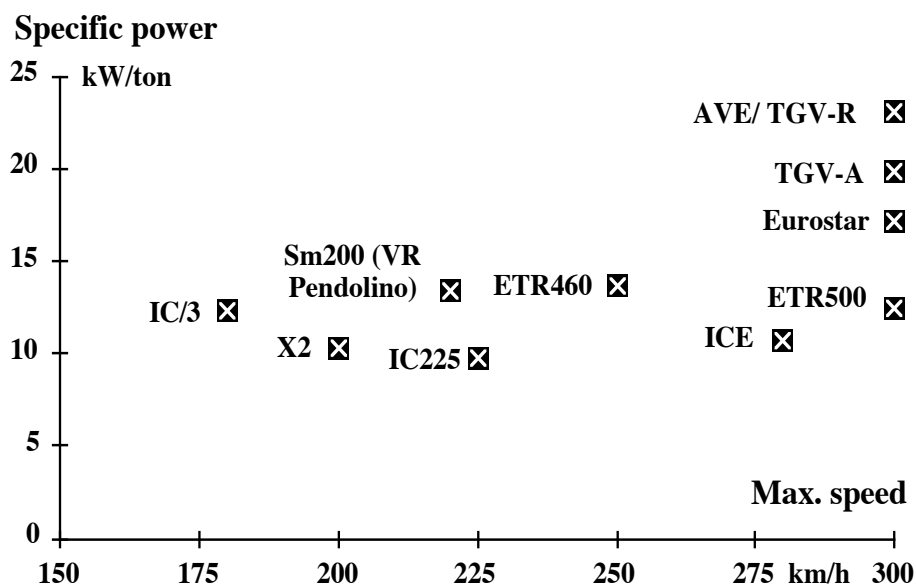


Figure 3.46 Specific power (kW/ton) related to maximum speeds for some modern European trains.

The need for power increases with speed and figure 3.46 shows the choices made regarding the dimensioning of the trains' (hourly) power, as it relates to the weight for trains of different speed levels. Certain train-types, such as. IC225, ETR500 and ICE can have a different number of passenger-coaches. Here long trains are assumed: IC225 with 10 coaches - ETR500 and ICE with 14 intermediate coaches. Under these circumstances especially ICE and ETR500 are "weak" trains. ETR500 is built for 300 km/h but is meant to run at 275 km/h in regular operation.

⁵⁷ Lukaszewicz, P., *Running resistance of passenger and freight trains*, Railway Technology KTH, TRITA-FKT Report 1995:16, 1995

I have developed a travelling time simulation program (in Basic). This simulation program produces running times, average speed and energy consumption, as well as a graphic printout like the one shown in the following figure.

Speed

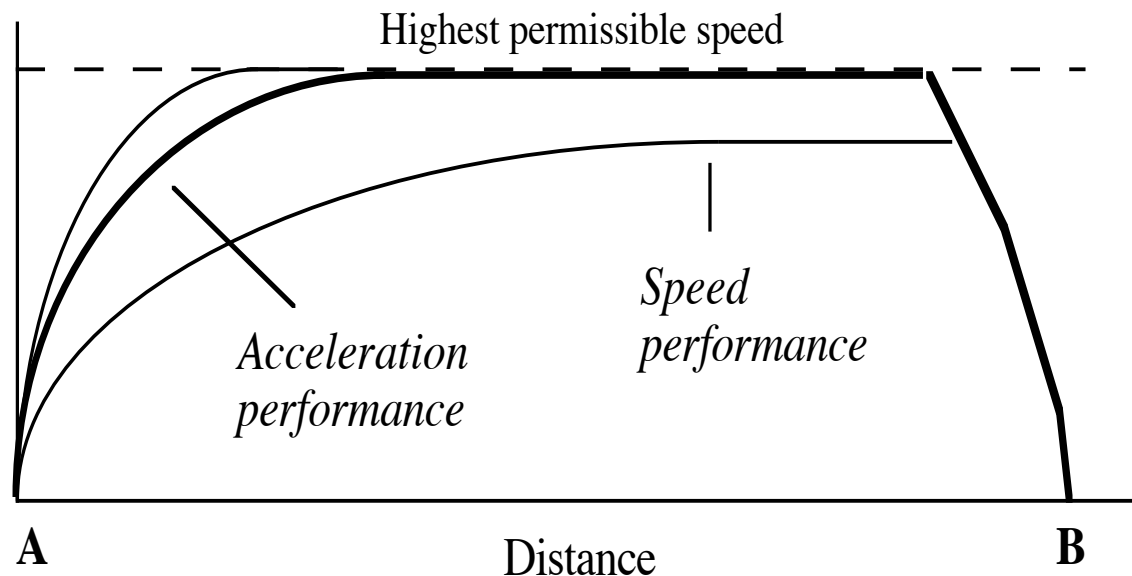


Figure 3.47 Speed/distance diagram for trains with different performance levels driven between A and B. (Corresponds to the printout from a simulation program in Basic, Kottenhoff 93)

This diagram shows how the speed varies on the distance between A and B for three trains with different performance levels. The thicker graph represents the speed of a train with average performance. The graph to the left represents a train with higher performance and generally higher output power per train weight. The bottom graph represents a train with poorer acceleration and speed performance which is due to too low power per train-weight.

From the difference in the area between average performance and poorer and higher performance, it is clear that time can be gained if the train is given sufficient speed performance and sufficient acceleration performance. For trains with few stops it may be sufficient with good speed performance, when regional trains also need good acceleration performance. This has been analysed in deep in the KTH project Efficient Passenger Rail Services for the Future⁵⁸.

3.4.2 Maximum speed and average speed

The speeds which are reached in practice in different countries are shown below. The maximum speed is the “speed limit” for the train and track (HPS = highest permissible

⁵⁸ Railway group KTH, Andersson, E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik*. (Efficient Passenger Rail Services for the Future, in Swedish – English version is underway, 1999), KTH Railway group report 9702, 1997

speed). The maximum average is the highest average speed between two stations according to the timetable. This is followed by the maximum speed in an important relationship and, finally, the lowest value, the average speed over long distances (> 500 km).

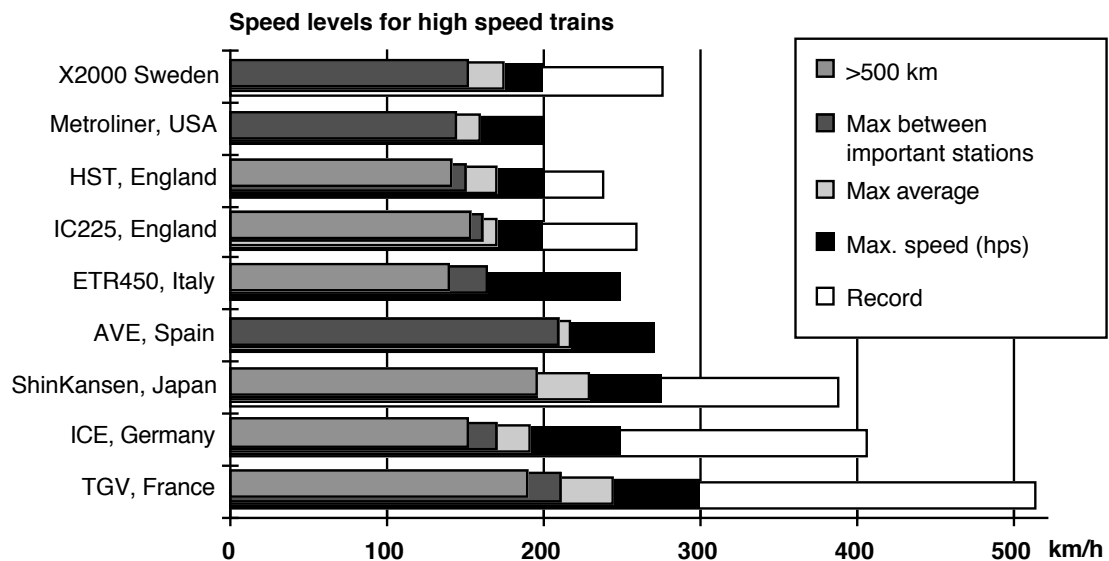


Figure 3.48 Record speed, highest permissible speed in traffic (hps), average speed from station to station and best average speed for an important relationship in each country. Most data from *Railway Gazette International* ⁵⁹

There is a large difference between record speed, maximum speeds and the average speeds at which trains travel in real-life passenger traffic. For example, a specially-tuned TGV train of reduced length travelled at 515 km/h on a record run, whereas in traffic over a distance of 500 kilometres it travels at a maximum of 180 km/h.



Figure 3.49 A specially-tuned TGV trainset has reached 515.3 km/h in a test run.

It goes without saying that the average speed of a train in service will never be as high as the highest permissible speed for the train and track.

⁵⁹ Taylor, C., Speed surveys, *Railway Gazette International*, September September 1991, October 1993 and October 1995. Another source has then been *Cooks International Timetable*.

High speed is hardly an aim in itself, even if it plays an important part in the image of the railway. What travellers are looking for is short travelling times. This can be obtained via high average speed, which requires:

- short acceleration and braking times
- few stops, such as waiting times at stations
- short waiting times at stations
- few speed reductions
- a track which permits high speed; the HPS of the track
- vehicles which permit high speed; the HPS of the vehicle

The decrease in travelling time for high speed operation usually stems from a combination of factors: a higher top speed, fewer instances of slowing down, fewer stations and more straight lines. Take the Madrid-Sevilla leg as an example. Before 1992 the Talgo and the “Electrotren” were in service on the 570 km long line, having 4-5 inter-stations and doing it in approx. 5h 50 min. The AVE-trains now do the new AVE line in approx. 2h 30min inclusive one stop. The average speed has been augmented from ca 100 to 185 km/h and the distance is 18% shorter. A conjecture is that every inter-station skipped saves 5 minutes, i.e. in this case a quarter of an hour. From these data we calculate that:

- Fewer stations saved about 1/4 hour
- A shorter leg could have saved about 1 hour (if no raise of speed)
- A raised speed could have saved about 2 1/2 hours (if the old path had been used for building the new line).



Figure 3.50 AVE, Spain

In the next diagram a comparison is made of how far different high-speed trains reach in a certain time.

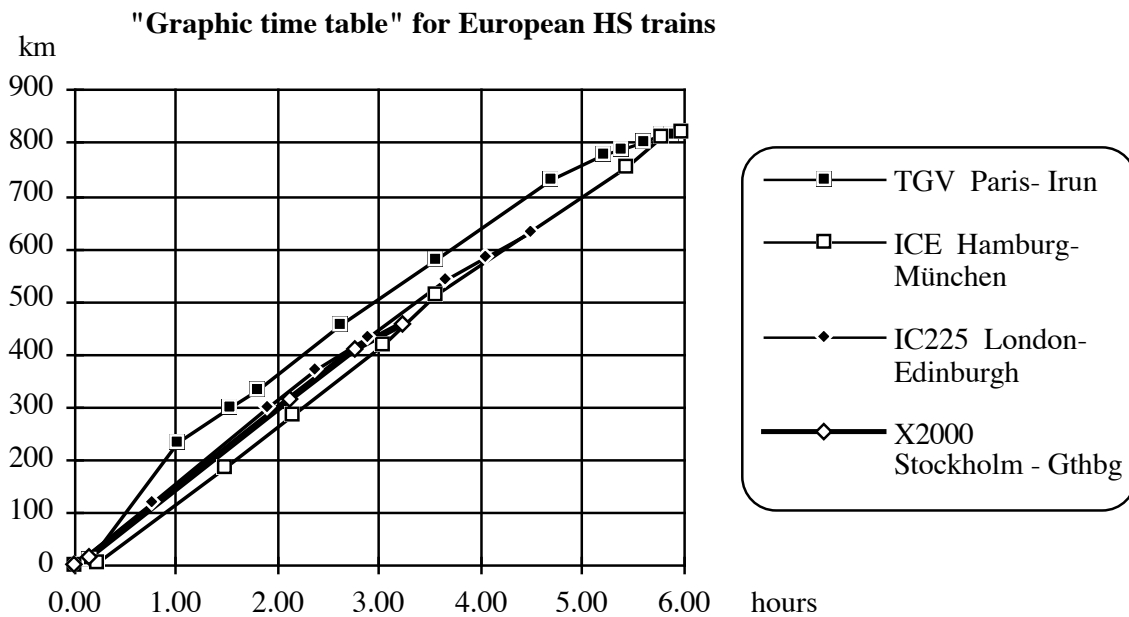


Figure 3.51 "Graphic time-table" for some European high speed trains. The table pertains to certain chosen, representative departures (Cooks Timetable⁶⁰).

Some representative departures have been chosen. These were neither the fastest nor the slowest ones:

6:55	TGV-A	Paris-Bordeaux-Irun (Spanish border)
6:51	ICE	Hamburg-Wuerzburg- Munich
9:00	IC225	London-Newcastle-Edinburgh
8:00	X2000	Stockholm-Skövde-Gothenburg

We can see from the diagram that TGV reaches almost twice as far during the first hour as do the other trains. This results in TGV keeping the lead all the way up to a distance of 800 kilometres. We can also see that in three hours we get about as far with the rest of the high speed trains, X2000 included.

In this comparison one must remember that the track means a lot, maybe the most. X2000 on many secondary routes is slower than on the Gothenburg route, and the British IC225 would not be able to run fast without having good tracks all the way.

3.4.3 Energy

The use of energy rises more quickly than the speed. The diminishing usage of time decreases with the augmentation of top speed. Taken together, this means that to save one minute the energy consumption increases with the speed cubed (for the same train type).

⁶⁰ Cooks International Timetable, spring 1994 (?)

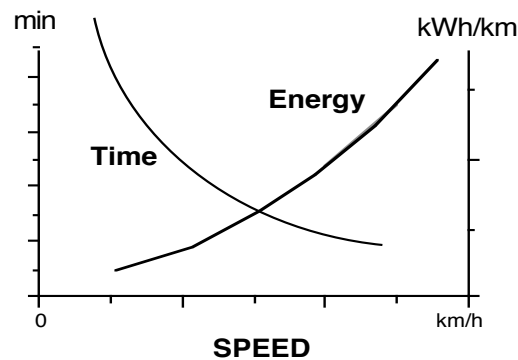


Figure 3.52 How the energy use and the time spent depend on the top speed. The length of the distance between stops in the simulation was 50 km. (Kottenhoff simulation)

High speed trains are designed differently than regular passenger-trains. The air resistance is 25 - 50 % lower and some braking energy is fed back. This contributes to energy being saved. Even a higher space utilisation may contribute. These things may result in the high speed train consuming half as much energy as a conventional train-set, at the same type of operation (number of stops; speed). That makes it possible for high speed trains to run at speeds up to 40 % higher than regular trains, without a higher energy usage⁶¹. than these trains.

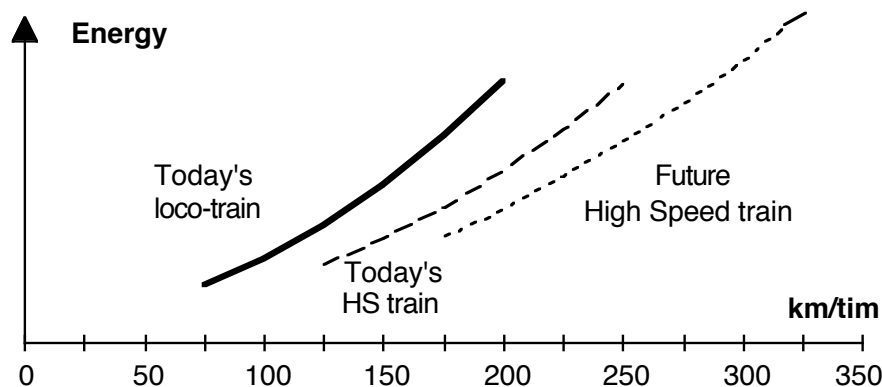


Figure 3.53 Energy use, in principle, of today's trains and future HS train.

In a comparison of energy use by different modes of transport on a national level one should take the primary energy into consideration. In Sweden an important part of the electricity used by the railway stem from hydroelectric power stations and today SJ is buying "green electricity" (SJ pay extra for buying environmentally clean electricity; from wind and established hydroelectric plants). The situation can be different in other

⁶¹ Andersson, E., *Järnvägens energiförbrukning i framtiden*, (Railway's energy use in the future, in Swedish), Railway Technology KTH, TRITA-FKT Lecture Notes 1996:49, ISRN KTH/FKT/N--96/49--SE, 1996

countries. Zängl⁶² has written a critical book which deals with environmental impacts and high primary energy usage of the German ICE and trains.

3.4.4 Vehicle motions

Acceleration, braking and lateral forces

These motions creates forces when the train accelerates, brakes or runs through curves. These are forces which last for more than about one second. The forces can be measured with an accelerometer in the form of acceleration values.

The normal maximum levels are around 1 m/s². This applies to lateral acceleration when cornering or braking retardation. The acceleration levels in trains are lower, usually around 0.5 m/s². On a study trip in April 1992, I measured the lateral acceleration levels of trains in several countries and found that the situation there was much the same. The idea behind measuring was to see the "quality" passengers on various railways in Europe experience, not to evaluate specific vehicle types or track standards.

The acceleration levels were measured with a "clinometer", a kind of spirit level for sailing boats which then measures the roll angle in degrees. This instrument has two scales: -5 to +5 degrees corresponding to ± 0.9 m/s² and one scale of ± 30 degrees.

In this case, the angle of the force resultant is measured. The lateral acceleration levels are shown by figure 3.54.

⁶² Zängl, W., *ICE die Geister-Bahn*, Raben Verlag, 1993

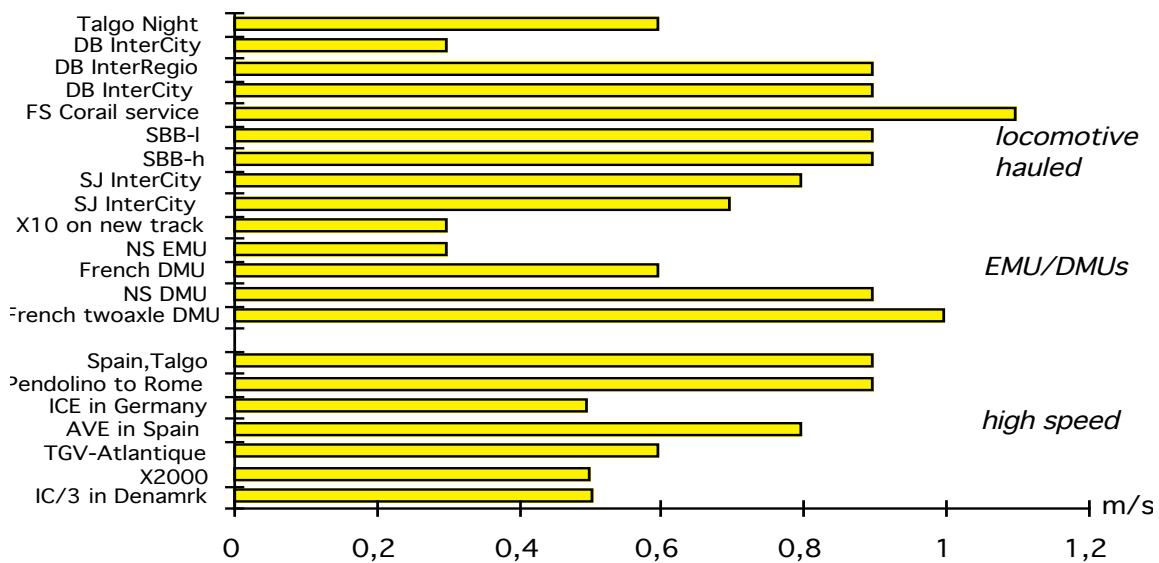


Figure 3.54 Lateral acceleration levels measured in test runs over different distances. These readings are only to be seen as approximate indications of the lateral forces one can experience in rail services in Europe.

On many occasions, 0.9 m/s² was measured as the lateral acceleration in curves. Lower values were measures on several of the high speed trains, not least the Swedish X2 (X2000). The French railways appear to expose passengers to somewhat higher lateral forces on interregional trains than many other railways do. The measured figures are of the same order as the theoretical lateral acceleration figures.

Tilting

There are passive and active systems for making coaches tilt inwards on curves. The passive ones are based on the concept of positioning the centre of torsion of the coach at a higher point than the centre of gravity. The data for a few systems is shown below.

Table 3.7 Data for a number of different carbody tilting systems.

Passive tilt		Max. tilt
Neiko (SIG)	for passenger coach bogies	1.2°
TALGO	for TALGO-Pendular trains	3.5°
Active tilt		
Adtranz (X2)	for the X2 (X2000) and other	6.5° ⁶³
FIAT	for Pendolino trains and other	8°

⁶³ Effective tilt between carbody and track. Tilting mechanism tilts up to 8 degrees.

It should be noted that, if the above systems are compared with standard passenger train vehicles, 1-2° should be added for the roll (roll angle) which is also compensated. As an example, the betterment of the Neiko system thus becomes 2-3°.

The following diagram shows how many per cent faster it is possible to drive with coach tilt on bends, but without taking account of limitations in track forces.

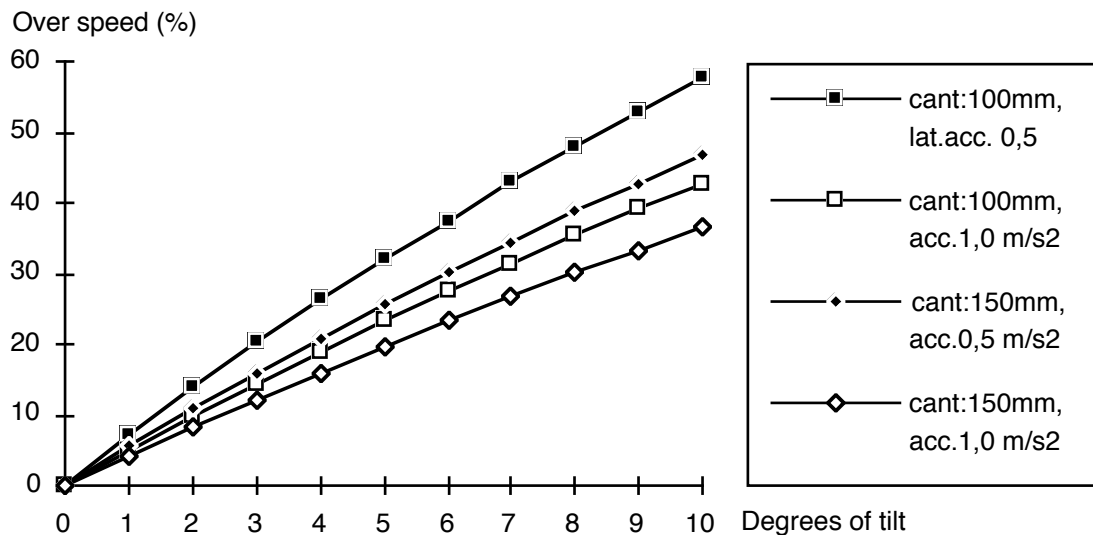


Figure 3.55 Diagram showing the possible increase in speed on bends with different levels of coach tilt, different track cants and different permissible acceleration levels in the carbody. Calculated using formulae from compendia⁶⁴.

This diagram demonstrates that, with an active coach tilt system which produces a tilt of six to eight degrees, it is possible to drive 20-40% faster on bends, whereas, with a (passive) system of three degrees, it is possible to run 10-20% faster. It also shows that the system offers the greatest potential increase in speed when low levels of lateral acceleration in the compartment are required (0.5 m/s²). A low track cant level (100 mm) also results in a larger improvement, i.e. greater need for coach tilt technology.

The time savings which can be achieved by tilting trains depend on the number of curves on the track. German running time calculations reveal that the X2 travelling between Stuttgart and Zürich can reduce travelling times by 19%⁶⁵. It is claimed that the passive Neiko (Neigungskompensation) system can permit reducing travelling times by 4-7%.

Number of accelerations, bends and stops

One way of quantifying forces is to specify the number of times the vehicle starts, stops and negotiate curves. This provides a gauge of the number of times travellers have to brace themselves in different directions and how long they can relax.

⁶⁴ Andersson, E., Järnvägsteknik (Railway Technology), Course TC242 (?) at KTH

⁶⁵ Kottenhahn, V., NEITEC-Systeme in Vergleich (A comparison of NEITEC (coach-body tilt) systems, in German), *Eisenbahntechnische Rundschau* 42, (1993) H.1-2 Jan./Feb., 1993

Sudden changes in speed

Sudden changes in speed are defined as a change in the acceleration per time unit. If the acceleration level changes at irregular intervals, the change in speed and resulting jerk is greater. Smooth transitions between acceleration and retardation (braking), for example, result in low speed-change values.

Jerks are produced for example when bus drivers change gear, when an underground railway stops accelerating and when train drivers brake to a standstill without successively reducing braking force⁶⁶.

Vibration and shaking

This comprises oscillatory motions at frequencies between 0.5 and 100 Hz. From about 20 Hz and upwards, these oscillations produce audible sound. Under 20 Hz, the vibrations help to produce infrasound. Normal levels for these vibrations are around 0.1 m/s² as a mean value during a period of 10 seconds on a good track, both vertically and laterally.

Vibration and impact on passengers is due to speed and to suspension design of the vehicle. It is also highly dependent on the track quality.

Level of traffic and road standard affect comfort and travel sickness

With every type of vehicle, the comfort depends on the type of traffic and the roads or tracks on which the vehicles are used. Long distances between stations and limited effects by other traffic result in fewer accelerations. Signals and other traffic result in more acceleration. Straight highways create the conditions for relatively high comfort levels in buses. A high track standard and straight tracks create the same conditions for rail traffic.

In both Sweden, Italy and Japan, it has been found that tilting trains can cause travel sickness. During a study trip to FS, the following answer⁶⁷ was received when it came to the question of travel sickness on the Pendolino. In 1970 or thereabouts, a study was conducted on the Rome-Ancona line:

- about 7% became travel sick,
- the same number and the same people who get travel sick in automobiles.

In Sweden, this problem is being studied by Förstberg⁶⁸ at VTI (Swedish Road and Traffic Research Institute). The causes of travel sickness can be the increase in vertical forces to which train passengers are subjected and the higher frequency (an oscillation every ten to five seconds) which results from higher train speeds. It possible to calculate that the so-called “movement dose” increases in express trains with a tilt mechanism.

⁶⁶ On one occasion I experienced a lady braking her leg beacuse of this: She was carrying her hot coffee in the restaurant coach when the train stopped with a sudden jerk. She got hot coffe on her and fell so badly that her leg was broken. (The train was delayed and the driver seemed to try to catch up with timetable.)

⁶⁷ Surace & Buffa at FS in Rome, 1992

⁶⁸ Förstberg,J., *Motion-related comfort levels in trains – A study on human response to different tilt control strategies for high speed train*, Railway Technology KTH, TRITA-FKT Report 1996:41, 1996

Förstberg's research also indicate that the roll velocity should be limited (to about 2.3 degrees/sec) in combination with a lower degree of tilt. Similar results are reported in Japan. The decreased tilt compensation increases lateral forces but decreases the vertical component somewhat.

Wz measures ride comfort; vibrations and oscillations

When it comes to rail traffic, a ratio has been used, W_z (Wertung-Ziffer) to measure the ride comfort of rail vehicles. The W_z ratio measures the oscillations to which a passenger is subjected when he/she travels in a specific coach, on a specific track and at a specific speed.

The W_z scale goes from 5 to 1, where 5 represents very poor movement characteristics and 1 represents very good ones. Modern passenger cars on good tracks have a ratio of around $W_z=2$. In the past, it was felt that 3.25 was the poorest value which should be accepted for passenger traffic.

$$W_z = 0.9 \cdot a^{0.3} \cdot (F(f)/f)^{0.1}$$

where a is the acceleration in cm/s^2 and $F(f)$ is a filter function. The centre frequency for W_z is approximately 5 Hz.

The W_z ratio can be seen as a means of combining vibrations at different frequencies. $F(f)$ in the above formula indicates the filter characteristics. W_z is expressed on a five-point scale. The W_z scale is defined as follows:

$W_z = 1$ corresponds to "very good movement characteristics"

$W_z = 2$ corresponds to "good movement characteristics"

$W_z = 3$ corresponds to "acceptable movement characteristics"

$W_z = 4$ corresponds to "passable movement characteristics"

$W_z = 5$ corresponds to "unacceptable movement characteristics"

So the W_z ratio takes account of vibration and shaking but virtually no account of normal acceleration and braking or jerking movements or sudden vehicle movements. The first of these is due to the fact that W_z does not take sufficient account of low frequencies and quasi static accelerations. The second is due to the fact that W_z is obtained by calculating the average value over a longer period of time, such as 10 minutes or one kilometre of track. It is also possible to measure W_z continuously and in this case the ongoing average value over 10 seconds is normally measured.

Advanced measurement equipment which measures W_z in different directions and in real time is currently available.

ISO standard

An ISO standard has been developed "for assessing whole-body vibrations. The limits in this standard represent a reasonable compromise between the available data and should meet the need for simply, easy-to-comprehend recommendations for general application".

The standard sets guiding limit values for the mean square values of the measured acceleration of the vibration as a function of vibration frequency and exposure time. A

number of experiments with human test subjects were used as the starting point when these limit values were obtained. One new feature in this standard compared with the previous results and standards is that it takes account of exposure time. When the exposure time is doubled, the tolerance is reduced to just over half the acceleration level or by 4-6 dB. The exposure times presuppose daily exposure for long periods of time, including lifetimes. This time dependence is shown below.

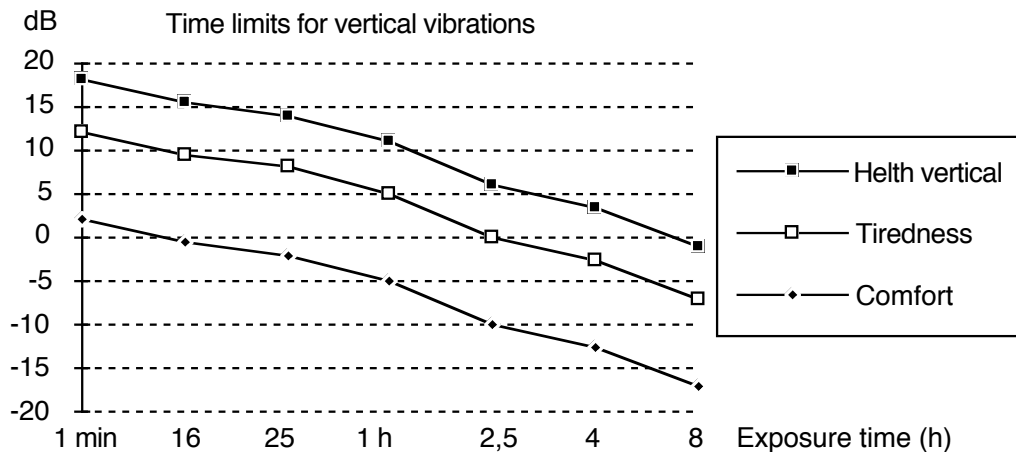


Figure 3.56 Time dependence in ISO standard 2631. Exposure levels in dB on the y-axis. (The 0 dB level was chosen arbitrarily when the diagram was drawn.)

ISO 2631 has three different limit value levels. The starting point is the limit value for tiredness and reduced working capacity. The exposure limit for health and safety is 6 dB higher (double amplitude) and the limit for reduced comfort is 10 dB (about 3.2 times) lower.

When it comes to vertical vibrations, people are most sensitive in the 4-8 Hz range and the standard therefore has a frequency-sensitivity graph which is straight in this range. A variant of this standard has been accepted in the UK. It takes greater account of vertical vibrations in the range of 0.2-2 Hz. In the case of horizontal movements, it is instead a question of low-frequency oscillations rather than "vibrations".

For this project, I have built a vibration meter using the following weighting curves. 0 dB corresponds to 0.1 m/s².

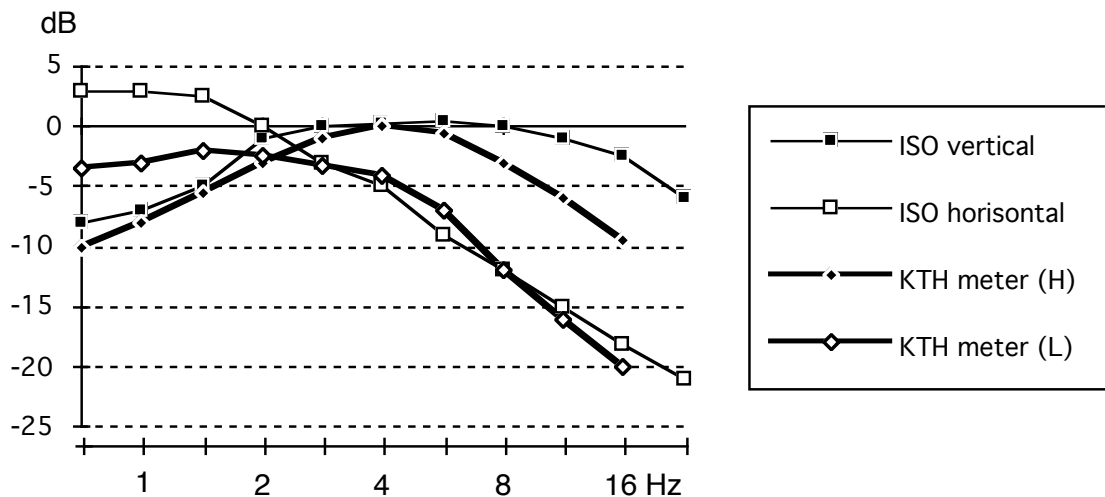


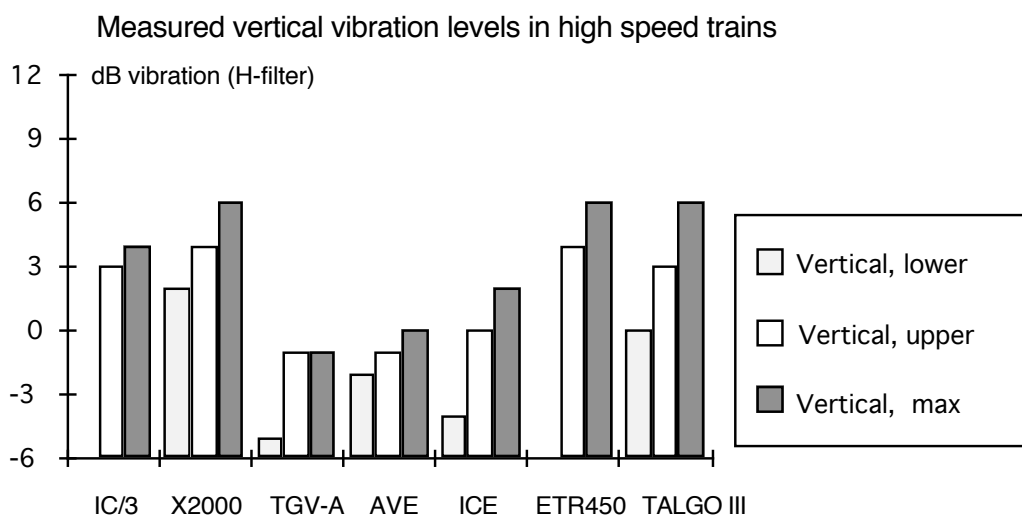
Figure 3.57 Frequency weighting curves for the project vibration meter and ISO 2631 weighting curves.

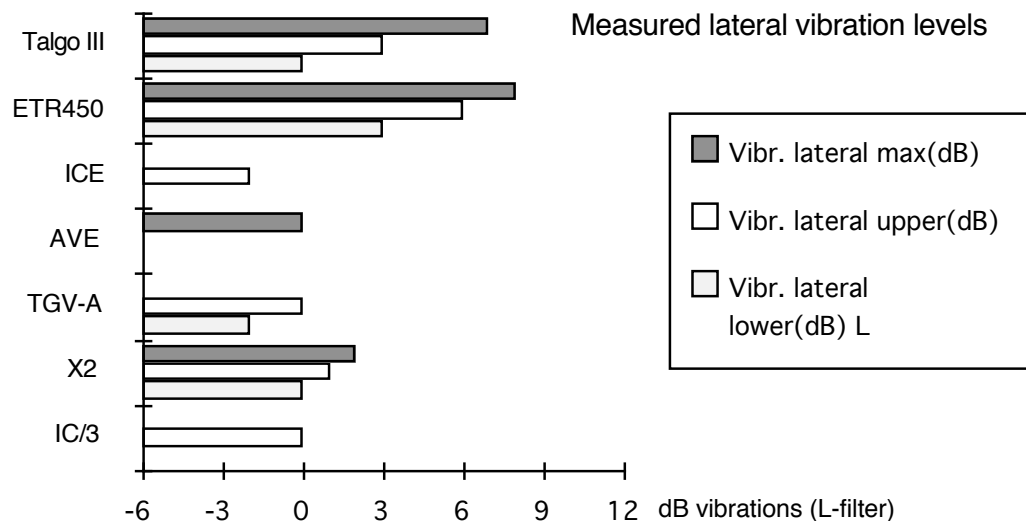
As figure 3.57 shows, the instrument has two measurement ranges, H = High (frequency) and L = Low, with different filter curves. L goes lower in terms of frequency and is designed to correspond to horizontal sensitivity. These ranges correspond partly to the ISO standard.

Measured vibration values

During a study trip in April 1992, I measured accelerations, primarily lateral “forces”, vibrations and noise.

This summary only presents the vibration values for the high speed trains I tested by travelling in them. When studying the diagrams, it is important to remember that the vibration level is the result of both the vehicle type and the track. The AVE and ICE were only measured on newly-built tracks, while the TGV was measured primarily, but not exclusively, on newly-built, high-speed sections of track.





Figures 3.58/59 Vibration levels measured vertically and laterally for various high speed trains on different sections of track. Note that different weighting curves (H, L) were used for vertical and lateral vibrations.

As the diagrams show, the French high speed trains, the TGV and AVE, in particular had low vibration levels. The ICE also obtained good measurement values, but the subjective experience in the ICE was less good, in my opinion. The low levels in the TGV are impressive if one considers that they were measured on a 300 km/h track.

3.4.5 Internal noise

Internal noise is generated by wheel-rail contact, propulsion systems, aerodynamic interfaces (wind noise) and auxiliary equipment such as fans, but it may also be the result of rattling interior fittings. The mean values for normal noise levels in long-distance trains are about 60-70 dB(A), with peaks 5-10 dB higher.

An early study at KTH Railway Technology⁶⁹ shows that the noise level in trains is lower than in private cars, buses, and particularly aeroplanes.

Infrasound can be tiring and is therefore worth taking into account. In buses and passenger cars, infrasound can reach levels of 100-120 dB(IL), which is fairly high.

The degree of displeasure from noise depends not only from the mean and top levels of noise, but also from the content of the sound. A work⁷⁰ has been made at KTH about this. The aim was to identify such physical measures of the sound that correspond well to the displeasure people experience. It was found that for example the amount of sharpness means a lot.

⁶⁹ Jerlström, H., Namumburg, C., *Jämförande mätningar av vibrationer, accelerationer och ljudnivåer hos tåg, bussar, flygplan och personbilar*, (Measurements to compare levels of vibrations, accelerations and noise in trains, buses, aircrafts and automobiles, Railway Technology, KTH, AERO MEMO 90-2, TRITA-FPTT-057, 1990)

⁷⁰ Möller, V.-H., Wahlström, P., *Acoustic comfort on trains – Sound quality assessments*, Railway Technology & The M.W. Laboratory for Sound and Vibration Research (MWL) at KTH, TRITA-FKT 1997:39, 1997

On my study trip in April 1992, I measured the noise levels in the trains in which I travelled. These measurements were made on a random basis and coincidence had some effect on the measurement values. The noise meter is home-made and the frequency-correction curve resembles A weighting (dB(A)). Measurement errors may be large. Later in the project a digital time-integrating sound level meter Bruel&Kjaer has been used.

The measured values are presented below. "Upper" and "lower" values, the mean values measured when the train has gathered speed and maintains a uniform speed, are given. In addition, maximum values, the values on bends, points or poorer stretches of track, were measured.

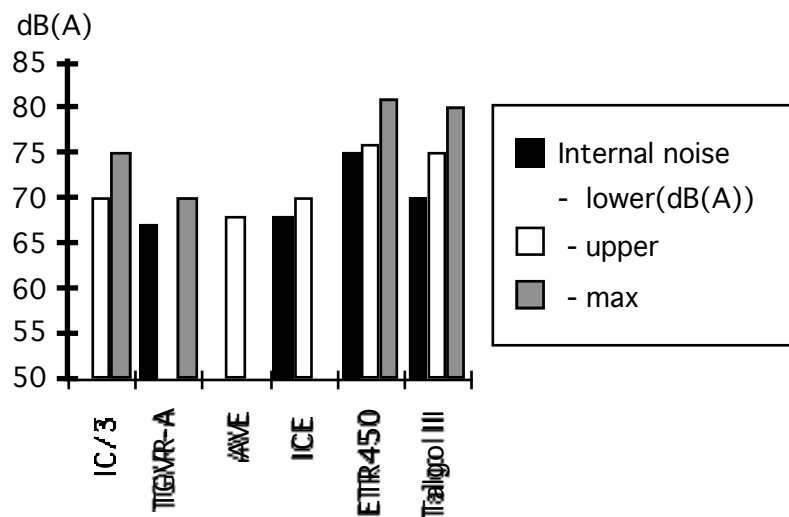


Figure 3.60 Examples of noise levels measured inside some European trains. Comments in the text.. Kottenhoff April 92.

According to my measurements and personal experience, the TGV/AVE was quietest, in spite of the fact that the measurements were made at cruising speed (300 km/h). The ICE was also quiet, but this measurement was made in a compartment near the end of the coach and it is therefore difficult to compare. The Pendolino = ETR450 and the Talgo III were both relatively noisy. On the other hand, the Talgo train was fairly quiet, around 70 dB, on good tracks at intermediate speed. The IC/3 is diesel-powered and is possibly therefore somewhat noisier than it might otherwise have been.

Measurements made later with the professional Bruel&Kjaer meter has revealed lower levels than the ones measured with the home made meter. 54 dB(A) has been measured in X2000 (at around 200 km/h) and 60 dB(A) in a double decked trainset borrowed by SJ in November 1998⁷¹.

⁷¹ Kottenhoff, K., *Utvärdering av Bombardier dubbeldäckat tåg "Competence"*, (Evaluation of Bombardier double decked trainset, in Swedish), report in progress, Traffic & Transport Planning KTH, (1999)

3.4.6 Illumination/lighting environment

The design of lighting in passenger coaches can vary in terms of planning. In less luxurious passenger cars, it is usual to have nothing but general lighting using bluish-white fluorescent tubes. This kind of lighting is still used in Sweden on the Y1 and X10, for example. The next stage is to supplement this lighting with reading lamps which passengers can turn on themselves. Separate reading lamps make it possible to reduce the general lighting. The fluorescent lamps can be replaced with spot lighting facing the centre aisle, for example. The fittings that are used for both reading lamps and spot lighting can be attractive.

Indirect general lighting is used in some coaches. This results in uniform light which does not dazzle anyone.

The choice of the colour temperature of the lighting has a decisive effect on the atmosphere in a coach. Choosing a lower colour temperature, around 3,000-4,000°K, creates a warmer indoor atmosphere. A high colour temperature, on the other hand, creates an impression of “rationality”. To bring out the colour of the interior and do justice to the facial colouring of the passengers, full-colour fluorescent tubes or bulbs, such as halogen bulbs, should be chosen.

As travellers have different expectations when it comes to journeys, it is an advantage if they can adjust the light themselves. Anyone who so wishes can then sleep and those who wish to read can do so.

3.4.7 Climate

One of the most frequently voiced requests from Swedish rail passengers is to improve the climate/ventilation in rail coaches. Many people feel that air conditioning is lacking in the summer.

The climate can be defined as the number of times the air is exchanged every hour and as the temperatures which can be maintained inside depending on the outdoor temperature. It should, however, be pointed out that air conditioning which makes the air too cold can be just as disruptive as too much heat. Tinted glass and/or curtains can be used to screen off thermal radiation from the sun. One way of avoiding high indoor temperatures can be to use reflective outer walls and roofs, such as white or unpainted metal surfaces.

Smoking areas should be separated from non-smoking areas. One alternative to smoking sections could be “smoking cubicles”. Allergy sufferers must be able to seat in sections where furry animals are never allowed.

3.5 Auxiliary systems

In this context, auxiliary systems primarily comprise different types of equipment which provide a service, such as information or entertainment.

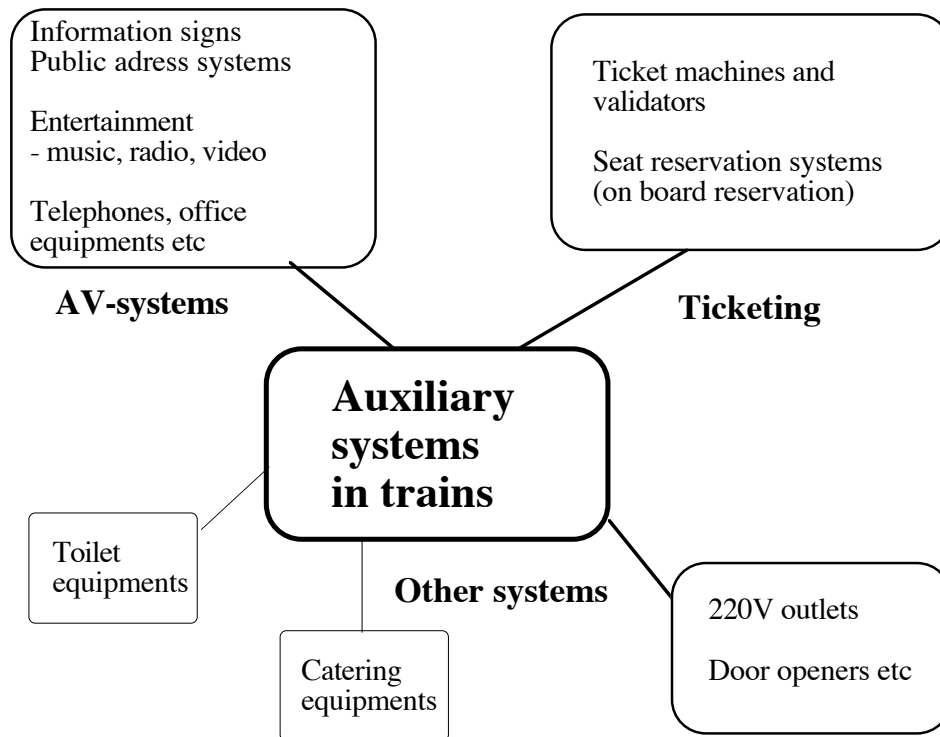


Figure 3.61 A number of specially-selected auxiliary systems in passenger trains, primarily those which provide or facilitate services to travellers. (Some auxiliary systems, as toilet and catering equipment are not dealt with)

3.5.1 AV systems

Loudspeaker systems for announcements from train drivers, guards and refreshment staff are currently available in most Swedish and non-Swedish trains.

Information systems which present visual information can be found in the Danish IC/3 train, for example. On the walls at the ends of passenger coach saloons, there are integrated matrix-dot signs (LED) which display station information, delays and so on. In the vestibule, there is also a map of the operational railway network, on which light diodes (LEDs) show the position of the train and the following stations.

In some trains, like the German (ICE), Spanish (AVE), Danish (IC/3) and Swedish express train (X2000), and in modern sleeping cars, outlets for headphones have been installed in passenger seats. They provide access to radio and music channels and accept either the passengers' own headphones or rented sets. A system of this kind has also been installed on a test basis in a converted regional motorised diesel coach (Y1).

Almost all Spanish trains covering long distances have a video system with a number of screens (12-14 inch) in each passenger coach to enable everyone who wishes to watch video films to do so.

If video is to be offered at seats in passenger coaches, this can be done using about four monitors per coach. The sound can be broadcast through the loudspeaker outlets for the above-mentioned audio system. Is video needed in every coach, together with a central video recorder? There are video recorders for vehicles which are able to withstand vibration more effectively.

In the German ICE trains, LCD monitors have been installed in some seat backs.



Figure 3.62 LCD video monitors in ICE.

In Sweden, there are a small number of cinema cars. Half the coach has been turned into a cinema with a sloping floor. Films are shown using Super VHS. The other half of the coach is a bar. Every afternoon/evening, two to three films from the current cinema selection are shown. The tickets are somewhat less expensive than normal cinema tickets.

Technology: Multiplex systems have been developed to distribute data, audio and image information. Using these systems, a number of audio and video channels can be broadcast, thereby creating the flexibility that is needed to extend the range in the future. To make radio reception in tunnels possible, there are relatively expensive systems involving the re-broadcasting of radio waves via radiating coaxial cables. Another problem is that vibrations in vehicles make it necessary to produce special equipment, which is therefore relatively expensive⁷².

⁷² Some of this information about AV systems has been taken from *Passenger Rail Management* July/Aug 93, pp.28-29.

3.5.2 Ticketing equipment

To sell tickets on board trains, some form of ticket sales equipment is required. Using modern computer technology, it should be possible to produce small, portable ticket machines which can sell tickets for journeys and for seats for at least one national railway network. If on-board sales are to become a dominant method, the security involved in handling cash on board should be dealt with.

An electronic seat-reservation system has been installed on the Danish IC/3 train. The guard can find and reserve a seat for passengers who have recently boarded the train, using a handheld computer terminal ("remote control"). An on-board system of this kind should improve the utilisation of seats, as it will be possible to use seats which are obviously empty. To obtain the maximum flexibility, systems on board trains should be able to communicate with a central seat-reservation system for tickets purchased in advance.

3.6 Technical quality

The term "quality" can be defined and used in many ways. Technical quality is focused here, when the type of quality "owned" by the passengers is focused in section 8.2. In both cases quality has to do with fulfilment of some requirements.

An official definition of quality is the ANSI standard⁷³ quoted from Ladkin⁷⁴:

Quality is the totality of features and characteristics of a product or a service that bears on its ability to satisfy the given need.

An example of this satisfaction ability is if the product conform to specifications. The words "quality control" mean that a check is made to see whether something has the desired characteristics (the quality) or whether specifications have been complied with. In this context, deviations are made from what could be described as a "reasonable ideal condition".

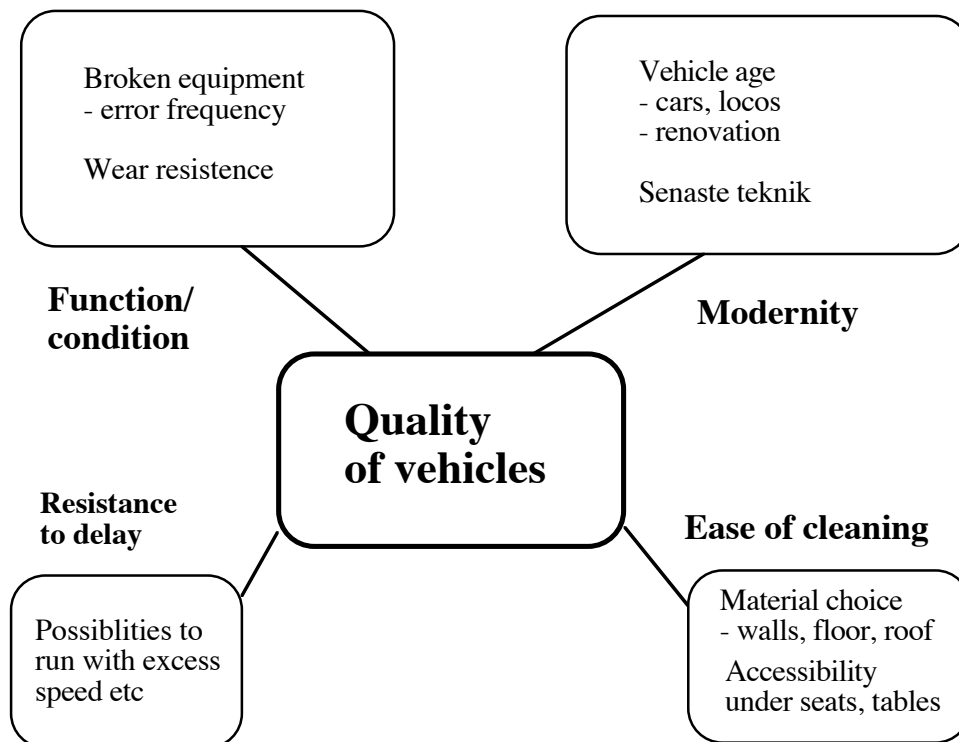


Figure 3.63 Characteristics which can be regarded as the technical quality of vehicles.

⁷³ ANSI/ASQC A3/1978

⁷⁴ Ladkin, P., *Mesuring the quality of service*, published on Internet (nakula.rvs.uni-bielefeld.de/made/folie/folie01.html), Univ. of Bielefeld

These deviations include for example:

- The train being late
- The train being worn and in poor condition
- The train being dirty - poor cleaning
- The train breaking down frequently - high error frequency

Resistance to delays

One aspect of quality when it comes to traction is the ability of the train to deal with wet autumn leaves on the track without slipping and thereby being delayed. One factor which ought to enhance quality in this respect is drive on several axles. When adhesion is reduced, it is more important that the percentage of adhesion weight is high.

Temporary reductions in speed and traffic disruptions which result in stoppages on the line extend running times. These problems should increase as the speed levels increase, as additions to running time increase as a result of braking. According to the section on performance (Figure), the time lost by a stoppage on the line is at least one minute at 120 km/h and at least two minutes at 210 km/h. These losses of time can be partly compensated for by high propulsion effect levels.

Another way of compensating for delays is to permit driving at sporadic excess speeds in the event of delays.

Function/condition

The condition of train material is a combination of wear resistance (durability) which results from the design and the level of maintenance.

In some cases, there may be some conflict between attractive design, such as the number of refinements, and durability. The 1980s trams in Göteborg in Sweden are examples of vehicles in which resistance to vandalism has been (over)emphasised.

Modernity

Modernity can relate to the actual age of vehicles and/or to the degree to which the latest technology or design has been used. Products can be designed to be trendy or timeless. A more timeless design may be regarded as boring, but, on the other hand, it may last longer as time passes.

If the latest technology is chosen, it is possible that the vehicles stay modern for longer - their service life increases. On the other hand, new technology usually has teething trouble which could result in poor function and a short service life.

Ease of cleaning

Vehicles which are easy to clean quickly offer greater accessibility. One possibility which is frequently discussed is to hang the seats from the ceiling in order to clear the floor.

4. Cost estimations

There are fixed and variable costs for infrastructure and train services. In Sweden the National Rail Administration is responsible for most of the infrastructure. The infrastructure is financed mainly by the state but part of the variable costs are covered by rail fees. The operators⁷⁵ are responsible for covering the costs for purchase of rolling stock and operation of trains. For this reason the definition of "train service cost" includes the *operators' expenses for buying and maintaining rolling stock, running the trains, including the rail fees, with some marginal expenses for ticketing and shunting etc. added.*

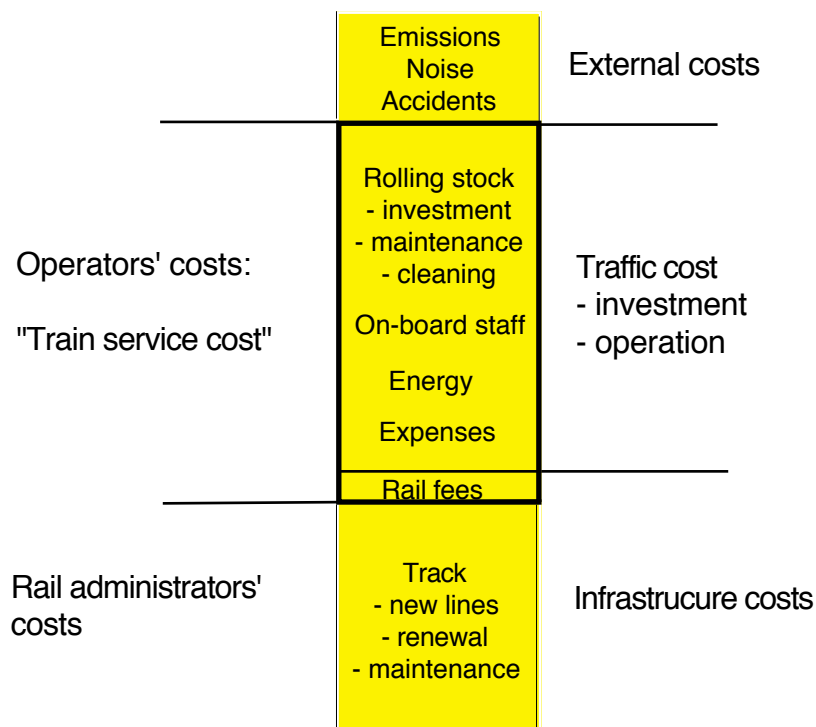


Figure 4.1 A simplified cost structure for rail costs. When train service cost is used in this thesis it means the operators' costs as illustrated in this figure. "Traffic cost" is about the same.

Swedish economists' analysis of passenger-train costs deals to a large extent with marginal costs and pricing of passenger-train services⁷⁶. Taking this point of view one risks

⁷⁵ In a few cases the vehicles may be owned by a regional public transport principal or by a special rolling stock holder. The operator then runs the trains without owning the vehicles.

⁷⁶ See for example Jansson, J.O.et.al., Optimal fares and financing of railway passenger transport, (In Swedish with summary in English), TFB & VTI forskning/research, No.5, ISSN 1101-2986, July 1992, and

Lind, G., *Regional Trains. An analysis of pricing strategies*, (in Swedish) ISSN 0282-8014, TFB report 1991:32

reaching the conclusion that even longer trains are advantageous. The approach in this thesis is different. The traditional approach is feared to conserve principles of transportation that have not been competitive enough vis a vis coaches, buses and aeroplanes, which are all small scale vehicles compared to trains.

4.1 Cost model for passenger train services

In order to calculate the cost of passenger rail services, an economic model⁷⁷ has been developed. The real cost figures for the main operator in Sweden, SJ, are not official and can not be used explicitly. The economic model is therefore based on other sources; in part on cost assumptions in the “Handbook on Investment Cost Benefit Analysis” by the Swedish Rail Administration⁷⁹. The cost levels has been checked against other sources (Baumgartner 1996⁸⁰ and various railway journals⁸¹).

The structure of the model is shown in figure 4.2. From inputs in the top row fixed costs/year and dynamic costs/run are calculated. The trains are supposed to operate according to one of different alternatives, for example high speed, fast, InterCity, express, InterRegio or regional traffic.

The model output is train service cost per passenger-km using different input values, such as vehicle investment, maintenance, staff, energy costs and rail charges. The trains are supposed to operate according to one of a number of traffic type alternatives. In the examples further on, InterCity services with a line distance of 500 km, 10 stops and a maximum speed of 140 km/h have been used.

⁷⁷ The economic model has been named "Tåganalys" in Swedish

⁷⁸ The economic model has been named "Tåganalys" in Swedish

⁷⁹ Banverket, *Beräkningshandledning*, (Calculation manual, in Swedish), BVH 106 and Bengtsson, M., *Underlag till Banverkets beräkningshandledning*, (Background figures for the calculation manual, in Swedish)

⁸⁰ Baumgartner, J.P., *Orders of magnitude of costs in the railway sector*, EPFL Ecole Polytechnique Fédérale de Lausanne, Institut des Transports et de Planification, 1996, Report for UNIFE

⁸¹ Railway Journals; IRJ (International Railway Journal), PRM (Passenger Rail Management), RG (Railway Gazette)

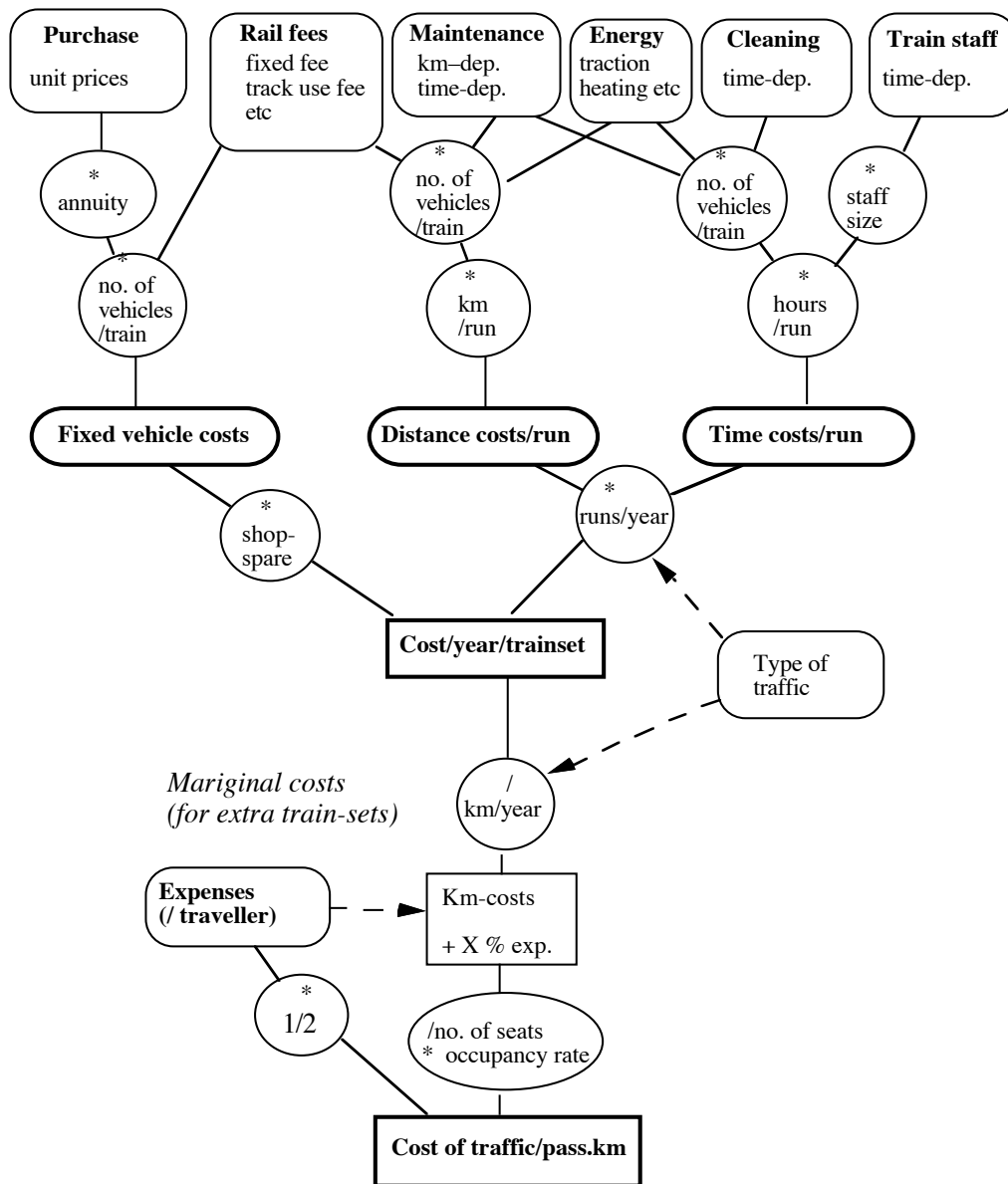


Figure 4.2 Economic model used to calculate train service costs and elasticities.

Vehicle purchase and fixed rail fees add to fixed costs. Marginal rail fees, maintenance and traction energy costs add to distance dependent costs (per run). Energy for heating, cleaning and train staff costs are time dependent costs that add to time costs (per run). The three cost types, fixed, distance and time, add to cost/year/trainset. This cost is divided by train-km/year, number of seats and average occupancy rate. Expenses are estimated to be roughly 20-25% extra. These should represent costs for station services as ticketing, train shunting and so on. Approximately half of the expenses are estimated to be proportional to the number of passengers. Finally the *cost of traffic per passenger kilometre* is calculated.

Approximate levels of the input values are outlined in section 4.2.

Tåganalys 1.0 © Karl Kottenhoff, Järnvägsgruppen KTH Trafikpl., december 1995

Välkommen till Tåganalys 1.0 för Excel 5. Programmet beräknar kostnader för att trafikera med olika slags fordon på olika typer av schablon-banor.

För att köra programmet på enkelt sätt; stanna kvar på denna sida (som heter Dialog) men rulla ner så att den blå ytan ryms på bildskärmen. Om ytan inte ryms helt bör du välja Helskärm under Visa. Tryck på knappar för att välja fordon och trafikering. Data inom ram får ändras.

För mer avancerade analyser kan man ändra data på bladen Fordonsdata och Tågtrafikdata. Glöm inte att ändra tillbaka före stängning eller spara ej vid stängning. Data inom ram är indata.

TRAFIKERING

Välj typ av trafik

Höghastighet

Snabb

Intercity

InterRegion

Express

Regional

FORDON

Välj typ av fordon

X2

långt loktåg

kort loktåg

MV160(X12)

MD130 (Y1)

MD180 (Y2)

Ledbuss

RÄNTENIVÅ

7%

Kostnadsfördelning

kr/pkm

■ Fasta ■ Avstånd ■ Tid ■ Pålägg

Trafikdata InterCity

Linjelängd, km	500
Stationsavstånd, km	50
Turtäthet, tim	1
Max. hast. km/tim	160
Medelhast. km/tim	112
Andel morgon/kväll %	20
Andel fredag/söndag %	20
Antal tågsätt för trafiken	12,1
Omkostnader/personkm	0,10 kr
Beläggningsgrad (%)	35

Tågdata för mv160 (X12)

Antal motorv.	2
Antal platser	244
Tågvikt	220
Tåglängd	100
luftmotst-faktor	1
konduktörer	2
serveringsp.	1
tågvårdar	0

RESULTAT

	Kr/pkm	Jmfrvärde	Skillnad (%)	Elasticitet
Tågtrafikkostnad/ pkm inkl. pålägg	0,79 kr	0,79 kr	0%	0,00

Sätt in jämförvärde

Figure 4.3 A copy of the dialogue frame of the economic model "Tåganalys".

The program lets you choose one of six default types of traffic or products and combine these with one of seven types of vehicles or rolling stock types. Some of the default input data as traffic and vehicle features can be modified from the dialogue frame. There is also an input for varying the interest level.

Outputs on the dialogue frame are SEK/passenger kilometre for the actual combination and an earlier reference combination of traffic and vehicle types. The cost difference is presented in % of the cost. Given you make a 10% change in some input parameter, the elasticity for that measure is also presented.

Finally there is a diagram presenting the cost share for fixed costs, distance and time dependent costs and expenses.

4.2 Cost levels for rail passenger vehicles and operation

Cost figures are needed as input to the economic model. While the main purpose of the economic model is not to give as exact output as possible, but to give an idea about levels and the various influences, approximate input costs can be used. Table 4.1 shows vehicle investment costs.

Table 4.1 Vehicle investment costs. (X2 is the vehicle type for X2000 services).

INVESTMENT	From Banverket/ other estimation	From EPFL (Baumgartner)
Electric locomotive, 4 MW	30 MSEK	5,5 MCHF (4-6) ≈ 30 MSEK
Electric locomotive, 6 MW		6,5 MCHF (5-7) ≈ 35 MSEK
Two-body suburban EMU	30 MSEK	5 MCHF (4-6) ≈ 28 MSEK
X2000 with 5 cars (200 km/h)	90 MSEK	
Tilting train with 9 cars (220-250 km/h)		25 MCHF (24-30) ≈ 140 MSEK
Coach (Am. passenger car)	10 MSEK	1,3 MCHF ⁸²
Dining car	15 MSEK	2,0 MCHF ⁸³ (AC)
		3,0 MCHF

An ordinary locomotive investment costs around 30 MSEK. The new 6 MW generation locomotives have just a slightly higher price. A passenger coach (traditionally) designed for InterCity services costs around 10 MSEK. The costs of EMUs differ a lot, depending on the size of train, but also depending on performance and business reasons.

Maintenance costs are often presented as costs per kilometre. This is done below too, by EPFL. Banverket has divided the maintenance costs into maintenance and cleaning, where the latter is related to time. It is believed that in reality much of the wear and tear is time dependent, for example interiors and part of the propulsion equipment.

⁸² This price is given for a coach without Air Condition

⁸³ This price refers to a coach with Air Condition (AC), but there are probably many more design differences in comparison to the coach without AC

Table 4.2 Vehicle maintenance cost levels

MAINTENANCE COSTS	From Banverket/ other estimation	From EPFL ⁸⁴
Electric locomotive,	4,8 SEK/km	0,7 CHF/km $\approx$ 4 SEK/km
Two-body suburban EMU	6 SEK/km + 30 SEK/h (clean.)	2,0 CHF/km $\approx$ 10 SEK/km
X2 with 5 cars (200 km/h)	11 SEK/km + 180 SEK/h (clean.)	
Tilting train with 9 cars (220-250 km/h)		5 CHF/km $\approx$ 28 SEK/km
Coach	1,2 SEK/km + 30SEK/h (clean.)	0,3 CHF/km ⁸⁵ 0,4 CHF/km ⁸⁶ (AC)
Dining coach	2 SEK/km + 40SEK/h (clean.)	0,6 CHF/km

Table 4.3 shows approximate cost levels for on-board staff. These costs levels are approximate for many reasons. Wages may differ from companies, types of service and not at least between countries, but the main reason is that the real levels are, at least by SJ, secret.

Table 4.3 On-board staff cost levels

ON-BOARD STAFF COSTS	From Banverket ⁸⁷ / other estimation
Driver	500-600 SEK/h
Conductors	300-500 SEK/h
Catering staff	300-400 SEK/h
Bus driver (road transport)	200-250 SEK/h

The staff costs include expenses for staying overnight, subsistence allowance, tax and so on.

The cost of electric energy is cheap in Sweden in an international comparison. Big industrial users, as SJ, pay even lower prices for electricity. The marginal price per kWh was in

⁸⁴ Baumgartner, J.P., *Orders of magnitude of costs in the railway sector*, EPFL Ecole Polytechnique Fédérale de Lausanne, Institut des Transports et de Planification, 1996, Report for UNIFE

⁸⁵ This price is given for a coach without Air Condition

⁸⁶ This price refers to a coach with Air Condition (AC), but there are many other design differences in comparison to the coach without AC

⁸⁷ Banverket, *Beräkningshandledning*, (Calculation manual, in Swedish), BVH 106 and Bengtsson, M., *Underlag till Banverkets beräkningshandledning*, (Background figures for the calculation manual, in Swedish)

the order of SEK 0.25 /kWh in the beginning of this decade⁸⁸ ($\approx$ 1990-1995). Costs for the electric installations are not included in this figure. For two reasons somewhat higher electricity price (SEK 0.30 - 0.40 /kWh) has been used in the calculations with the economic model:

- The Swedish electricity price level will probably rise in the future.
- A higher price makes the calculation results more adapted to international circumstances.

The calculations made in this project includes rail fees, as they were up to 1998. The Swedish government decided to lower the rail fees for passenger rail (and to exclude them for freight rail). In 1999 the rail fees were lowered⁸⁹ to level out discrepancies in socio economic cost responsibility between road and rail – to give rail transport the same level of subsidy as road transport, from a socio-economic standpoint.

Table 4.4 shows the Swedish Rail Administration fees⁹⁰ effective up to 1998.

Table 4.4 Swedish rail fees, up to 1998.

RAIL FEES (<1999)	Fixed cost	Track cost	Operation cost
Electric locomotive,	245.000 SEK/year	0,0076 SEK/tonkm	2,6 SEK/trainkm
Two-body suburban EMU	110.000 SEK/year	0,0027 SEK/tonkm	2,6 SEK/trainkm
X2 with 5 cars (200 km /h)	330.000 SEK/year	0,0035 SEK/tonkm	2,6 SEK/trainkm
Passenger coach (4-axes)	50.800 SEK/year	0,0035 SEK/tonkm (– 0,0025 with radial steering bogies)	

The rail fees as part of the total train service costs was moderate, but in comparison to buses on the road they were high. Buses had to pay 7 000 SEK road tax per year, fixed cost while a competing railbus had to pay about ten times more for using the tracks.

⁸⁸ Electricity invoices at SJ.

⁸⁹ Svensk Författningssamling, SFS 1998:1827, valid from January, 1st, 1999

⁹⁰ Svensk Författningssamling, SFS 1988:1378, SFS 1991:2038 and SFS 1995:740

4.3 Cost elasticities for various factors

The economic model is used to obtain “cost elasticities” or “cost influence rates”. The elasticity rates show how much the train service cost changes in relation to the relative change in input parameters. So, cost elasticity shows, for example, for a vehicle investment how great the marginal percentage change of train operating cost level becomes in case of a marginal change in the vehicle investment cost.

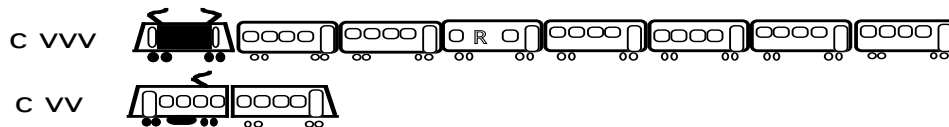


Figure 4.4 Train types and crews used for the example in the text

In the calculations in this example trains are assumed to work a 500 km long line with 10 stops (InterCity traffic). Average speed is 110 km/h and top speed 160 km/h. Calculations are made for a short multiple-unit set and a long locomotive-hauled train of 7 cars. Both cases refer to a Swedish case in the first half of the 1990's.

Share and elasticities for various resources – cost categories

Table 4.5 shows the incidence of different types of *real costs*. The cost categories in the table are input in the economic model used.

Table 4.5 The importance of some cost items of two train types. This can be most easily be recognised as a (weighted) cost elasticity, see text.

Part of cost per passenger-km	short emu-train	long locomotive hailed train	Cost elasticity, w eighted value
Vehicle investment	26%	32%	0,30
Vehicle maintenance	18%	18%	0,18
Cleaning	2%	3%	0,03
On board staff	27%	19%	0,22
Energy costs (electricity)	5%	5%	0,05
Track fees	9%	4%	0,06
Miscellaneous ⁹¹	15 - 25 %	15 - 25 %	

In order to realise the importance of different cost items, one can for instance reduce an item by 10% and multiply by the cost elasticity. The dominant factor, vehicle investment, has an elasticity of 0.3, which means that a 10% investment cost reduction results in a 3% operating cost reduction. After that, the most significant factors are on board staff remuneration and maintenance costs.

⁹¹ These costs include (part of) administration, ticket sales, shunting and traffic control etc

The influence of other factors

Table 4.6 shows the incidence of changing *other factors*, for instance the occupancy rate, space utilisation and number of km per vehicle and year. All of these, except the interest rate, influences the effective use of the vehicles, the vehicle-utilisation during its life time. Some of these factors are not explicit, but implicit in the economic model.

Table 4.6 Cost elasticity of different factors / input data into the economic model. The initial (normal) values have been put in brackets

Factor/ parameter	EMU-train	Locomotive hauled train	Weighted value
Average occupancy rate (0,35)	≈ -0,9	≈ -0,9	≈ -0,9
Space utilisation	-0,5 - -0,6	-0,3 - -0,5	≈ -0,5
Vehicle kilometre performance (250' km/year)	-0,25	-0,3	≈ -0,3
Speed increase ⁹²	-0,25 (150 - 200 km/h)	-0,15 (200 - 250 km/h)	≈ -0,2
Real interest rate (7 %)	+0,13	+0,17	≈ 0,15
Life (cars 25 / locos 30 years)	- 0,13	-0,12	≈ -0,12

The cost level decreases almost proportionally to the number of travellers on a certain train. This is demonstrated in that the cost elasticity of the average load is as high as about 0.8-0.9. Average load is the occupancy (share of seats occupied by travellers) taking into account the yearly, weekly and daily variations and varying occupancy of different departures and along a line. For ordinary Swedish trains today's (mid 1990) average occupancy is around 35 %. (Occupancy is higher on some InterCity and X2000 services but rather low on other services.)

Given a certain demand and average occupancy rate it is also of great importance that the vehicle space can be utilised for *travellers*. Space utilisation has been calculated as the number of seats per vehicle at a constant number of seats and occupancy. This implies that *a train with higher space utilisation is made smaller* (shorter). (Space utilisation may, but does not necessarily, influence space-related comfort and thereby the value of train riding).

⁹² The elasticity rates of speed increase relate to the same type of train but to different speed intervals.

Summary of different cost-influencing factors

Cost elasticity of some of the factors one often tries to influence have been summarised. The diagram below shows elasticities for some input dimensions:

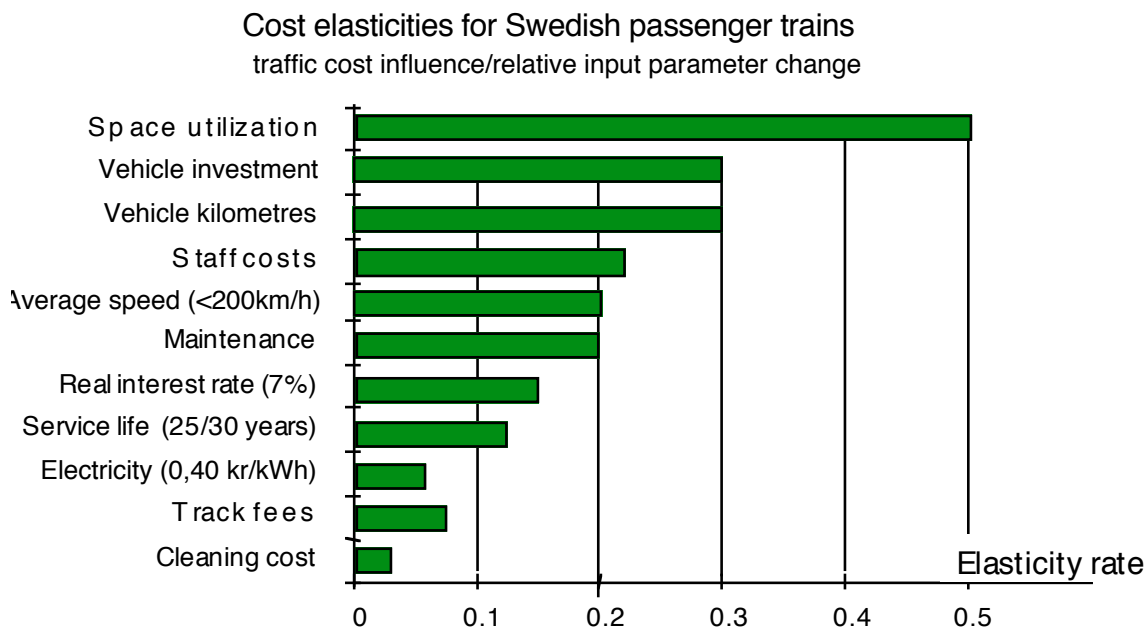


Figure 4.5 Cost elasticities; production cost change at marginal changes of various parameters.

Figure 4.5 shows that cost elasticity of space utilisation is higher than of any other factor one often tries to tackle. The elasticity rates show, for example, that, if vehicle investments could be, say, 20% lower, this would decrease the total train service cost by $0.3 * 20\% = 6\%$. To save the same train service cost by increasing space utilisation would require the utilisation to increase by only 12%, while it would hardly be possible to reduce train service costs by 6% by reducing electricity use or costs. This shows that the elasticity rate for spatial usage is comparatively high – higher than that of many other factors which are frequently addressed.

Another way of interpreting the results of the above figure is the following: In order to reduce production costs by 10% it is necessary to achieve

- 20% higher space utilisation or
- 40% lower vehicle investment or
- 50% train-crew reduction or
- 60% less expensive vehicle maintenance.

4.4 The potential for cost reductions

There are potentials for reducing costs of train services in various areas. One area, which is very much dealt with these days, is the organisation. How should the railway sector and how should a railway company be organised for lowering costs? An other area is production of rolling stock in the future and how to lower vehicle costs. How much can standardised components and modular vehicle designs contribute to lowering the cost level? These areas are not treated in this thesis. The focus is instead on the role of the general design of the rolling stock for passenger trains. Effective vehicle design to favour *space utilisation* seems to be the least difficult step. Another equally important measure is increased average speed levels.

Efficient use of space decreases costs

The space utilisation elasticity is high - about 0.5! This is due to the fact that several cost items can be reduced if a smaller number of vehicles can be operated with the same number of seats per train.

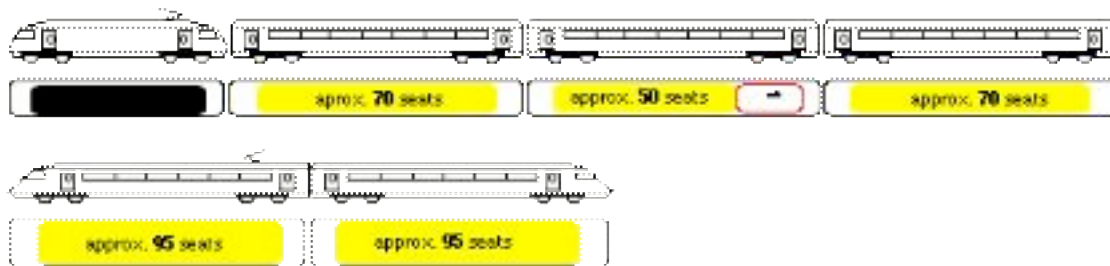


Figure 4.6 Increasing space utilisation – using smaller trains for about the same seating space. Note that the EMU train is wider, thereby permitting comfortable 3+2 seating (figure produced by Kottenhoff and Troche, first presented 1997 in *Efficient Passenger Rail Services for the Future*⁹³).

Space utilisation can be calculated as the number of seats or the furnished area per train length, given a fixed number of total seats or a fixed furnished area, that meet the demand in the individual market. This means that a train with increased space utilisation must be made shorter and is therefore cheaper. Simply increasing the number of seats with a given physical train size creates a train with higher capacity, for a different market – with higher demand.

Please note that as physically large, a train with more seats caters for another market and, consequently, this is an unsuitable definition of the term "space utilisation". The point is that the train can be made smaller and thereby cheaper.

⁹³ Railway group KTH, Andersson, E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik*. (Efficient Passenger Rail Services for the Future, in Swedish – English version is underway, 1999), KTH Railway group report 9702, 1997

Operating costs decrease at higher speed

Higher average speed reduces costs since the vehicles are being better utilised. What are the cost factors contributing to this and how do they vary with the speed level?

Here some simplified assumptions are made:

- *Energy costs* of propulsion increase with the speed while electricity heating is a function of time. Speed dependence normally is empirically in the order of $v^{1.5}$ where v is the top speed⁹⁴.
- *Capital cost* per km decreases with higher vehicle performance since the same vehicle by higher average speed can make more operating turnarounds per year. Due to terminus turn arounds which are not influenced by speed, part of speed increase can not contribute to lowering the capital cost. The calculation also takes into account that vehicles for higher speeds become (somewhat) more expensive.
- *Maintenance costs* of vehicles are about half dependent on distance-related wear of the bogies, propulsion, and braking systems. The other half concerns vehicle components (primarily interior fittings and auxiliary systems) that are not worn in relation to kilometres covered but to the scheduled service period.
- *Cleaning costs* are in principle time-dependent.
- *Track costs* are not included in *this* calculation. (Here it is assumed that existing track can be used for higher speeds without costs increasing more than marginally.)
- *Traffic-service type*: InterRegio with stops every 25 - 30 km.

Given these assumptions one can calculate a cost level related to the speed level according to figure 4.7:

⁹⁴ According to emperic figures from professor E. Andersson, KTH Railway Technology.

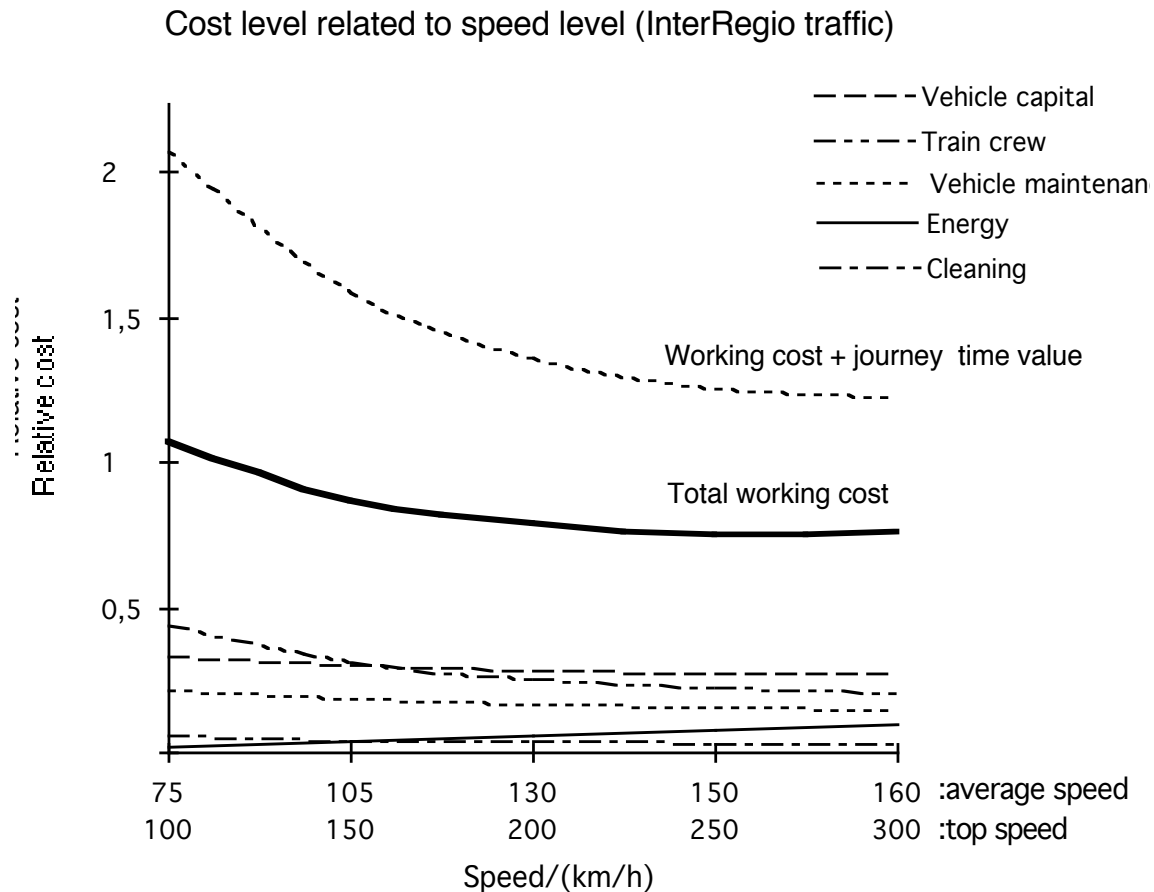


Figure 4.7 Cost of running trains at various speed levels on a track allowing 300 km/h. How a number of cost factors vary given the assumptions according to the previous text. The upper curve includes even the journey time value.

Cost levels in the above diagram are based on calculation with the economic model. It can be seen that, given the assumptions quoted, total production costs have a flat minimum at around 240 - 280 km/h. The price of electricity has been estimated at SEK 0.5/kWh which is about 70% higher than the present Swedish level. This has been done for two reasons: Electricity prices are low in Sweden in an international (European) comparison and they might be adjusted upwards in the future. With still higher energy prices the optimal speed becomes somewhat lower.

The upper thin dashed line in figure 4.7 shows the result of regarding (private) travellers' travelling time as a cost. In view of this time rating, "costs" continue to decrease above 300 km/h.

The significance of other factors

The interest rate and life chosen in econometrics are, of course, also vital. The elasticities of these model parameters are 0.12 - 0.15. Train size is also interesting and has been separately studied, see sections 4.4.2 and 4.4.3.

In the following two sections examples are given of the potential for various measures to reduce costs. In 4.4.1 examples are related to general features or performances and in 4.4.4 more effective EMU concepts are investigated.

There is a number of methods to improve the efficiency of long-distance rail passenger service as can also be seen from a thesis by Vieregg⁹⁵.

4.4.1 Estimation of the relative potential for various measures to reduce costs and the aggregate potential

The elasticities show the potential for various measures given equally relative changes of the input factors. However, different measures have different potentials. An attempt to estimate realistically sized measures is given here.

In this case both the elasticity method and more precise calculations by the economic model are used. The elasticity method is not intended for changes of greater magnitude than about 10-20 %, so this method can give approximate results.

Some of the assumptions regarding the various measures are:

- The occupancy rate can be raised from about 35% today up to 50% at most. Of course some lines, especially high-speed services between two big cities may reach even higher average loads, but for a national railway system as a whole even 50% is very high⁹⁶.
- The number of seats per train length may be raised by as much as 60% by a combination of measures. One is to change from loco-hauled trains to multiple units, which use space better, for passengers and not for equipment, and another measure is to have five seats abreast in a wide body design.
- Vehicle performance may be raised by higher speeds, more effective planning and maybe even by systematic timetables. (This may contradict to high occupancy rate.) Some years ago Swedish EMUs in regional service did not perform more than 150 000 km/year. This was a low figure compared to figures from 250 000 to 500 000 km/year for modern services. In table 4.7 a raise by 30-50% is being used, considering the same type of market (in this case the regional market).
- The average speed can increase by higher maximum speeds and less speed reductions made possible by new and upgraded railway lines and also by quicker acceleration and deceleration and shorter stops. An average speed increase of 50% (from 80-120 or 100-150 or 120-180 km/h) has already been achieved by modern trains on modern infrastructure. A good example is the regional line Svealandsbanan where the average speed has been increased by 70%. With high power EMUs it would be possible to reach almost twice the former average speed level.
- Vehicles can be made cheaper by standardisation. That means to have fewer types of vehicles, but more of each, to have the same vehicles in more countries and to use

⁹⁵ Vieregg, Martin, *Effizienzsteigerung im Schienenpersonen-fernverkehr*, Akad. Verlag München 1995, ISBN 3-929115-4

⁹⁶ Rosenlind, Stina, Thesis in progress, KTH Traffic and Transport Planning, 1998

standardised industrial components for the rail vehicles. The anticipated -30% is the cost reduction over and above the reduction that is due to smaller vehicles with better space utilisation.

- Maintenance costs can be reduced. More effective overhaul methods are of importance but also the use of cheaper components, standardised for industrial use.
- The on-board staff has long been redundant. Even rather small Swedish trains has had two conductors and one or two catering personnel plus the driver. In future trains the conductors and catering staff would be the same persons and in short multiple units it would be possible to let the driver give some sort of passenger assistance. There is a great potential for cost reductions, here -40% is proposed.



Figure 4.8 Costs for on-board staff can be reduced if the conductors also work with catering. This is the fact in some Swedish train, here in "Kustpilen", where the conductor serves coffee after having checked the tickets.

- The energy use can be reduced by better aerodynamics, lower weight, more efficient propulsion systems and by regenerative braking. A reduction of 30-50% is possible at the speed levels relevant in the future⁹⁷.

Each measure is supposed to take place separately. The effects of more measures can not be summed arithmetically. Instead the effect of all measures together has been calculated by the economic model.

⁹⁷ Andersson, E., *Energiförbrukning och luftföroreningar av svensk eldriven järnvägstrafik*, (Energy use and air pollution from Swedish electric train traffic, in Swedish), KTH Railway Technology, TRITA-FKT 9420, 1994

Table 4.7 Potentials for cost reductions by different measures and for all measures together. (The most right column are values calculated directly by the model for a small multiple unit train/ loco hauled train.)

Measures	Change, p to....	u	Elasticity	Change * Elasticity	Calculated by model
Higher occupancy rate	+ 30-40%		-0,8	≈ -25 %	-22% / -23%
Better space utilisation (shorter train, same service)	+ 60 %		-0,5	≈ -30%	-29% / -15%
Vehicle performance (km/year)	+ 30-50%		-0,3	≈ - 10-15 %	-9% / -11%
Average speed increase	+ 50%		-0,2	≈ -10%	-13% / -12%
Cheaper vehicles	- 30%		+0,3	≤ -10%	-9% / -11%
Lower maintenance costs	- 20%		+0,18	≈ -4%	-5% / -3%
Fewer on-board staff	- 40%		+0,22	≈ -8%	-10% / -5%
Lower energy use	- 30-50%		+0,05	≈ -2%	-2% / -2%
All measures above	—		—	—	-52% / -46%

As before, attending the cost elasticity figures, a better space utilisation is very significant. The figures also confirms the importance of higher average speeds and higher vehicle performance.

The figures for the effect of all measures above show a possible cost reduction of about 50% for the combination of all measures, but the method includes a few double calculations. The real potential may be in the interval 40-50% reduced cost level for passenger train services.

As can be seen, cost reductions are for most measures larger for the small multiple unit train than for the bigger loco hauled train. It seems even more important to prosecute as much of the measures as possible, when shifting to EMUs for passenger services.

4.4.2 Cost function for trainset size

Trains are made up of vehicles that are connected to each other. A preliminary calculation of how costs vary with train unit size is summarised below.

In this section we will use the three notions train, trainset and vehicle. The meanings of these are illustrated by figure 4.9, which shows one *train*, consisting of three *trainsets* of two *vehicles* each.

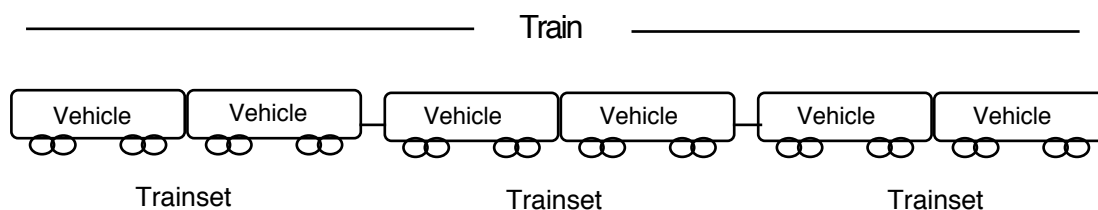


Figure 4.9 The notions train, trainset and vehicle.

The question is: How big should the trainsets be from a cost minimising point of view? This depends on divers technical, staff-related and traffic/service related circumstances, for example the cost of separate propulsion and driver cabs, the cost and number of staff needed, the travel demand and the nature of demand variations.

A simplistic calculation model has been made in work sheets (Excel). It takes into consideration:

- The marginal costs per seat, per vehicle, per trainset and per train.
- The level of the demand, the "scale".
- Demand variations between runs.

The model does not esteem how the investment costs are affected by runs of different lengths.

If only one train size exists this size is fixed by the maximum demand – the number of passengers on the most occupied run. The other runs have less passengers and the demand per run can vary according to three alternatives: convex, linear or concave. This is illustrated below.

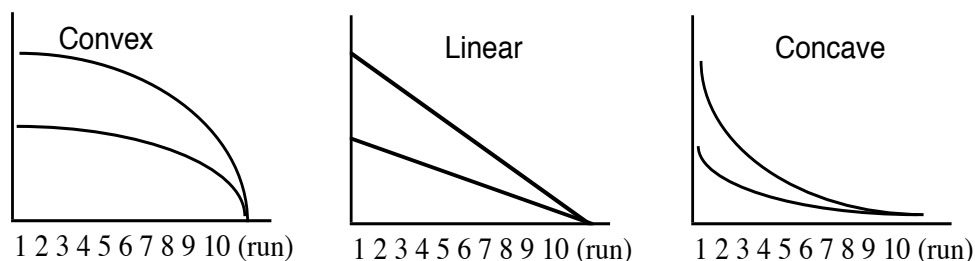


Figure 4.10 Variation of travel demand per run

The convex demand curve is more likely for long distance services than for short distance commuter services. The latter can be quite concave if there are few mid-day travellers and there is still a good number of runs.

It is assumed that if the train size is not flexible the convex demand curve will give lower costs than the linear and concave demand variations. It is interesting to analyse the potential benefit of smaller trainsets that can be coupled to large trains when needed. The result of such a, preliminary, calculation is shown below.

The calculation presumes that trainsets that are not needed a specific run can be easily decoupled. 70 seat vehicle size has been used.

The first diagram show the train service cost versus demand and trainset size. The demand figures represents the capacity needed on the run having the largest number of passengers.

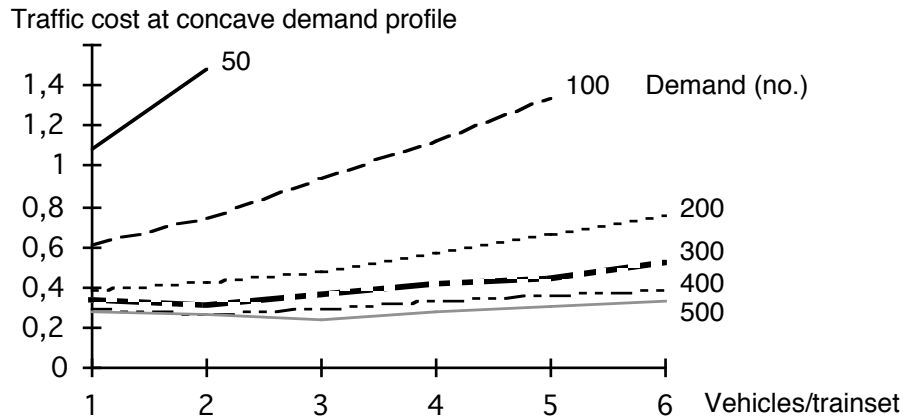


Figure 4.11 Traffic costs at different trainset-sizes with respect to demand level.

The first diagram (figure 4.11) shows that traffic cost increases with number of vehicles and this is especially distinct at low demand levels. For demand curves of 300 passengers or more two- or three-vehicle trainsets tend to be somewhat cheaper than one-vehicle trainsets.

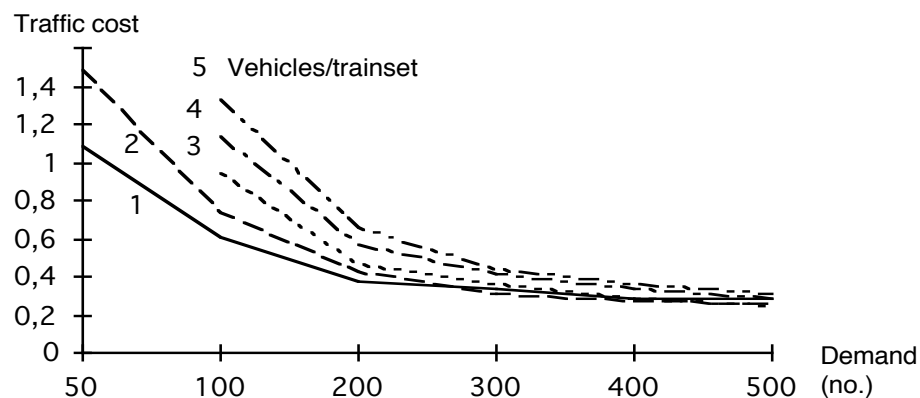


Figure 4.12 Traffic costs at different demand levels with respect to trainset-size.

The second diagram (figure 4.12) shows that costs sharply decreases with demand, at least up to 200 passengers. Up to this number one-vehicle trainsets are the cheapest and from 300 up, two-vehicle trainsets seem to be somewhat cheaper.

One conclusion of this is that if there are lines with low demand included in the total traffic system and the demand curve is concave, small *one-vehicle trainsets* should be reflected upon.

4.4.3 Staff use and gangways for trains with various number of trainsets

Two factors that interact are staff usage and the existence of gangways between trainsets in a multiple unit train. The usage of staff can be made more efficient if conductors can also work with catering. If there are gangways in between trainsets the staff can also be more effectively utilised. Naturally the combination of these two effects should also be considered.

The cost model, "Tåganalys", has been used for a clarified analysis of these effects. A Flexliner (IC/3) vehicle type with train sizes of one, two and three trainsets. The number of staff assumed is shown by the following table.

Table 4.8 Anticipated number of staff in trains with various number of trainsets and with/without gangways between trainsets.

	One trainset train	Two trainset train		Three trainset train	
		No gangway	Gangway	No gangway	Gangway
<u>Separate staff</u>					
Driver	1	1	1	1	1
Conductor	1	2	1	3	2
Catering staff	1	2	1	3	1
<u>Multi purpose</u>					
Driver	1	1	1	1	1
Cond.+catering	1	2	2	3	2

The resulting traffic cost (relative cost per passenger kilometre) is shown in the diagram below. A short train, of one trainset size, with 1 driver, one conductor and one catering staff is used for the reference cost level.

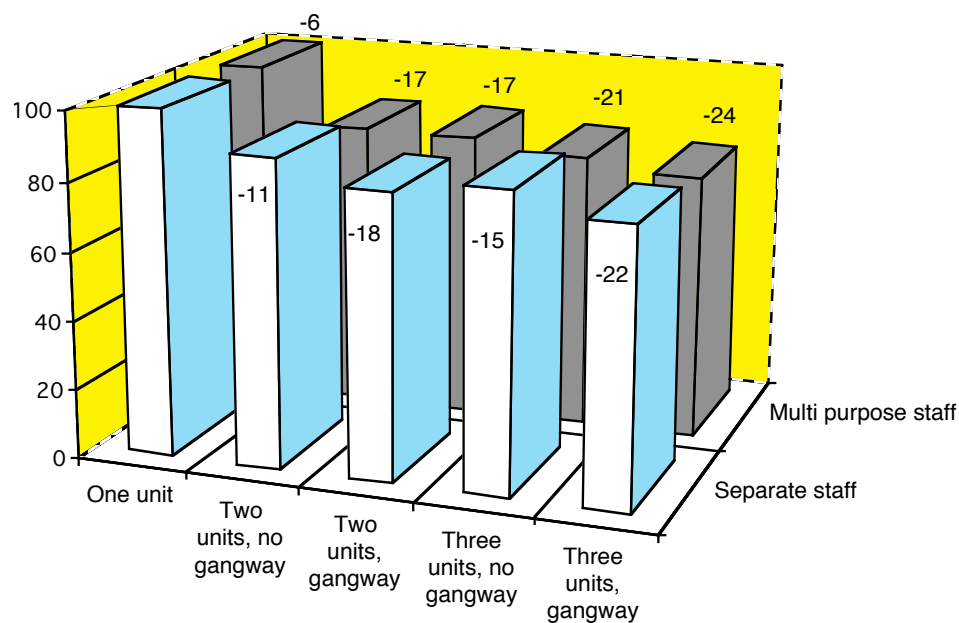


Figure 4.13 Relative costs for trains of different size, staff use and existence of gangways between trainsets.

Beside the fact that the traffic cost decreases with train size, the figure shows that both multi purpose use of train staff and gangways reduces staff costs and thereby traffic costs. The gain by having gangways is about 7-8 per cent of the costs for trains consisting of two and three trainsets. The gain of using the staff for multi purposes is estimated to be around 6-7 per cent when having no gangways. When utilising the on-board staff for multi purposes the gain by having gangways between parts of the train is reduced.

4.4.4 High speed, space efficient EMUs instead of loco-hauled trains

For the project "Efficient Passenger Rail Services for the Future" by the Railway Group, KTH cost levels have been calculated for various new vehicle types. Estimation of the investment cost levels has been made for wide multiple unit trainsets (WMU), double decked trainsets (DD) and for trainsets with wide and short bodies resting on Jacob bogies (SWMU).

The estimation starts from figures of the share of the vehicle investment cost for different sub systems in a multiple unit trainset (from Adtranz⁹⁸). The new cost level has been estimated by the working group for vehicles in the project Efficient Passenger Rail Services for the Future (KTH, 1997⁹⁹). Table 4.9 shows the potential for cost reductions.

These calculations include the cost of increased standard (performance, comfort etc.) but also estimated savings for larger series and the use of standardised components.

Table 4.9 Costs for different parts of an ordinary motor coach and possible reduction potential due to a lighter and more effective technique, as well as an increased degree of standardisation in a ten year perspective.

Part of vehicle	share of cost (%)	part cost MSEK	MSEK/ part	Reduction due to - lower weight	- efficient technologies	-standardisation	New cost level MSEK
Bogies	11%	2,8 Mkr	0,7	-0,05	-0,1	0	0,55
single axles							
Propulsion equipment	20%	5,0 Mkr	5	-0,3	-0,7	-0,5	3,5
Brakes + air	9%	2,2 Mkr	1,1	-0,05	-0,4	0	0,65
Carbody	11%	2,8 Mkr	1,4	-0,1	0	0	1,3
Doors, windows etc.	10%	2,4 Mkr	1,2	0	-0,2	-0,1	0,9
Seats etc.	10%	2,6 Mkr	1,3	0	0	-0,2	1,1
Fronts	15%	3,8 Mkr	1,9	0	-0,4	-0,2	1,3
Other	14%	3,4 Mkr	1,7	0	0	-0,2	1,5

⁹⁸ Adtranz conference presentation of new rolling stock, Copenhagen, Nov. 21,1996

⁹⁹ Railway group KTH, Andersson,E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik*. (Efficient Passenger Rail Services for the Future, in Swedish – English version is underway, 1999), KTH Railway group report 9702, 1997

Wide multiple units

The furnishable area of wide multiple units have been investigated. The drawing below show the assumptions made for a well utilised single unit.

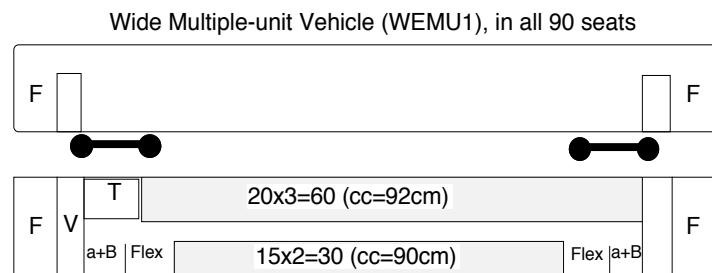
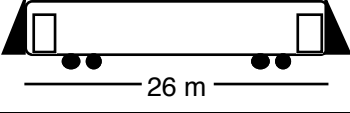


Figure 4.14 Outline for a single unit of a wide multiple unit concept. Figures show number of seats.

The first calculation pertains to wide multiple unit trainsets of different size; sets of 1, 2 and 4 cars, respectively. The wide carbodies are furnished with five seats next to each other. An intermediate coach is meant to hold 100 seats, and every driver-cabin is estimated to reduce the number of seats by 5. Due to this the various train-sizes are 90, 190 and 390 seats, respectively.

Table 4.10 Calculation of investment-cost for Wide EMUs of different size

	WMU1	WMU2	WMU4
Cost	13,1 MSEK	22,3 MSEK	42,2 MSEK
No. of seats	90	190	390
Cost/seat	145 kSEK	117 kSEK	108 kSEK

The calculation shows rather low future investment costs per seat in a ten years perspective, especially for the versions with two and four cars.

Double decked multiple units

It is interesting to investigate maximum space one can achieve in a double decked concept. The drawing below may be somewhat optimistic regarding the space needed for propulsion and auxiliary equipment.

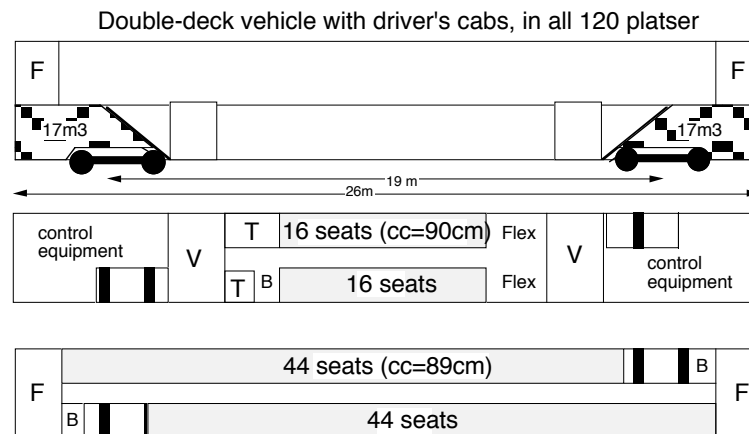
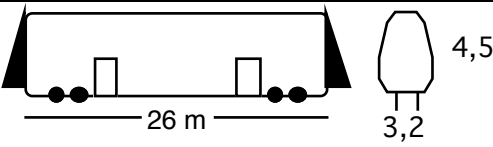


Figure 4.15 Outline for a single unit of a double decked concept.

The calculation below pertains to double-deckers of two sizes, 116 and 240 seats, respectively.

Table 4.11 Calculation of the investment-cost for double-deckers of various size .

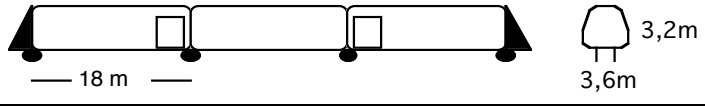
	DD1	DD2
Cost	14,4 MSEK	25,1 MSEK
No. of seats	116	240
Cost/seat	124 kSEK	105 kSEK

Short bodied wide multiple unit trainsets

The third calculation pertains to one-axle train-sets where the cars share axles, according to the figure in the table. Similar designs have often been investigated and sometimes even realised. The axle arrangement is used by Talgo and a similar design is used by the new suburban "S-Bane tog" in Copenhagen, the latter even having wide carbodies. In 1957 a Swedish design called KLL-Express was presented¹⁰⁰.

Two other interesting concepts are under development: In Germany the Regional Express 2000¹⁰¹ and in Japan a 250 km/h narrow-gauge concept¹⁰². Even for future high speed ICE this concept is being investigated¹⁰³.

Table 4.12 Calculation of the investment-cost for Short Wide EMUs of various size

		SWMU2	SWMU3
Cost		15,8 MSEK	22,2 MSEK
No. of seats		130	200
Cost/seat		122 kSEK	110 kSEK

In the cost-tables for the various vehicle-concepts there are additions for increased standard. The costs for increased vehicle-standard is explained by table 4.13.

Table 4.13 Cost additions for increased vehicle standard

Plus factors	per wide body (Mk r)	per double decke d (Mkr)
Wider body	+ 0,4	0
Tilt	+ 0,5	0
Interior standard	+1,0	1,3
AC	+ 0,2	0,3
Noise level	+ 0,3	0,3
Air pressure sealed	+ 0,3	0,4
Sum:	+ 2,8	2,3

¹⁰⁰ Aspenberg, von E., Der KLL-Express, *Eisenbahntechnische Rundschau* 1957, pp.336-342

¹⁰¹ Baur, von L., Pleger, J., Voss, M., RegionalExpress 2000 – Considerations relating to an innovative vehicle concept (in German), *ZEV+DET Glas. Ann.*, 117 (1993) Nr.1, pp.12-17, January 1993, and

Pleger, J., Wirtschaftliche elektrische Triebwagen – Potential und Realisierung (Economical electric railcars: Potential and realization (summary in English), *Eisenbahntechnische Rundschau*, 42 (1993) H.7-8 pp.475-485, July/August 1993

¹⁰² Wako, K., Miyamoto, M., Highspeed Train for Narrow-gauge Line, *QR of RTRI*, Vol.32, No.3, September 1991

¹⁰³ Technologitträger ICE21, Forschungsinformation Bahntechnik, *Eisenbahntechnische Rundschau* (ETR), ETR 44 (1995) H.1-2, page 228, figure 2, Jan/Feb. 1995

Cost comparison of wide, double decked and short-body vehicle concepts

In figure 4.16 is shown graphically how the investment-costs for the different vehicle-concepts relate to each other and to some type of vehicles of today.

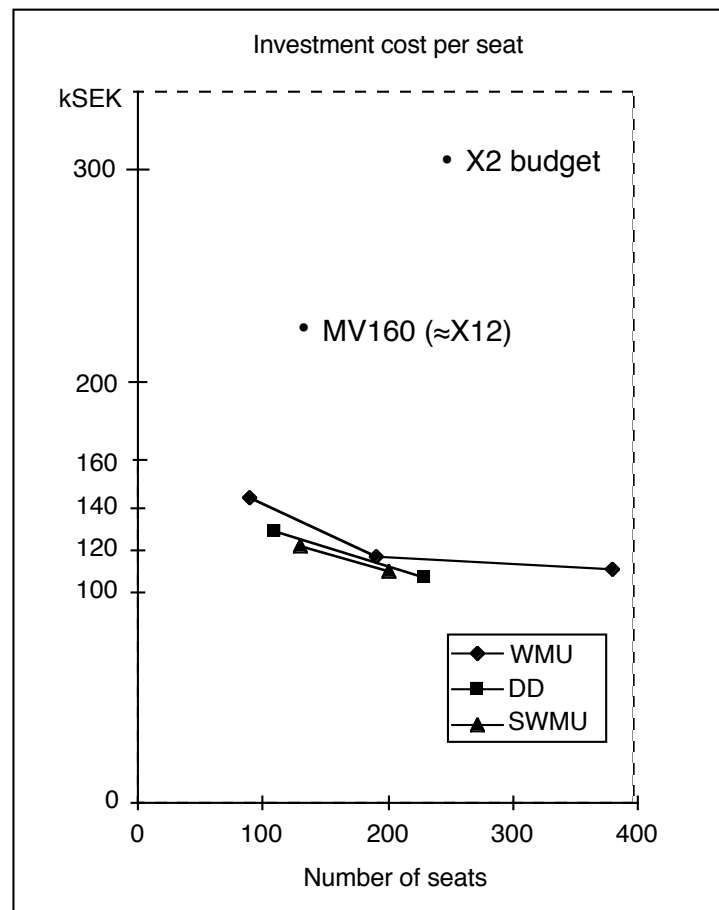


Figure 4.16 A comparison of the investment-cost per seat for different vehicle-size. Two existing types of vehicle have been included as a reference. One is X2 ("X2000") budget version with loco and 4 cars and the other (MV160) a Swedish EMU for regional traffic. All vehicles have 2nd class furnishings, only.

It is evident from figure 4.16 that the costs diminish with increasing size of vehicle. The vehicle concept also has an impact, but the differences may fall within the margin of error when comparing the cost at some given size.

C. Travellers' preferences

Last summer my family was visiting Gothenburg and the Swedish west coast by train. We had arrived to the Gothenburg area with a Swedish loco hauled InterCity train, because our young daughters don't like the running qualities of X2000. They trade off travel sickness in favour of a slower ride in an InterCity train¹⁰⁴.

Later we used the well equipped EMUs used in the Gothenburg region. They have soft reclining seats, individual reading lamps and radio outlets for earphones at each seat. Due to the soft running gears they are allowed to use some overspeed in curves. But my seven year old daughter was unhappy, crying of displeasure: -"Do we have to ride this train, daddy? Can't we take the one we used before?". I asked her what was wrong and got the answer: -"This train runs jerky, it has bad seats and there are no tables at the seats". My daughter showed strong opinions about issues in the area of my research. My daughter stated her preferences and I have asked a few thousand more people about their preferences.

¹⁰⁴ Increased travelling shows that most people highly value the short travelling times and high comfort level in X2000. A few persons have problems with travel sickness in X2000 as well as in other tilting trains, buses and ferries.

5. The passenger rail market and demand modelling

This chapter deals with the demand for passenger rail travel and the way modellers deal with the travelling market and, in particular, the way the demand for various passenger transport modes is modelled.

5.1 The competitive situation

It is assumed that the reader is familiar with the various passenger travel markets in general.

5.1.1 What does "demand" for train journeys mean?

"Demand" should be interpreted as the number of journeys that are actually undertaken. Travel statistics can show the historical demand. Demand models attempt to estimate future travel demand.

Sometimes the conception of "latent demand" is used. This constitutes the journeys that would have been undertaken if there had been no economic or other types of restriction. There are people who would travel more if

- they could afford it
- the transport system were better suited or adapted to their needs
- they had a car and a driver's licence
- they had time

When the first question – how much people will travel – has been answered, the next question is: How often will the train be chosen instead of the car, bus or air travel, for example?

5.1.2 What influences the choice of transport mode – the choice of the train?

In general, the choice of the train or some other mode of transport is influenced by

- Accessibility to the railway system and knowledge about it
- Characteristics or standard of the rail services
- Characteristics or standard of competing modes (car, bus and air)
- Cost of tickets and cost of competing modes
- Social factors and habits, lifestyle

Good railway accessibility is essential for train journeys to be perceived as an alternative. Short journey times are particularly important as they both enhance attractiveness and, as will be seen later, create a faster turnaround, thus reducing costs. For both reasons, the competitive edge is sharpened. Short travelling times can also help to generate new travelling habits.

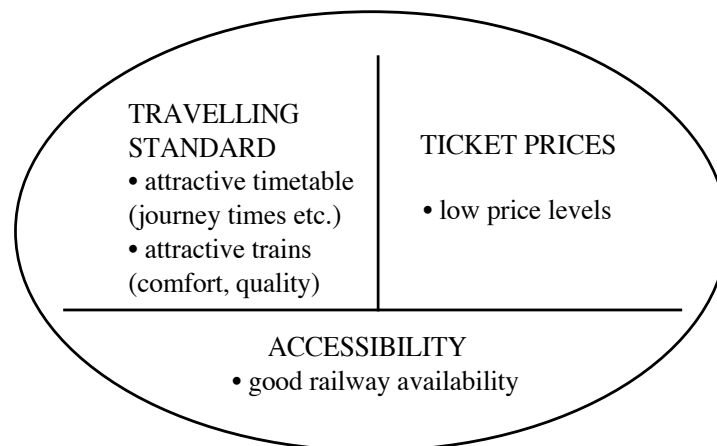


Figure 5.1 The competitive edge of the railways can be sharpened by improving the travelling standard and reducing prices. Good railway accessibility is a precondition.

Lower ticket price levels are of primary interest for many potential rail travellers.

Lifestyle also plays an important role, but only a few attempts have been made to link lifestyle to transportation (Uth, 1996)¹⁰⁵. Uth suggests that *travel-related lifestyle* should be defined as "the individual's pattern of those cognitions, emotions and actions connected with personal transportation that contribute to the personal and social identity of the individual". She gives an example of someone perceiving himself as a successful businessman who feels that going to work by car supports that identity, whereas going by bus would contradict that identity. (By introducing the X2000, SJ (Swedish Rail) staff have attempted to support the businessman identity – perhaps at the expense of other lifestyle identities).

In this context, the term "accessibility" means access *to the railway* not accessibility to other places made available by the railway system¹⁰⁶. At KTH, we divide this into physical and mental accessibility. A figure – an attempt or start when it comes to understanding mental accessibility – now follows (figure 5.2).

¹⁰⁵ Uth, T C, *Definitions of Life Style and its Application to Travel Behaviour*, Trafikdage AUC, Aalborg Denmark, August 1996

¹⁰⁶ Shilling, Rolf, *Accessibility to Train, from Information to Station*, Final Draft (RS 98-06-09), Railway Group KTH, KTH Traffic Planning, 1998.

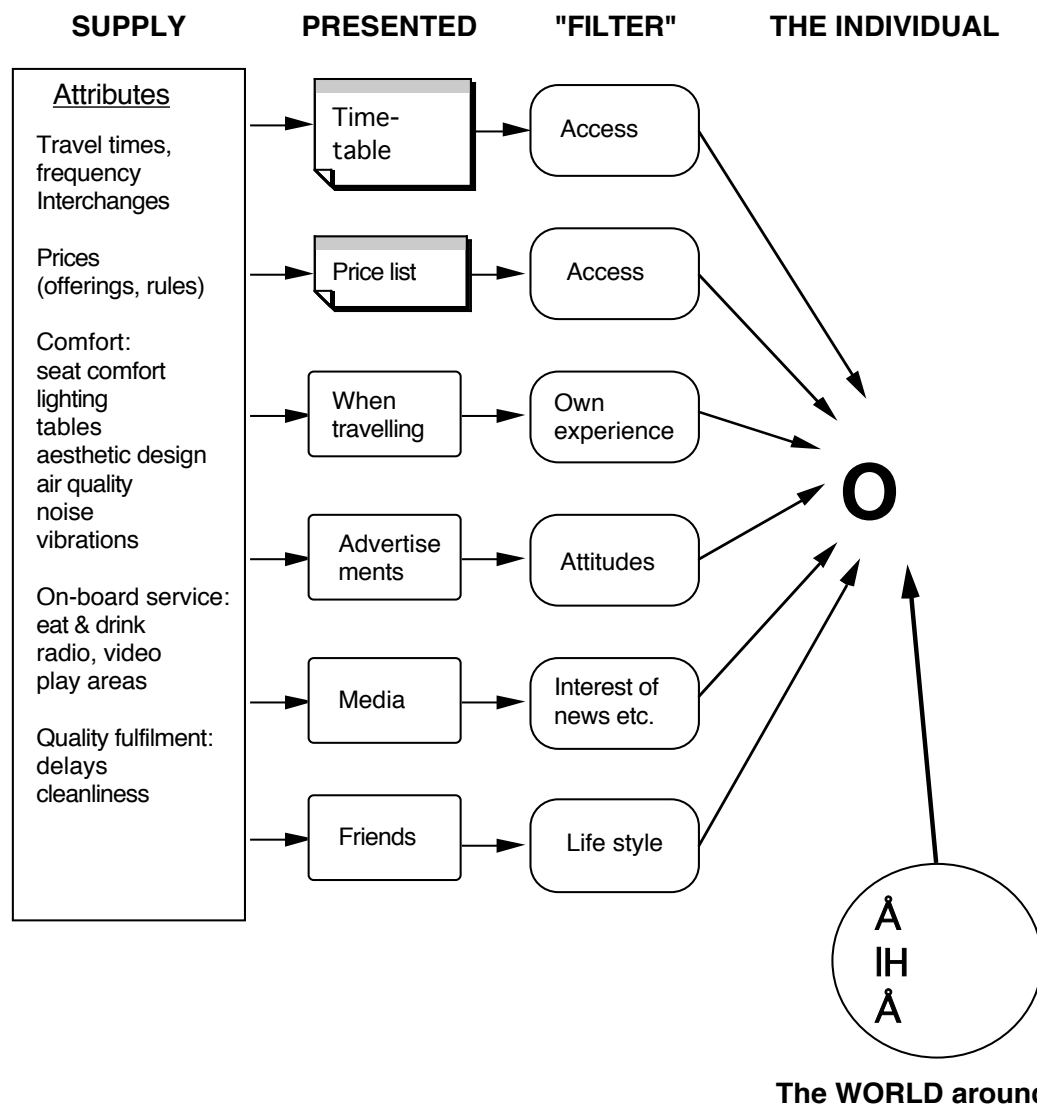


Figure 5.2 A visual model for mental accessibility and the influences when the train is chosen. The individual's awareness of such attributes which are studied in this thesis.

The supply features or attributes are to the left in the figure. They are presented in various ways, such as timetables, media or friends. This is followed by a filtering stage which can be the access to timetables or people's own experience. Finally, the world around influences people's perception and mental accessibility to the railways.

5.1.3 Interesting market segments

When it comes to passenger rail services, we often use the following classification in Sweden.

- Regional journeys are conventionally defined as being up to 100 km long, but, when speeds increase, another division would be more accurate; journeys that can be made on a daily basis in about one hour (in each direction).
- Inter-regional journeys are over 100 km long or take more than one hour.

A useful classification has been proposed by me and used by KTH. It divides journeys primarily into daily and non-daily.

	REGIONAL	INTER-REGIONAL	Restrictions
Distance	Max. 100-150 km	> 100 km	
DAILY	Work and school journeys	–	Max 1.0 to 1.5 h per direction Cost restrictions, depending on income level
NON-DAILY	Service, business and leisure journeys	Business and leisure journeys	Max 3 to 4 h per direction for one-day journeys

Table 5.1 The ordinary division of journeys into regional and interregional should be complemented or substituted by the division into daily and non-daily travellers.

From the table, it can be seen that journeys that take place on a daily basis have time restrictions of about 1.0 to 1.5 hours in each direction and the non-daily business journeys that should be made in one day have time restrictions of a maximum of three to four hours in each direction. For daily travellers to and from work and school, there are also cost restrictions. Some of the people who currently travel on subsidised regional fares would probably not be able to afford to travel as much if they had to pay the full cost.

The trend is for people to commute more and further. Commuters can be seen on long-distance trains in Sweden, as well as in other countries. I have observed that, in the rush hours, the majority of the travellers on German high-speed trains (ICE) could be daily commuters.

One interesting observation is that daily rail passengers travel much further, in terms of both distance and time, by train on an annual basis than many "long-distance" non-daily travellers. A commuter who has a 100 km journey which he/she makes on 200 days travels 40,000 km or about 400-600 hours a year by train. By way of comparison, an inter-regional traveller who makes 10 journeys of 400 km travels only one-fifth as much. This may imply that the division into daily and non-daily journeys could be an equally or even more important classification than the division into regional and inter-regional journeys. The results of my interviews with rail passengers also show that daily travellers impose rigorous demands on trains and their comfort.

At international level, the train is seen as an important strategic component for the integration of Europe. The hope is that international travelling by train will increase. Interoperability is one of the key words in current railway strategies.

The inter-regional market segment comes between regional and international distances. The travellers in this market segment often regard the train as a good alternative. Travellers are non-daily private or business, both groups with a greater capability to pay than regional travellers. Air travel is also competing successfully with rail. Only high-speed trains can

offer travelling times which can compete with air travel, over intermediate distances (300-600 km)¹⁰⁷.

The market segments in the future

My conclusion is that in the nearest, say 10, years passenger rail will continuously meet hard competition from air and car and the competition from long distance bus services will be added. The two main reasons for choosing train will be short travelling times and the possibility to use your travelling time on board. This will attract business travellers on medium distances where the train is faster or almost as fast as using air.

Commuters will also be attracted but they have a third requirement; that the ticket prices are so low that they can afford using the train. This will probably call for continuing purchase of railway services by the authorities.

Private/leisure travellers will be willing to pay for the cost of using train in some cases, in other cases they will choose bus or car and even air. The situation would change dramatically in favour of rail if the ticket prices could be generally lowered to match the cost level of bus and car travelling. (One aim of my work is to put forward measures that can contribute to lower travelling costs in the future.)

¹⁰⁷ Nelldal, B-L et.al., *Järnvägstrafikens förutsättningar i på den framtida resemarknaden* (The conditions for rail services in the future travel market), KTH Traffic & Transport Planning, Research report 11, TRITA-IP FR 96-11, 1996

5.2 Demand modelling

This thesis does not deal with demand modelling, but some of the models which are used are of the same type. Demand modellers also estimate the importance of various factors. The difference is that demand modellers are primarily interested in the resulting travel demand, while we are interested in the valuation of various train attributes.

5.2.1 The four-step model

The "four-step model" could be called the four-step method. The four steps in this method may contain various statistical models – sometimes different models in the different steps.

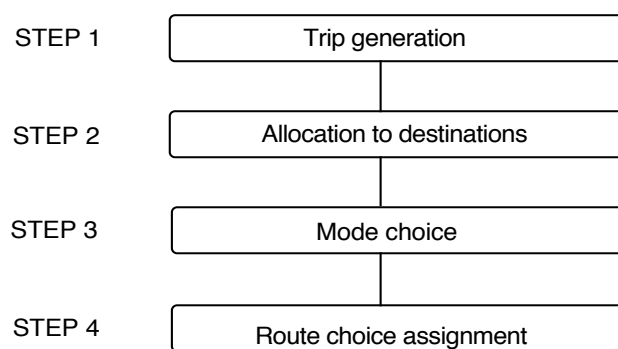


Figure 5.3 The four-step model

Some models have the four steps in another order or combines two or more steps into one. Step 3; mode choice is primarily relevant to this research project. It can be simplified as if the demand for rail travel depends exclusively on the mode choice. This simplification is fairly rough. In reality an important part of the increase in rail ridership has been found to be people who would not have travelled otherwise. New or improved rail services do generate new trips. One example is given by the travel demand estimate for the new high-speed services between Stockholm and Sundsvall¹⁰⁸. It was estimated that one-third of the increase in travel was accounted for by newly generated trips.

Another reservation is related to the pleasure of travelling. Would it be possible to make train journeys so attractive that people would make certain train journeys rather than buying other goods? Ferry traffic between Sweden and Finland certainly has this kind of attractiveness. The same thing also applies to many long-distance Amtrak services.

5.2.2 Behavioural econometric models

According to microeconomics theory, the demand and the cost correspond like a decreasing function of some kind. The "price" may mean the monetary cost, e.g. the price of the ticket, or the sum of the monetary cost and other sacrifices such as time and discomfort. The sum of the monetary travel cost and the valuation of the journey time in

¹⁰⁸ Transek, Snabbtåg till Sundsvall

money is often called the generalised cost (GC). In figure 5.4, price is on the Y-axis with demand (quantity) on the X-axis, in the way economists usually draw their figures.

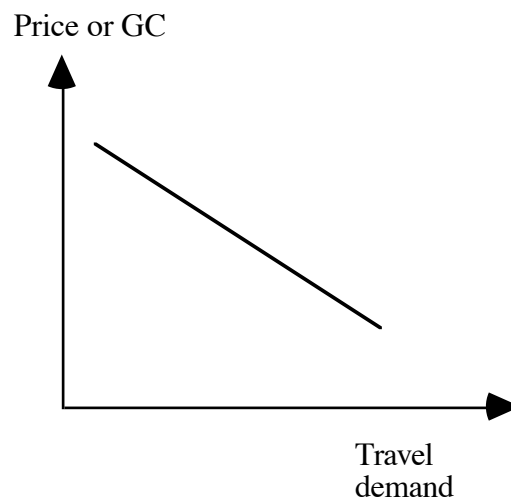


Figure 5.4 Possible relationships between travel demand and the cost (price or cost).

The demand for travel, as well as other products and activities, can be calculated from behavioural theories combined with econometric statistical models. The travel demand models are based on three assumptions (Michaels)¹⁰⁹ :

- People have some intrinsic needs that can only be satisfied by physical movement.
- Travelling choices are based on subjective perceptions of the utility of transport options.
- The basic choice processes by which decisions are made will not change and the variables determining these choice processes are universal.

Logit models are normally used for statistical modelling. Conventional mode choice logit models often have the following input:

- accessibility to a railway (station), e.g. the generalised cost of the connecting journey
- travelling time for various transport modes
- waiting times and/or frequency of public transport modes
- number of interchanges
- travel cost
- specific constants for the transport modes to include unexplained factors or attributes
- some social characteristics such as sex, age and income

All these factors are weighted using utility weights. In some models, the weights are equal for various modes – generic weights, in others the weights are specific for each mode or group of modes. For example, in the national Swedish InterCity model, generation II, the weight for travelling time in ordinary trains was half that of other transport modes. This

¹⁰⁹ Michaels, R.M., Behavioural Measurement: An Approach to Predicting Transport Demand, Northwestern University, in *Behavioral Demand Modeling and Valuation of Travel Time*, TRB special report 149, 1974

meant that a marginal change in train travelling times affected output half as much as changes in the travelling times for other modes.

Attributes that are not explicit in the conventional models include various comfort standards, service options and quality levels. Factors that can hardly be called "attributes" include image and people's knowledge of the various options.

5.2.3 Model system for valuations and demand forecasts

In Sweden and some other countries, model systems for traffic planning are used. One description is made by Algers&Widlert¹¹⁰. Systems of this kind are based on models and theories from various fields.

One base is microeconomics theory, another is choice theory for choices between discrete alternatives. A third feature is that the results are, or should be, consistent with socio-economic evaluations of transport alternatives.

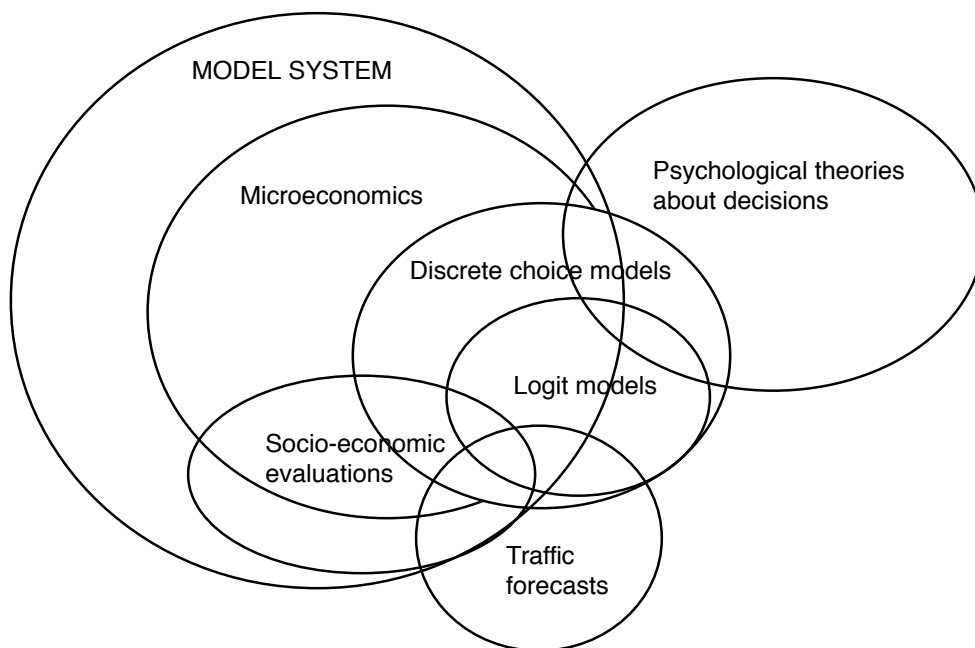


Figure 5.5 Diagram of some of the ingredients in a coherent model system. The psychological theories have been deliberately drawn somewhat outside the actual model system. (Kottenhoff)

The discrete choice theory often operates with logit models, which make them synonymous in everyday speech with the model system itself. The diagram above shows the ingredients in the model system presented as a mind map.

So far, most of the input for this model system has comprised statistical observations of real journeys, so-called revealed preference (RP) data. Today these data are sometimes

¹¹⁰ Algers, S., Widlert, S., thesis; *Hushållsbaserade trafikmodeller för konsekvensanalyser i flera dimensioner*, BFR R36:1992

combined with stated preference (SP) data. These show peoples stated judgements, preferences and choices when asked about hypothetical alternatives. Stated preference data are becoming increasingly integrated to complement the RP data.

If, as in this project, we are mainly interested in evaluations of different attributes of, say, train journeys, the logit model can be used in this way as well. We can "tap" the model system "half way" as shown in figure 5.6.

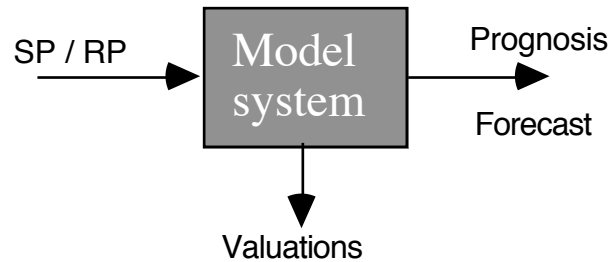


Figure 5.6 The model system is represented as a box which takes in Stated and/or Revealed Preference data and produces a forecast. One additional result is that taste weights or valuations of the factors in the model system can be tapped.

This tapping of a model system is only one way of acquiring evaluations. It is often possible to obtain rough estimates based on revealed preference choices made in real traffic systems. In the next chapter, the measurement of valuations will be discussed in more detail.

6. Measuring valuations of attributes

We do not know exactly what people do when evaluating travelling in general and choosing the train in particular. However, we are interested and researchers from various disciplines have various theories. Psychologists, economists and marketing specialists have (partly) different viewpoints of judgements and choices. Most of the practitioners use statistics as a tool, but the models they use can be different or differently interpreted.

Psychologists have studied in detail the way people make judgements and choices in general and how they behave when the experimental situations are set up in particular. So knowledge about choice processes and judgements is available.

Economists, on the other hand, often presume that people act according to certain axioms. These can imply that people act rationally and maximise their personal utility when making decisions. For the economists, it would be too difficult to include every divergence from the axiomatic models. Perhaps this would also be unnecessary.

Marketing experts may use theories and models from both psychology and economy over and above their own. They assist companies in the valuation of various product alternatives.

Traffic planners have a slightly different tradition. The modellers learned to use logit models which proved to work well for forecast modelling. The weights in travel demand models were estimated from so called revealed preference data which are based on choices people have already made. Later stated preference models were included and the traffic planners wanted to include results from these into the *forecast* models. What they have worked with somewhat less are models specialised for estimating the *values* of different transport solutions.

6.1 Measuring the weight of attributes

As mentioned at the end of Chapter 5, valuations can be "tapped" from a logit model forecast system. This shows that the valuations or weights of various measurements or attributes can be used to model demand. However, valuations can also be used for business-economy-related strategic decision-making and for socio-economic calculations. There are also ways other than "tapping" logit models for estimating the value of various measurements or attributes.

There are issues – opportunities and problems – at various levels, when it comes to the measuring and determination of valuations. At the upper level, the question is what measures should be implemented to make passenger train services more competitive. Knowing that both the price level and the qualities or attributes of the service influence the level of attractiveness, it is interesting to use a method in which attractiveness and competitiveness can be related. At lower levels, there are many properties and even method-related problems that are dealt with in this thesis.

6.1.1 Travel standard and attractiveness

The services which are offered can be described in terms of travel standard. There are many measurements that can be included here, such as travelling time and various vehicle features relating to performance, use of space, design and so on. These features can be measured technically in hours and minutes, metres, km/h and so on.

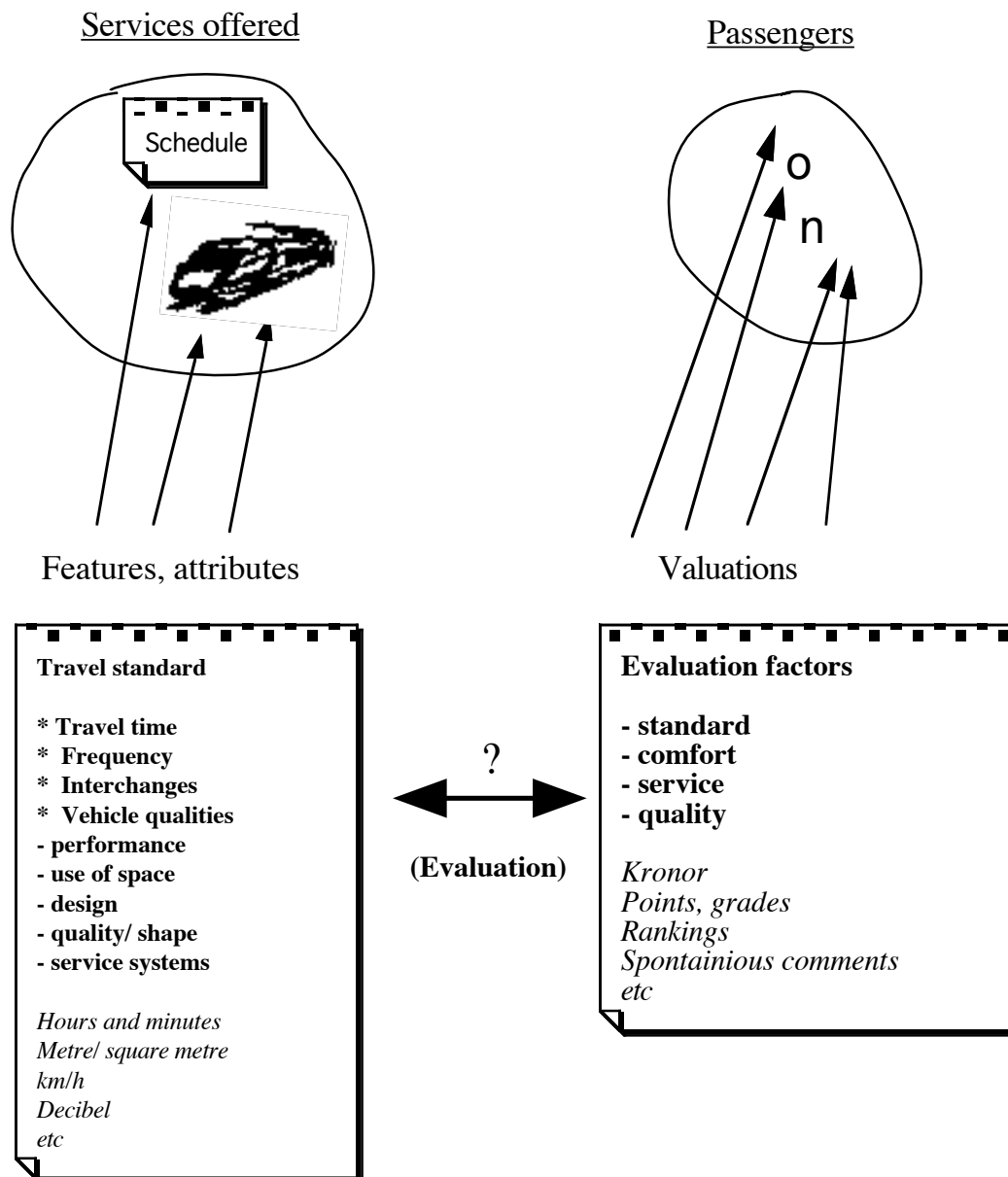


Figure 6.1 Correspondence between features of train services and travellers' valuations.

The services offered and the passengers' part of the drawing above is similar to the division into *supply* and *demand*. The main difference is that the concept above concentrates on passengers' evaluation and does not necessarily include any quantitative demand function.

The vehicle related train service evaluation factors, or attributes, from the passengers' view, the demand side, have been sorted under the headings timetable (standard in figure 6.1), comfort, on-board service and quality fulfilment.

The passengers' evaluation of the services which are offered, the supply, can be evaluated using questionnaires, interviews, observations and so on. The answers can be expressed in the form of scores, rankings, spontaneous comments and so on.

6.1.2 People make judgements and choices

People make judgements and choices at almost every moment of life. These choices the decision not to change a situation. When making choices, individuals use accumulated knowledge derived from experience, recommendations, word of mouth and various media¹¹¹.

Concepts and terms for choices and judgements

Judgements can be divided into value judgements and predictions. In this context, we are most interested in the *value judgements* people make about train services. These valuations can be used for socio-economic assessments and/or for *predicting* future *choices*. To study this, we can investigate the value judgements of train passengers and their choice of other modes.

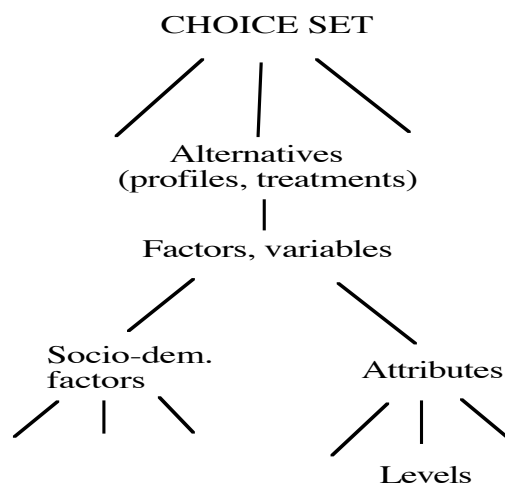


Figure 6.2 An illustration of terms used when analysing decisions.

The choices people can make belong to the *choice set* and are called *alternatives*. They are also referred to in literature as profiles or treatments. Each alternative has a set of *attributes* which is what people compare. (The alternatives do not necessarily have to be chosen, they can also be evaluated in other ways.) Other *factors* influencing judgement and choice, which can be modelled, are socio-demographic factors such as sex and income

¹¹¹ Louviere, J., Hensher, D., *Course notes for Stated Preferences and choice methods*. June 24-27, 1996

or whether the person has a car. When all the factors are modelled, they are treated as (mathematical or statistical) independent *variables*.

A few terms regarding judgement and choice theory are defined or explained in table 6.1.

Table 6.1 Definitions and explanations of terms used in this chapter about judgement and choice¹¹²

Term	Explanation / definition
Attitude	Predisposing tendencies to react to abstract stimuli. Can be explained as "biases" learned in a social context.
Preferences	The ordering or scaling of alternative satisfiers of a need or set of needs. Preferences emerge from experience in search of need satisfaction. Preference is the individual's <i>ideal</i> selection.
Choice	The operational selection of a specific satisfier. Choice is the individual's <i>actual</i> selection.
Factor	A condition that influence choices or preferences. These conditions include socio-economic factors and alternative related attributes.
Attribute	A factor which is evaluated by respondents.
Alternative	An alternative is composed of a number of attributes which take certain levels. Also called profile or treatment.
Design	A set of alternatives, all differing by the levels of their attributes.

Most of the following is based on a given set of choices; e.g. car, train and air travel. However, for many people and in many situations and for specific reasons, the set of choices can be different, often smaller. People do not consider alternatives that are not in their set of choices. So what causes an alternative to be included in a set of choices?

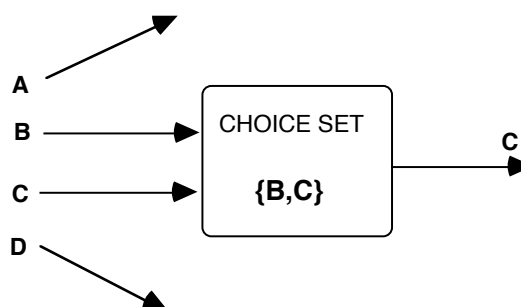


Figure 6.3 There are often more alternatives than those included in the actual set of choices. {B,C} are the considered alternatives and C is the choice in this figure.

¹¹² A few definitions are taken from Michaels, R.M., Behavioural Measurement: An Approach to Predicting Transport Demand, Northwestern University, in *Behavioral Demand Modeling and Valuation of Travel Time*, TRB special report 149, 1974

Hensher stresses the importance of considering the complete set of alternatives available to the sampled population and what subset of alternatives is included in each individual's set of choices? Is there a fixed set of choices across the sample or does the choice set vary? What is the "evoked set"?

Rystam (1998)¹¹³ has developed models for three types of choice set. The first is a model to determine whether the bicycle (in her case) belongs to the "possible" or "impossible" alternatives. The remaining possible alternatives are then regarded as a choice set at the next level. However, this set itself contains a chosen alternative and two types of not chosen alternative; spontaneously expressed alternatives and alternatives which are only admitted or conceded when asked about. So the other two models relate to the choice sets which include and exclude the conceded alternatives.

The judgement and choice process

Each individual has a set of built-in prejudices, or tastes, which have arisen over time for many reasons. Some can be traced to socio-economic characteristics and others to special constraints, such as the physical availability of some subset of alternatives.

When modelling consumer behaviour, the framework in figure 6.5 is used by Morikawa and others.

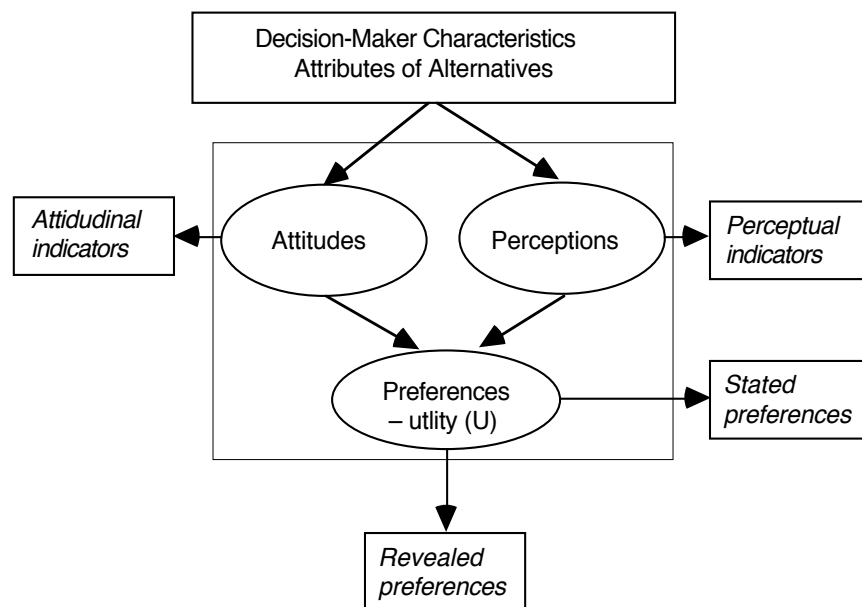


Figure 6.4 Framework for analysis of market behaviour. from Morikawa¹¹⁴ and Ben-Akiva¹¹⁵.

¹¹³ Rystam, Å., *Färdmedelsvalet och valprocessen för lokala resor till regional tågtrafik (the choice of mode of transport and the selection process for local travel to regional rail services)* (In Swedish), LUTVDG/ (TVTT-1017)/(1998) & BULLETIN 163, ISSN0346-6256

¹¹⁴ Morikawa, T, *Incorporating Stated Preference Data in Travel Demand Analysis*, Dissertation June 1989, MIT

¹¹⁵ Ben-Akiva, M., Walker, J., Bernardino, A., T., Gopinath, D., A., Morikawa, T., Polydoropoulou, A., *Integration of choice and latent variable models*, Draft revised May 1998, MIT, for presentation at AMA ART Forum '98, Keystone Colorado

The framework shows that both the attributes of the actual alternatives and the decision-makers' characteristics affect their attitudes and perceptions. These in turn affect market behaviour. What we can study are various *indicators* attitudinal and perceptual indicators, as well as preferred and revealed choices.

Ben-Akiva points out that all the concepts inside the large rectangle are *latent*, which means that these concepts cannot be observed by us. We can only observe the indicators outside the large rectangle. Attitudes and perceptions are observed by attitudinal and perceptual indicators. These can be investigated using a questionnaire. (Thurstone¹¹⁶ has demonstrated methods for measuring attitudes quantitatively.)

In figure 6.4, preferences are operationalised by the latent concept of "utility" (U). While utility is also a latent concept, revealed and stated preferences are two methods for identifying indicators for this utility. The choice alternatives are used as indicators of the utilities of the alternatives. From this, the weights of various attributes can be calculated.

An alternative representation for the judgement and choice process, inspired by Svensson¹¹⁷, is presented in figure 6.5.

¹¹⁶ Thurstone, L.L. & Chave, E.J., *The measurement of attitudes*, University of Chicago press, 1929 and Thurstone, L.L., *The measurement of values, part III Attitude measurement*, University of Chicago press, 1959

¹¹⁷ Svensson, O, Differentiation and consolidation theory of human decision making., *Acta Psychologica* 80 (1992), pp 143-168

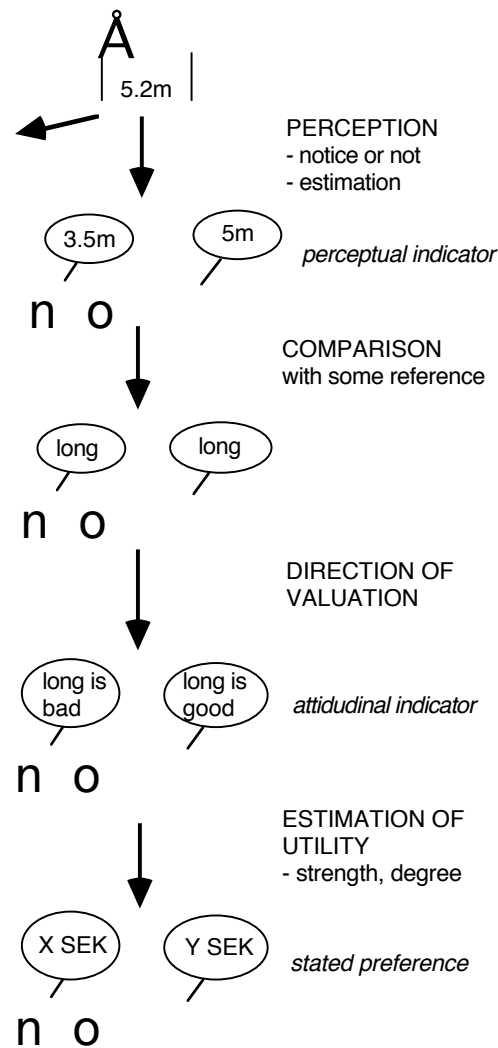


Figure 6.5 A model for the relationship between an attribute and stated preferences. The figure illustrates the valuation of the length of a car. The author, inspired by Svensson (1992).

Figure 6.5 shows two people's evaluation of an attribute, the length of a car. The steps are perception, comparison, direction of valuation and estimation of preference. As is shown above, there are indicators at various steps. These indicators could be investigated by interviewing. This is an interesting option which has not been much used in this thesis.

Perception: In the above example, people may notice that the object is a car and they may also notice its make. However, not everyone may notice the number of doors or the colour of the interior. The length of the car may be perceived as 3.5 m by one person and as 5 m by another.

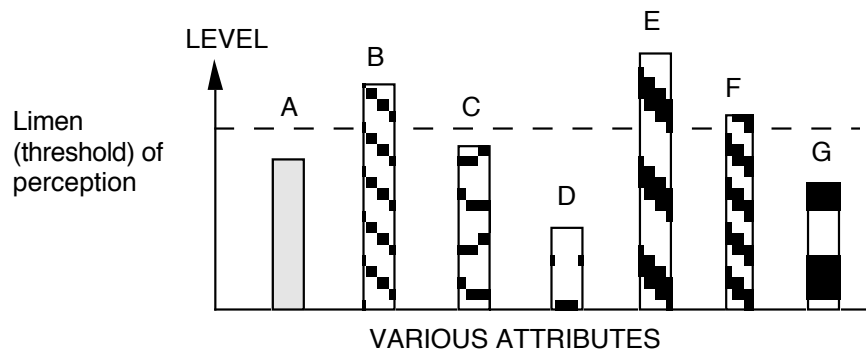


Figure 6.6 There may be thresholds for attributes to be consciously noticed.

Thresholds in perception may be relevant for the importance of factors like comfort. If noise or vibration levels are normal, many people will not take any notice of them. Service equipment like music outlets may not be noticed.

Comparison: When making comparisons, people assess the attribute with some reference they have in mind. For example, the perceived lengths, 3.5 m and 5 m respectively, may be perceived as being long in both cases (by both persons).

Direction of valuation: We may think that, as a result of the comparison, long should be positively valued, but this need not be the case. Someone wanting a short car may value "long" as bad. A typical example from the area of train comfort is that some people value face-to-face seating as positive, while others are of the opposite opinion.

Estimation of preference: The estimation of preference presupposes that there is a concept called utility. This utility is influenced by all the previous steps: perception, comparison and direction of valuation influenced by attitudes.

A more authentic summary of Svensson's¹¹⁸ description is: an alternative (e.g. a car) will be presented by the *levels*¹¹⁹, E (e.g. 5.2 m) of *attributes* (e.g. length). The *physical* length of 5.2 m corresponds to a *perceived* length; $\psi = J(e)$, which is linked in turn to *attractiveness scale* of length of cars. To illustrate, a 5.2 m long car may be (visually) perceived as being shorter than another car of the same length. The attribute of *perceived* length of cars is related to a corresponding *attractiveness attribute* of length through a $= J_a(y)$. The attractiveness (a) is close to the utility (u) and value (v).

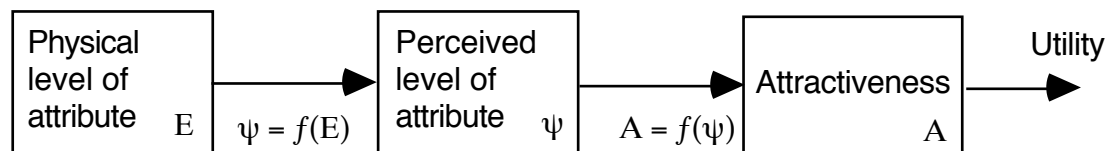


Figure 6.7 The relationship between an attribute and its utility.

¹¹⁸ Svensson, O, Differentiation and consolidation theory of human decision making ..., *Acta Psychologica* 80 (1992), pp 143-168

¹¹⁹ Svensson writes aspects but more often, talking in SP terms, levels are used.

One fundamental characteristic of attractiveness, as used here, is variability; the fact that it varies among people and situations, for example. It may have its maximum at a certain value or increase monotonously.

6.1.3 Scaling

One object of this thesis is to present methods for measuring and comparing the rail service supply with the passengers' evaluation of it. The type of measurement scale that is used has important implications for the type of statistical tools that are utilised. The question of measurement principles and scaling is therefore of interest.

Any measurement may have one or more of three different properties¹²⁰

- a) Numbers applied to a set have some order and consistency in this order.
- b) Distances among members of the set are ordered.
- c) The series has an origin that is real and determinate.

As most readers know, there are four common types of measurement scale: The *nominal* scale, which is used for categorisation, the *ordinal* scale, which only possesses characteristic a, the *interval* scale, which possesses a and b, and the *ratio* scale, which possesses all three characteristics. Usually, measurement scales refer to the assignment of numbers to properties of objects, but a nominal categorisation may be presented without numbers. Another type of scale is the *absolute* scale, which is described as the "highest" type of scale¹²¹. It is, for example, used to count the number of occurrences. No scale transformation is admissible for the absolute scale. It is absolute in relation to relative scales.

Table 6.2 Types of scale

SCALE TYPE	PROPERTIES
Nominal scale	Only categorisation
Ordinal scale	Some consistent order
Interval scale	Some consistent order and distances among members of the set
Ratio scale	Some consistent order and distances among members of the set and the series has a determinate origin
Absolute scale	Counting the number of occurrences, no scale transformation is admissible

¹²⁰ Michaels, R.M., Behavioural Measurement: An Approach to Predicting Transport Demand, Northwestern University, in *Behavioral Demand Modeling and Valuation of Travel Time*, TRB special report 149, 1974

¹²¹ Ladkin, P., *Mesuring the quality of service*, published on Internet (nakula.rvs.uni-bielefeld.de/made/folie/folie01.html), Univ. of Bielefeld

One classical example of the difference between interval and ratio scale is the measurement of temperature, where the Celsius and Fahrenheit scales are interval-scaled, while the Kelvin scale is ratio-scaled. Examples of absolute scaling are frequency and probability.

Michaels¹²² argues that, "to measure attitudes and preferences, we must develop scalars that have interval properties, at least".

Another, often overlooked, aspect is the way the attributes are described. This means that we can even use the term scaling in relation to the description of the attributes in which we are interested.

Attribute description scaling¹²³

A question that has sometimes been overlooked, at least in the past (see, for example, Holmberg, 1977¹²⁵), is the description or measurement scaling of the attributes to be evaluated. Questions of this type have often been put forward: "What is more important, travelling time or ticket prices?". The two attributes in this description are very imprecise. In table 6.3, different levels of attribute description are illustrated.

Table 6.3 Different levels of attribute description.

TYPE OF DESCRIPTION	ATTRIBUTE DESCRIPTIONS – examples
Nominal	- Travelling time - Ticket price - On-board comfort
Ordinal	- Shorter travelling time - Lower ticket prices - Better on-board comfort
Interval	- One hour shorter - SEK 50 lower price - 6 dB lower noise level
Ratio	- 3 h total travelling time - SEK 150 ticket price - 20 cm legroom
Absolute	- Two interchanges - Six seats per compartment

An interval attribute description, for example "one hour shorter travelling time", will sometimes be called *attribute shift* in this thesis.

¹²² Michaels, R.M., Behavioural Measurement: An Approach to Predicting Transport Demand, Northwestern University, in *Behavioral Demand Modeling and Valuation of Travel Time*, TRB special report 149, 1974

¹²³ The phrase "attribute description scaling" is mine

¹²⁴ The phrase "attribute description scaling" is mine

¹²⁵ Holmberg, B, *Standard i lokal kollektivtrafik – metoder för mätning och beskrivning*, Nordiska institutet för samhällsplanering, R 1977:1

Louviere¹²⁶ argues that measurements must be based on theory that includes random utility theory (RUT). Otherwise, these measurements are uninterpretable or even meaningless. Examples of measurements include rating scales used to "measure" attitudes, beliefs and preferences.

An example (Louviere): *"How satisfactory was your wait in line to buy your ticket?"*.

The answer is "6" on a scale of 0 to 10. The "6" may mean, for example, *"not too satisfactory"* or *"a bit better than average waits in the past"* or *"about what I expected"*. This information does not give a clear answer about what the transit authority should do. Should it improve the wait in line to achieve "7" or "8" next time? Is "6" really bad? According to Louviere, these questions require a theory of the process using which consumers allocate a "6".

Examples of attribute descriptions and response scaling

An example of an evaluation that is problematic to interpret or use in a model is the following, where the attributes are nominally described and the evaluation consists of acceptance (goodness) as response:

<u>ATTRIBUTE</u>	<u>RESPONSE SCALE (acceptance)</u>
Travelling time	Not good
Cost	Acceptable
Comfort	Very good

Firstly, in the response column, it is difficult to compare the qualitatively described (nominal) concepts "travelling time", "cost" and "comfort" with one another. Secondly, in the evaluation column, it is difficult to say how much better "very good" is than "not good", for example. How do we interpret the information about the level of satisfaction and is this specific attribute important?

The response column can be numerically scaled, as acceptance:

<u>ATTRIBUTE</u>	<u>RESPONSE SCALE (scaled acceptance)</u>
Travelling time	2.9
Cost	3.5
Comfort	4.3

These figures are still difficult to use. They do at least indicate an order, but the attributes are very imprecisely described. How should this be interpreted? Is the attribute cost 20% more important than the attribute travelling time? Is it, for example, more valuable for passengers to reduce the ticket price by 10% than to reduce the travelling time by 10%?

So the following is a more useful form of evaluation:

¹²⁶ Louviere, J., *Stated preference and choice methods for land use and transport planning applications*, course materials for stated preference course in Stockholm, June 1997

<u>ATTRIBUTE</u>	<u>RESPONSE SCALE (% of fare level – price)</u>
Time (A): 10% shorter travelling time than in today's trains	+7%
Cost (B): 10% lower cost than today's ticket prices	+10%
Comfort (C): introduction of reclining seats and 10 cm more legroom	+14%

Here both columns have more precise, quantitative descriptions. The attribute shifts are valued monetarily.

One important property when it comes to using stated preference conjoint experiments for the evaluation of attributes, instead of ordinary multiple-choice questions, such as point setting, is that the statistical evaluation models which are used (logit or probit) rate the attributes on an absolute scale. When using logit modelling, the two parameters for travelling time and comfort may have been

$$\beta_T = 0.10 \text{ [/minute]}$$

$$\beta_C = 0.20 \text{ [/SEK]}$$

which means that the preference or "taste weight", for one unit of attribute Cost (SEK), with respect to actual supply levels, is twice that for one unit of Time (minute) on an absolute scale.

6.1.4 Alternative- and attribute-based evaluation of attribute weights

In alternative-based evaluations of attribute weights, the weights are indirectly evaluated by evaluating the alternatives.

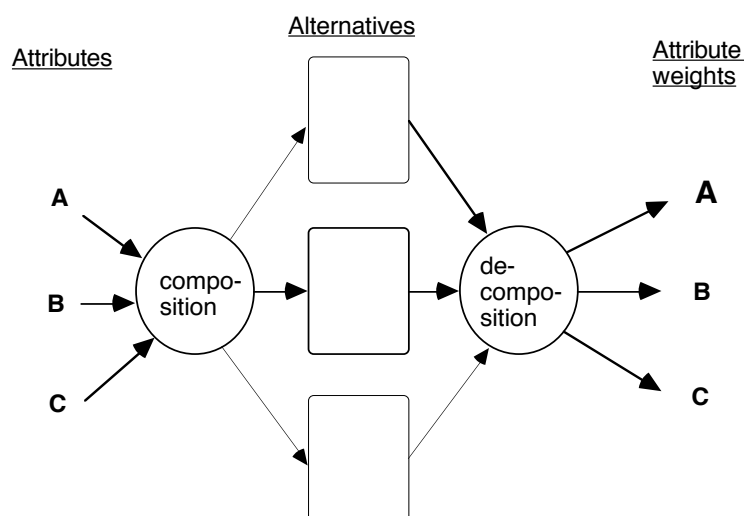


Figure 6.8 Alternative-based evaluation using composition and decomposition.

An attribute-based evaluation method involves the respondents judging attributes directly and not via the elicitation of alternatives.

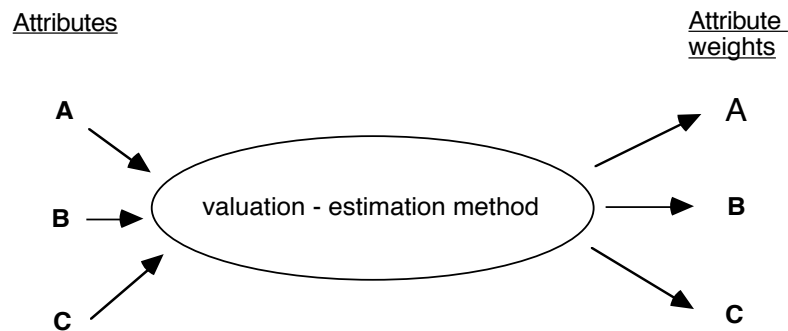


Figure 6.9 Attribute-based evaluation. This figure is very simplified; the valuation estimation method may comprise several steps.

It would perhaps be easier for the experimenter and for the respondents to use an attribute-based elicitation method. One drawback might be that interactions between attributes would be more difficult and perhaps impossible to detect. On the other hand, how often is this done in practice?

A revised version of Morikawa and Ben-Akiva's framework for judgement and choice models shows where an attribute-based evaluation is supposed to be used.

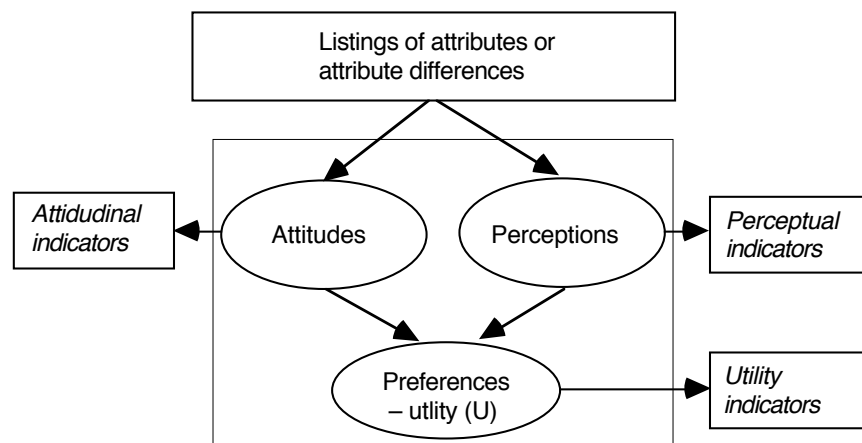


Figure 6.10 Revised version of Morikawa and Ben-Akiva's framework for judgement and choice models with an attribute-based evaluation of utility.

The framework presupposes that preferences or latent utility can be investigated using utility indicators for attributes. Methods for this will be described in the next section.

Judgement procedures

Stated preference interviews are usually conducted by rating, ranking or choosing alternatives in the form of a judgement procedure or response mode. A list of judgement procedures for alternatives is given below.

Table 6.4 Alternative-based elicitation methods

Alternative-based procedure	Response mode	Example
Rating		
Rate alternatives	Non-monetary ratings	"Rate each alternative on a scale of 1 to 100"
Value alternatives	Monetary "ratings"	"Value each alternative in Swedish kronor"
Ranking		
Rank alternatives	Ranking of all alternatives from 1 to N	"Put the cards into four groups and then rank them internally in all groups"
Matching		
Payoff matching – Transfer price	Determine a missing value by providing a payoff	"Fill in the missing sum that makes these alternatives equal"
Probability matching	Matching by providing a missing probability (in risky decisions)	"Fill in the missing probability that makes these alternatives equal"
Choice		
Choose one alternative	Choice of one (or none) of all the alternatives	"Which of these alternatives do you prefer? (Choose none if you cannot decide)"
Pairwise choice	Choice of one (or none) of two alternatives	"For every pair of alternatives, choose the one you prefer, or none if you cannot decide"

So far, the judgements have been based on alternatives, but it is also possible to base judgements on attributes. Questions can be asked about both the importance of different attributes and the satisfaction with today's level of these attributes. The latter is often done in customer satisfaction interviews, in a problem detection study (PDS study), for example.

In this case, we are interested in methods that can produce valuation levels on an absolute scale and many standard interview methods cannot achieve this. However, there are some attribute-based methods that should be able to provide absolute valuations of the attributes.

Table 6.5 Attribute-based elicitation methods

Attribute-based procedure	Response mode	Example
<u>Comparisons of attributes</u>		
Paired comparisons of attributes (or attribute shifts)	Choice of the better ones (in a long sequence)	"For every pair, choose the one you prefer"
Ranking of attributes (attribute levels or attribute shifts)	Rank numbers	"Rank these ten factors from best (1) to least good or worst (10)"
<u>Allocation of points/money</u>		
Allocate money	Percentage of a given monetary amount	"Assign (allocate) this SEK 100 to the following factors (attributes)"
Allocate points	Percentage of a given total of points	"Assign (allocate) these 100 points to the following factors (attributes)"
<u>Contingent valuation (CV)</u>		
Maximum willingness to pay	Monetary	"What is the maximum you would pay for a reserved seat on a train?"
Binary CV method	Yes or no	"Are you willing to pay SEK 35 to have a reserved seat?"
<u>Other methods</u>		
Ranking of measures	Ranking of measures (attribute shifts) from a list	"Rank the measures in order of importance/value to you"
Selection of important measures	Choice of more or less important measures (0/1) from a list	"Mark the factors (or measures) which are most important to you"

The method of paired comparisons is described by Thurstone¹²⁷. He shows that this method produces approximately correct values when the distributions are normal. Rankings can be converted to paired comparisons.

One important point is that the attributes included in attribute-based procedures are well defined – the attribute descriptions must be precise. Attribute description scaling has already been discussed. It may also be important to check the reference level. What is the alternative to a specific attribute – for example, the alternative to no interchange? Is it one interchange or more interchanges? One suggestion is to work with attribute level differences such as "One interchange instead of no interchange". These can also be called attribute shifts. Another level shift would be "One interchange more than today".

There is a new method called best/worst conjoint that could be described as a hybrid form. It uses alternatives, but the response mode is an attribute.

¹²⁷ Thurstone, L.L., *The measurement of values*, University of Chicago Press, 1959

Table 6.6 Hybrid elicitation methods

Hybrid procedure	Response mode	Example
<u>Best/ worst conjoint</u> ¹²⁸		
Indication of best and worst	One best and one worst attribute+level for each alternative	"Mark the factor you feel is best and the one you feel is worst (most and least attractive) in this alternative"
<u>Other methods</u>		
E.g. "Hybrid conjoint model" ¹²⁹		

The best/worst conjoint method will be dealt with in section 6.6.1. At this point, the fact is simply mentioned that the alternatives are designed in the same way as for other SP/conjoint procedures and that the respondents are asked to choose one "best" and one "worst" attribute for each alternative.

6.1.5 Statistical theory and prerequisites

The theory outlined here refers to discrete choice models such as the logit and probit models. It is assumed that these models are known, but a few lines on them now follow (partly from Hensher¹³⁰). The models predict the share of choices among alternatives.

It is assumed that the decision-maker considers attributes that are relevant to him and implicitly weighs them up as part of the process of integrating the information. The analyst does not have the full information about the individual's decision "calculus". So there will always be a number of unobserved influences. The analyst does not know the true mathematical relationship between choices and attributes. He therefore makes some simplified assumptions when using choice or valuation models. In many cases, they include:

- The set of observed influences which describe an alternative are denoted by V .
- There is a random component for the set of unobserved influences, denoted by ϵ .
- Each alternative in the choice set can be represented in terms of relative utility by an additive function $U = V + \epsilon$. This utility is supposed to be different for different individuals, in different situations and from time to time, so there is a variation – hence the random term. The utility is random, constituting a *random utility model*.. Ben-Akiva¹³¹ mentions four sources of randomness:

¹²⁸ Louviere, J, Swait, J, *Best/Worst Conjoint: A New Preference Elicitation Method to Simultaneously Identify Overall Attribute Importance and Attribute Level Partworths*, working paper revised Dec 1995 and Nov 1996

¹²⁹ Hu, Clark, *Conjoint analysis*, published on the Internet at huc@nevada.edu, UNLV Hotel College, 1997

¹³⁰ Hensher, D.A., *Discrete choice modelling and analysis*, course materials for stated preference course in Stockholm, June 1997.

¹³¹ Ben-Akiva, M., Lerman, S.R., *Discrete choice analysis. Theory and application to travel demand*. The MIT Press, Cambridge, Mass., 1985

1. unobserved attributes,
2. unobserved taste variations,
3. measurement errors and imperfect information,
4. instrumental (or proxy) errors.

Sonesson¹³² reminds us that there is a distinction between random and constant utility models. In the latter model type, the individual's utility of an alternative is constant but he may not be skilled enough to always chose the alternative with the highest utility, especially when the difference in utility is small.

The utility function for an alternative A can be written as follows:

$$U_A = V_A + \varepsilon_A$$

where U is the total utility, V is the common utility and ε is the variation. In random utility models this variation is due to the analyst's lack of complete information when in constant utility models there may be a lack of skill or consequence by the decision maker.

In any case the set of random variables are assumed to have some joint distribution (such as normal or Gumbel). This is illustrated below.

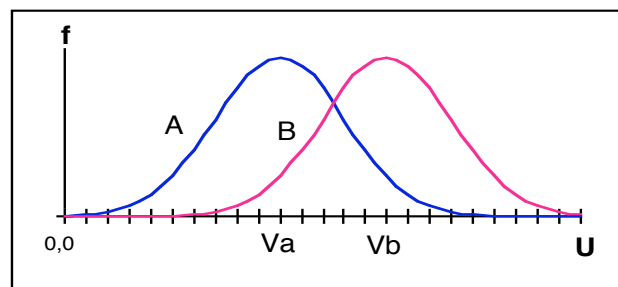


Figure 6.11 Graphic representation of two utilities U_A and U_B with their variations ε around V_A and V_B . It is assumed that these curves have some known distribution such as normal or Gumbel.

- The observed set of influences V for alternative A is assumed to be represented by

$$V_A = c_A + \sum \beta_i X_i$$

where i includes 1 to I (the number of included attributes), X_i are attributes and β_i are the "taste weights" or parameters that indicate the contribution of each attribute to the overall level of relative utility. The β weights for an attribute are not absolute but depend on the weights of other attributes and the model description of the model being estimated. c_A is an alternative specific constant that depends on the weight of the alternative – an alternative specific constant.

The values V_A and V_B are figures that are normally thought of as not being random (once estimated), so all the randomness then lies in ε . In fact, there is a discrepancy between this prerequisite and reality in many cases.

¹³² Sonesson, T., *Estimering av efterfrågan på långväga persontransporter*, Linköping Studies in Management and Economics, Dissertations No.36, 1998

As a result, there are also taste variation models. In a model of this kind, the weights differ from individual to individual:

$$U_A = c_A + \sum (\beta_i + \varepsilon_i) * X_i + \varepsilon$$

- *Rational behaviour* means that an individual is expected to evaluate the set of available alternatives and will choose that alternative which he experiences giving the greatest relative utility.

The *random utility maximisation rule* is mathematically described by:

$$\text{Prob}_j = \text{Prob}\{(V_j + \varepsilon_j) > (V_{j'} + \varepsilon_{j'})\}$$

where $j \neq j'$ and j is the number of an alternative in the choice set.

Facilitating an intuitive understanding of the choice between alternatives

For those readers (and myself) who are not so familiar with statistics language I will give an example which hopefully facilitates an intuitive understanding: Five individuals have different utilities for car and bus alternatives. The utilities have been randomly assigned to the alternatives. Each individual chooses the alternative that gives him/her the greatest utility (See figure 6.7).

Table 6.7 Conceivable utilities for car and bus for five individuals and their resulting choices.

Individual	Utility of car	Utility of bus	Choice
Adam	-1.5	+0.5	Bus
Bertil	-0.5	-1.5	Car
Cecilia	0.0	+1.5	Bus
David	+0.5	-1.5	Car
Erika/Elsa ¹³³	+1.5	0.0	Car

We find that 60% of these people choose car and 40% choose bus and the result is close to the 50/50% we can calculate analytically.

The utilities assigned for car and bus should be distributed in accordance with the assumed model.

The logit model

For logit models, the variation ε is assumed to be Gumbel distributed which is close to normal distribution. The random components (ε_j) have the same distribution and are independent (IDD = Independent and Identically Distributed) across the set of alternatives for the sampled population.

The probability of choosing alternative A and not B is:

$$P_A = \frac{\exp(V_A)}{(\exp(V_A) + \exp(V_B))}$$

¹³³ My daughters' names are Erika and Elsa and they want an impartial father.

This function is illustrated below in graphic form:

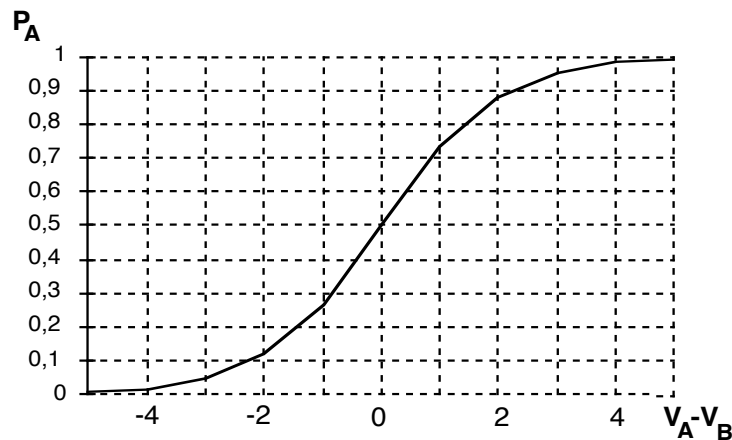


Figure 6.12 The share of one alternative (A) of two $[A,B]$ using the logit model. The x -axis shows the difference in utility between A and B.

Let us say that A is the train and B is the car. The figure then shows how the market share increases when the value of the train rises.

The probit model

The logit models rely on the utilities to be Gumbel distributed, while the probit models rely on the more common normal distribution. The two distributions can be adjusted to overlap effectively and the results produced by the two models are similar.

The probit model is more complicated to set up and estimate, but statistical packages that can handle both are currently available¹³⁴. The probit model is capable of handling models with heteroscedasticity; different variances, as well as error terms that are correlated over alternatives.

Probit models have not been used regularly in this work, although they have some interesting features.

More about the assumed distribution of the utility of the alternatives

The utility of an alternative is distributed among individuals. To be able to integrate over the utility space, some possible and workable distribution for the ϵ must be imposed. Two options are normally used:

1. A normal distribution
2. An extreme-value type I (EVI) distribution, which is also known as Gumbel or double-exponential distribution¹³⁵.

¹³⁴ Limdep from Econometric Software Inc. Australia and SPSS advanced statistics module.

¹³⁵ Louviere, J., *Stated preference and choice methods for land use and transport planning applications*, course materials for stated preference course in Stockholm, June 1997. (Louviere ALSO includes the Weibull distribution, but it has no negative observations and a slightly different frequency distribution than the Gumbel distribution.)

The cumulative distribution function of Gumbel distribution is given by the function:

$$F(x) = \exp(-\exp(-x)) = e^{-(e^{-x})}$$

The form of this function is about the same as the normal distribution function, but it is somewhat skewed.

The Weibull distribution has been found in Excel (5.0) and in Johnson's book on statistics¹³⁶. It resembles the Gumbel distribution, but it has no negative values. The variation and the skewness of it can be adjusted.

The normal, the Gumbel and the Weibull frequency distributions are shown below.

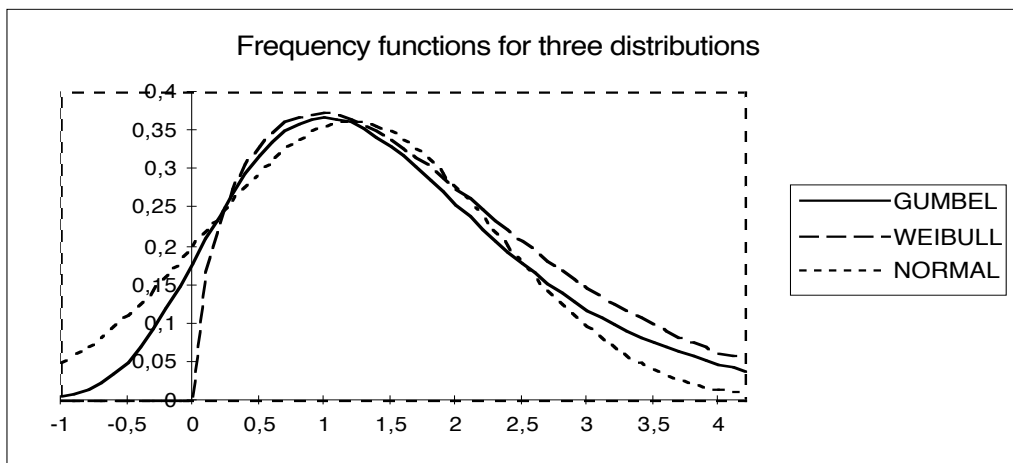


Figure 6.13 Frequency functions for three similar distributions. At this point, the Weibull follows the normal distribution well, except that it has no values that are negative. This is a reasonable assumption for many attributes such as the value of money.

The Normal distribution is symmetric while the other two are not. An important feature of the Gumbel distribution is that even though its frequency distribution is skewed, the logit models' probability distribution is symmetric around $\Delta U=0$.

Brundell-Freij¹³⁷ has investigated the influence of taste variation by the use of Monte Carlo simulation. She found that a general variation of tastes may well be captured within the assumed random variation of an ordinary logit model.

6.1.6 Estimating the weights

Louviere quotes Luce & Suppes¹³⁸ who have shown that "dominance measures can be transformed to be consistent with RUT". Dominance data arise from any numerical assignment measurement which satisfies the following criteria: Objects measured = or > or < one another (i.e. equality, direction and order). Examples of these measurements include:

¹³⁶ Johnson, R.A., Miller & Freunds, *Probability & Statistics for Engineers*, fifth edition 1994

¹³⁷ Brundell-Freij, K., *The logit model applied to the modal split of regional commuting, a case study and Monte Carlo simulations*, (PhD thesis), Department of traffic planning and engineering, Lund Institute of Technology, Bulletin 123, 1995

¹³⁸ Luce & Suppes (1965) (reference has not been checked).

- Rating options on scales.
- Complete ranking of options (without degrees of preference).
- Discrete choice of one option from a set of competing ones. This can be the first choice of an alternative in a conjoint/SP experiment.
- "Like"/"do not like" options: Binary responses which classify options into two groups can yield preference information. One could, for example, ask travellers about the modes they would seriously consider, using the answer options "yes" and "no".
- Allocation of fixed resources (e.g. trips or a sum of money).

Rating experiments, in which the respondents rate each alternative, can be estimated by linear regression. One then assumes that the rates express utility. Rating can also be transformed into ranking of the options. Ranking can be estimated by logit modelling.

Aggregated choice proportions can be estimated using regression methods, while individual choices should be estimated by logit or probit (Hensher¹³⁹). The estimation procedure for logit estimation in the Alogit software packages and in Limdep uses maximum likelihood, which means that it attempts to maximise the probability that the resulting model can return the original choice proportions.

The development of more sophisticated estimation procedures is a popular research issue. At KTH, Algiers and Dillén¹⁴⁰ are working on a mixed logit model which permits normally distributed taste variations. Ortúzar & Garrido (1993)¹⁴¹ discussed ways of estimating pairwise choices other than binary logit. They demonstrated that a binary logit model was superseded by both ordinal probit and a regression model in which the semantic responses (Always A, Probably A....etc.) were transformed to an adjusted response scale.

6.1.7 Interpretation of the weights/parameters

How can we interpret the result of the estimation? How can we use the numerical parameter(s)? There may be several answers to these questions.

1. We can obtain an indication of whether we can say people care or whether the estimation result is accidental or random, if we know the t-value (or the standard error) of the parameter.
2. We can rank (or put into order of importance) the attribute levels, with some degree of probability.
3. We can interpret the parameters as rates, perhaps by multiplying all the factors by the same constant, so that we obtain a scale level that we recognise more easily.

¹³⁹ Hensher, D, Stated preference analysis of travel choices: the state of practice, *Transportation* vol 21, No 2 May 1994, pp 107-134

¹⁴⁰ Algiers, S., Bergström, P., Dahlberg, M., Lindqvist-Dillén, J., *Estimating the value of time by means of a mixed logit model*, KTH, Transek, Uppsala University, work in progress, 1998

¹⁴¹ Ortúzar, J, Garrido R A, On the semantic scale problem in stated preference rating experiments, *Transportation* 21: pp 185-201, 1994

4. We can divide estimates for various attributes by one another. Often, we divide the parameters for other attributes by the parameter for marginal price change. Other useful "dividers" include the travelling time parameter. In this way, we obtain the willingness to pay or accept, or a *trade off* between cost, time and other attributes. To ascertain the passengers' valuation of a comfort attribute expressed monetarily, for example, we divide the parameter β (β_a) by the cost β (β_c) like this: $V_a = \beta_a/\beta_c$, where V is the monetary value.
5. By simply looking at the parameter value, we can find the percentage that would choose the attribute (factor and level) instead of choosing the contrast attributes. An example: if the dummy parameter for the attribute of train is -1.0, when the contrast attribute is car (parameter = 0), the percentage of people choosing the train would be about 27%, while 73% would choose the car, provided that all the other known attributes influencing the choice were the same.
6. By multiplying the parameter with an actual attribute level and multiplying by the market share (1-P) we get the elasticity for that attribute.

$$\text{Elasticity} = p_1 * A_1 * (1-P)$$

Example: If time parameter is 0.01, travelling time A is 60 min and current market share = 20%: Travelling time elasticity is $0,01*60*0.80 = 0.48 \approx 0.5$

6.2 Psychological knowledge of judgements and choices

Many experiments focusing on the way people make decisions and valuations are conducted in ways similar to those used for SP interviews. The sets of choices often contain alternatives with a number of attributes and a number of levels. The respondents have to choose, prioritise, rank or value the various alternatives. This makes it relevant to investigate and discuss what we can learn from the choice experiments in relation to the assumptions made for SP interviews. (SP interviews are also called SP *experiments*.)

Much of this section (6.2) comes from a literature survey and it has been included in the thesis to illustrate the difficulties associated with judgement and choice theory.

A stated preference interview has a great deal in common with many psychological experiments about decision-making. However, how much do these experiments have in common with reality, with choices in life? There are many questions, for example:

- What decision-making rules do people use in SP experiments?
- What happens if people do not maximise their utility?
- What role does the number of attributes and levels play?

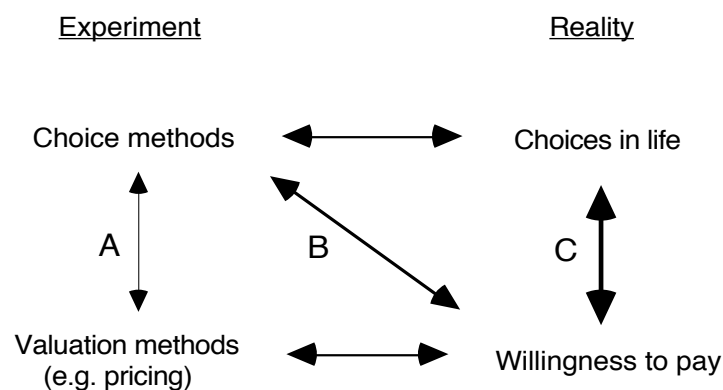


Figure 6.14 Relationships between choices and valuations in experiments and in reality.

Three relationships are indicated by the letters A, B and C in the above figure. A represents the correlation between choice and valuation methods. B is the correlation between choices in the experiments and real willingness to pay. C represents the correlation between choices in life and willingness to pay. One question when it comes to C is, for example: Can we accurately estimate people's willingness to pay from their observed choices; their revealed preferences?

Psychologists have found that the correlation A in figure 6.14 is not always strong, represented by a thin arrow. Preference reversals are quite easy to demonstrate. Microeconomics theory prioritises correlation C, shown by a thick arrow. When we use stated preference choice methods, e.g. pairwise choices, at KTH for willingness to pay

(WTP) studies, we assume that correlation B is good. One interesting question is: How accurate are the estimated WTP results, compared with the real WTP?

Decision-making is studied by psychologists (and other researchers). Gärling (1994)¹⁴² has criticised conventional travel choice modelling for overlooking behavioural assumptions and findings. According to Gärling, travel choice modelling is based primarily on statistical theory and lacks any substantial theory of the real world process.

Cohen¹⁴³ describes a few paradigms that have been used historically by decision researchers. The first is the formal-empiristic paradigm that has or had behavioural and formal evaluation criteria. If behaviour failed to fit the model, it was not regarded as "irrational"; instead the model was regarded as inadequate. Secondly, the rationalist paradigm, which includes value maximisation and takes decision theory as a norm that is justified by its formal properties. It views discrepancies between real behaviour and a model as (human) "errors". One way of responding to the deficiencies of the second paradigm, classical rationalist theory, which attracts me, is to retain the general logic and structure of the classical theory but to make modifications to some of the theory's components and operations in the light of research findings. The psychological knowledge and shortcomings of the classical theory that are summarised below have been chosen to guide such a view of the theory.

To argue that a formal model sets limits to what can exist, is about as illogical as arguing that the rules of chess sets limits for how a real horse can move. (Freely from Osqledaren #4 1998).

The concept of utility

Microeconomics theory presumes that utility is or can be represented by a mathematical expression that influences or "explains" the *choices* that are made. It does not specify the way utility is maximised by the decision-maker.

Psychologists state that it is, for example, possible to distinguish between predicted and experienced utility and decision utility. This is the difference between the anticipated satisfaction, the experienced satisfaction that comes from consuming something good and the weight which was actually given when choosing. Frisch¹⁴⁴ uses the terms "decision preference" and "experience preference". Gärling, in collaboration with colleagues, has also investigated motivational concepts such as "happiness", "an interesting life", "inner harmony" and "moral obligation".

The difference in utility concepts is relevant when it comes to decision-making utility in relation to socio-economic utility. These two utility concepts may have different values in real situations. Experienced utility can be the same as satisfaction from consuming something good.

¹⁴² Gärling, T, *Behavioral Assumptions Overlooked in Travel-Choice Modelling*, Paper at the seventh international conference on travel behavior, Santiago, Chile 13-16 1994

¹⁴³ Cohen, M S, Three paradigms for viewing decision biases, published in *Decision making in action: Models and methods* by Klein et.al., Ablex Publishing Corp. pp 36-50

¹⁴⁴ Frisch, Deborah, Reasons for framing effects, *Organizational beavious and Human decision Processes* 54, pp 399-429 (1993)

6.2.1 Making choices and judgements

Individuals make judgements and choices at almost every moment of life. This includes the decision to not change a situation. When making choices, individuals use accumulated knowledge derived from experience, recommendations, word of mouth and various media. Louviere¹⁴⁵ points out that there are certain steps that surround the actual making of a choice. These steps are:

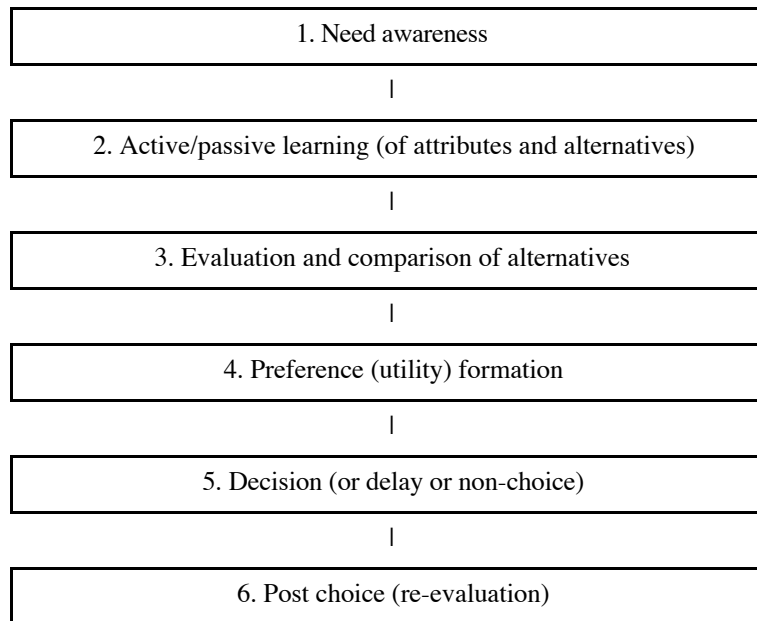


Figure 6.15 Steps in the choice-making process, see text.

Before people can decide, they must be aware that they have the opportunity to choose and they must learn about the alternatives. They can then compare and evaluate the alternatives which are supposed to lead to the formulation of individual preferences. After the choice is made (or not made), a re-evaluation may question whether the decision was right. This re-evaluation also influences future choice processes.

The term "decision" is used here as the point at which one of a number of alternatives is definitely chosen, while "choice" in this section is used for the choosing process.

Differentiation and consolidation

Svensson¹⁴⁶ puts forward a theory of interest when it comes to understanding why people may find it difficult to change their mode of transport, from the car to the train, for example. The theory is interesting for other reasons as well.

¹⁴⁵ Louviere/ Hensher, *Course notes for Stated Preferences and choice methods*. June 24-27, 1996

¹⁴⁶ Svensson, Ola, Differentiation and Consolidation Theory of human decision making: A frame of reference for the study of pre- and post-decision processes, *Acta Psychologica* 80 (1992) pp 169-184

Differentiation means that, in the process of making a choice, one alternative is tentatively chosen and gradually differentiated from the others until the degree of differentiation is sufficient for a decision to be made.

Consolidation in this case is the term for the post-decision differentiation processes. It serves the purpose of defending the decision from threats which may evolve. Consolidation may involve the decision-maker unconsciously increasing his or her appraisal of the attractiveness of the chosen alternative in relation to an important attribute.

In contrast to most decision-making rules, the differentiation theory suggests that the goal of a decision-making process is to select not only the best alternative but also an alternative that is sufficiently differentiated from its closest competitor.

Some SP experiments are designed and/or evaluated (estimated) with a parameter representing this such inertia. I have found in one of my studies (study in section 7.4) found inertia for bus passengers switching to train and the opposite.

Decision-making rules

It is assumed that the "best" decision-making rules are compensatory. Such rules are often used as reference rules, when psychologists compare different ways to make judgements and choices. Only these rules can compensate for low values for some attributes with high values for others. A few rules will be presented for the sake of discussion.

The compensatory rules are sometimes called *rational rules or strategies*, while the non-compensatory rules are sometimes called *heuristic rules or strategies*.

There are problems with both compensatory and non-compensatory decision-making rules. The problems with compensatory rules are (Montgomery¹⁴⁷):

- too complex value judgements, especially between attributes,
- difficulty obtaining a good overview – the short-term memory may be limiting,
- the attractiveness measure (utility) may be regarded as too abstract,
- good things have to be given up, something people hate.

The non-compensatory rules are easier to use, but they have other drawbacks, for example:

- there is a risk that important information will be neglected.

A decision-maker can combine two or more rules as a strategy. He/she may, for example, first eliminate some alternatives by EBA and then use the more complicated WADD for the rest of alternatives. A strategy of this kind would be called EBA+WADD.

Payne et al.¹⁴⁸ have found that people have a repertoire of strategies for solving decision-making problems at their disposal. They are aware or feel that different strategies, or ways of thinking when making decisions, are more or less difficult. According to Payne, individuals select strategies by trading off their relative advantages and disadvantages. As a

¹⁴⁷ Montgomery, H., *Decision rules and the search for a dominance structure: towards a process model of decision making*, Dep. of Psychology, Univ. of Göteborg, 1982

¹⁴⁸ Payne, J.W., Bettman, J.R., Johnson, E.J., *The adaptive decision maker*, New York, Cambridge Univ. Press, pp.70-116, 1993

result, they often use rules that are good enough for them. Sometimes they change strategy "on the move".

Table 6.8 Decision-making rules (source: Montgomery ,1982 and others)

Abbr.	Name of rule	Choice requirement
<u>Compensatory rules</u>		
AU	Addition of utilities	Choose the alternative with the greatest sum of (weighted) attractiveness (utilities) across all the attributes.
WADD	Weighted additive rule	
	Linear model	
AUD	Addition of utility differences rule	Add "differences" $D_k = f(a_{1k} - a_{2k})$ Choose A_1 if the sum of differences is positive.
	Ideal point model	Alternatives are evaluated by their distance from the ideal point on different attributes.
<u>Non-compensatory</u>		
DOM	Dominance rule	Choose alternative A_1 if it is better for at least one attribute and not worse for <i>all</i> the others.
CON	Conjunctive rule	Choose only alternatives which exceed or are equal to all of a set of criterion values C_i for the attributes.
DIS	Disjunctive rule	Choose only alternatives which exceed or are equal to <i>at least one</i> of a set of criterion values D_i for the attributes.
LEX	Lexicographic rule	Choose the alternative which is best for the most important attribute. If it is equal, repeat this procedure with new attributes in order of importance.
EBA	Elimination by aspects rule	Exclude all the alternatives which do not exceed a criterion C_i for the most important attribute. Repeat this procedure with new attributes in order of importance.
MNA	Maximising number of attributes with greater attractiveness	Choose A_1 rather than A_2 if A_1 differs favourably (over A_2) for a greater number of attributes than the number of attributes for which A_2 differs favourably (over A_1).
<u>Combined rules (example)</u>		
EBA+ WADD	Elimination by aspects plus weighted additive	First eliminate a number of alternatives, then choose the one of those that are left that has the greatest utility.

Two of these rules, the disjunctive and conjunctive rules, may be easier to understand by a graphic illustration. A way illustrate them is shown below:

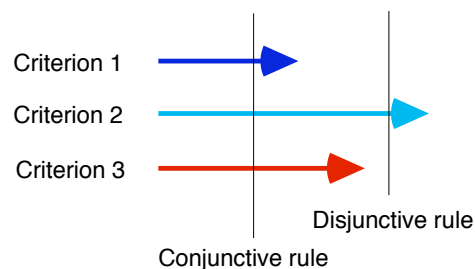


Figure 6.16 The way disjunctive and conjunctive decision rules relates to a set of criterion

The accuracy and effort of various decision-making rules

As has already been mentioned, Payne believes that individuals select strategies by trading off their relative advantages and disadvantages. The major advantage considered by decision-makers for a strategy is its anticipated accuracy. The major disadvantage is the cognitive effort that is required.

Hogarth (1987)¹⁴⁹ notices individual "*costs*" of making choices. Some of the costs are as follows. It can highlight uncomfortable uncertainties and make trade-offs explicit (which may be unpleasant to face) and, thirdly, there are costs associated with acquiring, processing and outputting information. Not to mention the time a careful decision-making process takes. One comment here is that intelligent people may be better off making decisions, at least if they can accomplish the utility maximisation rule. The general intelligence relates to the ability to draw conclusions from complex information¹⁵⁰.

For a variety of decision-making rules, the effort of making choices increases considerably as the number of alternatives and attributes increases¹⁵¹. The calculated effort expressed as the number of EIPs (elementary information processes) increases most heavily for the compensatory rule.

Payne et al.¹⁵² have conducted a computer simulation in which a computer uses various decision-making rules for a set of choices. It can be seen that there are decision-making strategies that require far less effort but produce half or more of the accuracy compared with using the weighted additive strategy.

¹⁴⁹ Hogarth, R.M., *Judgement and choice*, Chichester, England: Wiley. 1987

¹⁵⁰ Gustafsson, J-E (professor at Gothenburgh University) in a popular science interview in Dagens Nyheter, Sunday July 6, 1997 (Are you stupid, or.... The one who is good at one thing is good at other things.)

¹⁵¹ Payne, J.W., Bettman, J.R., Johnson, E.J., *The adaptive decision maker*, New York, Cambridge Univ. Press, pp.70-116, 1993

¹⁵² Payne et al. *The adaptive decision maker*, p.117-144. Original source: Payne, Johnsson, Bettman and Coupey, Understanding contingent choice: A computer simulation approach, IEEE Transactions on Systems, Man and Cybernetics, 20 (1990) p.305

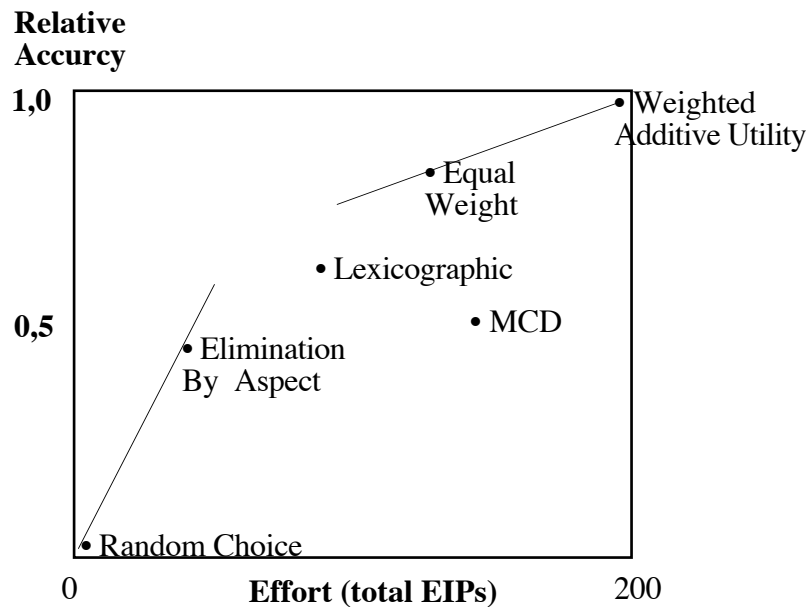


Figure 6.17 There is a relationship between the accuracy of a decision-making strategy and the effort it requires. The dotted lines are trade-off lines for accuracy and effort. Freely loaned from Payne et al.

The lexicographic strategy (LEX) produced almost the same accuracy as the reference, weighted additive rule (WADD), but with only one third of the effort. It is most accurate when dispersion is high. The accuracy then reaches 90%. With low dispersion among attributes, the accuracy for LEX reached almost 70%.

The simulation did not identify the strategy a decision-maker would select in a given environment. As a result, we do not know the accuracy we normally obtain from decision tasks like this one, which is comparable to SP tasks. However, we can assume that the accuracy is not too poor if people use some of the effective heuristic or non-compensatory rules.

6.2.2 Imperfections found in psychological experiments on judgement and decisions

By imperfections I mean discrepancies in outcomes between reality and experiments but also discrepancies between different preference elicitation methods or SP designs/SP methods. Two methods or two different designs can show preference reversals. Another type of imperfection is that people does not (always) maximise their own utility, as they should according to the rationalist paradigm.

Preferences may be constructed in the generation of responses

One important research direction is reason-based choice, as described by Shafir et al. (1993)¹⁵³. They show that decision-makers often seek and *construct reasons* in order to resolve conflict and justify their choice, to themselves and to others. That means, for example, that people conducting a stated preference experiment (interview) may construct reasons for choosing one or the other alternative during the experiment.

¹⁵³ Shafir, E., Simonson, I., Tversky, A., Reason-based choice, *Cognition*, 49 (1993) pp 11-36

According to Payne, Bettman and Schadke¹⁵⁴, preferences of any complexity or novelty are often constructed – not merely revealed – in the generation of responses to judgement tasks. They do not agree that answers in surveys reflect what was already on consumers' minds. It may be wrong to assume that people have a set of well-defined preferences among bundles of goods – that they know their preferences beforehand.

Seemingly complete data presentations can blind people to the fact that important aspects of a problem have been omitted. This is further discussed in conjunction with framing and focusing effects.

Focusing and framing when making decisions

A suspicion that is frequently voiced is that SP attribute estimates are too high for single attributes or features in which the commissioner of the study is interested. There are various reasons for this and one of them can be labelled *focusing*. This involves, at least in this report, the fact that respondents' focus is narrowed to include only the factors and attributes that are present in the study or even in the alternatives for assessment. Legrenzi et.al.¹⁵⁵ describe focusing: "Individuals are likely to restrict their thoughts to what is explicitly in their models."

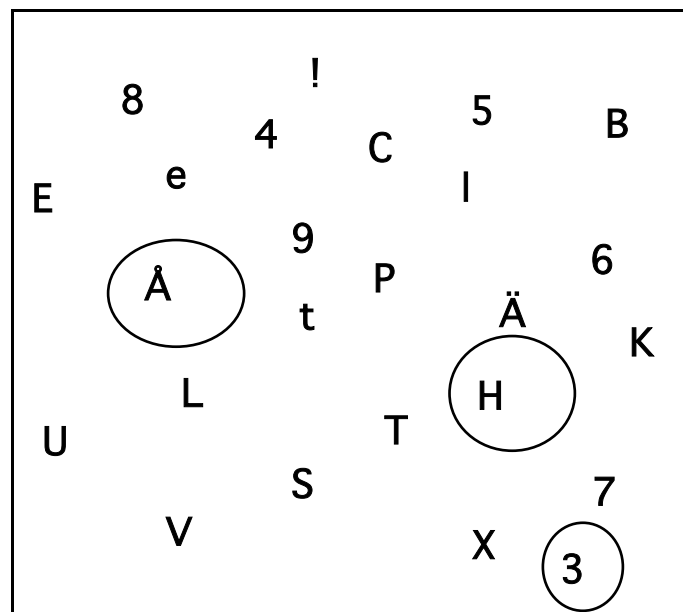


Figure 6.18 In a world full of things, "attributes", each study focuses on a few attributes. In this case, a car, a railway coach and a chair (seating) is put in focus.

The focusing effect may lead to the respondents forgetting or underestimating the importance of the attributes and other factors that are not included or explicitly mentioned

¹⁵⁴ Payne, J.W., Bettman, J.R., Schadke, D.A., *Measuring constructed preferences*, NSF Symposium, UC Berkely, July 30, 1997

¹⁵⁵ Legrenzi, P., Girotto, V., Johnson-Laird, P.-N., *Focussing in reasoning and decision making*, *Cognition*, 49 (1993) pp.37-66, 1993

in the interview. "Factors" can be constraints that are important in real decision-making or judgement situations.

The manner in which information is presented – *framing* – can affect judgement; for example, the order in which information is presented. If previous informational inputs dominate the individual's final opinion, this is known as a "primacy" effect and, when the latter information dominates, it is called the "recency" effect. From a normative viewpoint, the order of presentation should not affect the final opinions.

Framing is (partly) associated with the formulation of judgement problems. Frisch¹⁵⁶ describes the "framing effect" in a very straightforward manner using the finding that subjects often respond differently to different descriptions of the same problem. One example is that "50% will die of the disease" or "50% will be saved", which result in different responses.

Hogarth (1990)¹⁵⁷ defines framing as follows: "Outcomes are evaluated as deviations from reference points or levels of aspiration". This can make people evaluate outcomes as gains or losses which may induce choice reversals.

Individuals are often unaware of alternative frames and of their potential effects. An example given by Kahneman & Tversky (1981)¹⁵⁸ is shown below.

Problem A: Imagine that you have decided to see a play and paid the admission price of \$10 per ticket. As you enter, you discover that you have lost a \$10 bill. Would you still pay \$10 for a ticket for the play? [88% answered Yes and 12% answered No] Problem B: Imagine that you have decided to see a play where admission is \$10 per ticket. As you enter, you discover that you have lost the ticket. The seat was not marked and the ticket cannot be recovered. Would you pay \$10 for another ticket? [46% answered Yes and 54% answered No]

The difference between the responses is an effect of framing and psychological accounting. The purchase of a new ticket is seen as a total ticket price of \$20, while the loss of \$10 is not linked specifically to the ticket purchase.

Frisch (1993) conducted tests to see whether subjects agreed or disagreed that two normatively equal problem descriptions are the same. One of her examples is how much people are willing to pay for a cold bottle of beer from a run-down grocery and how much people are willing to pay for a cold bottle of beer from a fancy hotel, in the same situation, a hot day at the beach. Some respondents said that they would prefer beer from the nice place because the beer may have been treated better there – an objective reason. Others referred to subjective reasons such as "the fancy hotel has the right to charge a little more". The latter involves a feeling of fairness.

¹⁵⁶ Frisch, Deborah, Reasons for framing effects, *Organizational behaviour and Human decision Processes* 54, pp 399-429 (1993)

¹⁵⁷ Hogarth, R M, *Judgement and choice*, p 217 (Chapter 10: Human judgement – an overview), John Wiley & Sons

¹⁵⁸ Kahneman, D, Tversky, A, *The framing of Decisions and the Psychology of Choice*, Science, vol.211, p 453, 30 Jan.1981

Inspired by a paper by Reyna and Brainerd¹⁵⁹, I would like to describe "gain"–"loss" and "positive"–"negative" formulations with train delays as an example. Let us assume that a situation in which 10% of the trains are delayed is going to be described.

	<u>GAIN</u>	<u>LOSS</u>
POSITIVE:	"will be on time"	"will be delayed"
NEGATIVE:	"will not be delayed"	"will not be on time"

A complete description of the situation, or alternative, with redundant information would be: "90% of the trains will be on time so 10% will not be on time, which means that 90% of the trains will not be delayed so 10% will be delayed". This formulation is very redundant and includes numerical information – the information is very detailed. One finding is that negations make the understanding of the alternative more difficult.

Numerical information is not always exactly understood and treated. The above example could be interpreted as: "A few trains are delayed and most trains are on time", especially when the respondents are not asked to compare with other numerical levels of delay.

Preference reversals

The experiments with preference reversals put their finger on the fact that varying formulations of attributes and alternatives may influence the utilities, estimated from SP experiments. Ideally, the result of an SP interview should give the same valuation levels, independent of the procedure that is used. *Procedure invariance* means that the order of preferences should not vary from one response mode to the next. Various procedures for presenting attributes and alternatives should not influence the preferences given by the respondents. If they do, there are *preference reversals*.

Description invariance states that the way a situation is described should not affect one's decision (Frisch, 1993).

Risky decisions

A great deal of decision research has been conducted on risky situations such as gambling and lotteries. In these situations, preference reversals often arise. The researchers argue that these preference reversals are violations of the expected utility theory. This theory is based on axioms, one of which states that the utility of a risky project is equal to the expected utility of its outcomes.

Examples of risky choices and judgements when travelling are when delays must be considered and when estimating the time one has to wait for a bus at a bus stop. Traffic planners often use the expected value – average waiting time, which is equal to half the interval between departures ($50\% \cdot t_i$), while people appear to estimate this time as twice the average or simply the interval time ($100\% \cdot t_i$).

¹⁵⁹ Reyna, V F, Brainerd, C J, *Fuzzy-trace Theory and Framing Effects in Choice: Gist Extraction, Truncation and Conversion*, Journal of Behavioral Decision Making, Vol.4, pp 249-262 (1991)

Compatibility effects in judgements and choice

One interesting effect is known as compatibility. A compatibility effect is the correspondence between the scales in which the inputs and outputs are expressed. If we have monetary information as input, this governs the elicitation made by respondents; monetary output (elicitation) is favoured. This can be called *scale compatibility*. Another form of compatibility can be called *strategy compatibility*. A qualitative strategy of selecting (e.g. dominance) that is superior to the more important dimension is more likely to be employed in the qualitative method of choosing, whereas a quantitative strategy based on trade-offs between dimensions is more likely to be used in the quantitative method of matching.

Fisher & Hawkins (1993)¹⁶⁰ have investigated compatibility effects in non-risky cases. They found that the *strategy compatibility* effect was much stronger than the *scale compatibility* effect. They had been conducting experiments in which students had to evaluate student apartments that had two attributes; rent (in \$) and distance (in minutes). Four elicitation methods were tested: choice, rating, price matching and distance matching. The results are shown in the next figure.

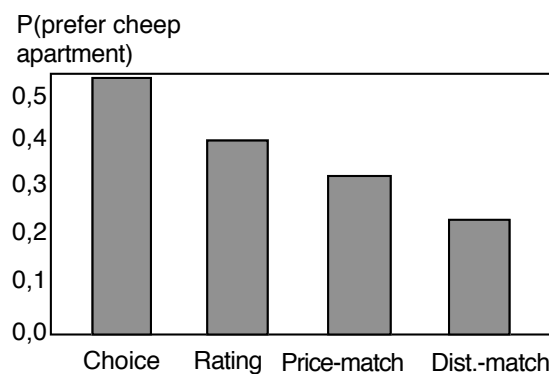


Figure 6.19 The preferences resulting from four different elicitation methods in an experiment by Fisher & Hawkins (1993). See text.

The figure shows that students most often chose the less expensive apartments. This can be explained by strategy compatibility and the prominence effect. The students had separately stated that price was the most important factor for them – the prominent attribute. Choice is a qualitative response and the prominent attribute has a major influence. Being prominent is a qualitative feature. Matching, on the other hand, calls for an intellectual procedure involving the quantitative weighing of attributes. Matching produced the lowest probability that the cheaper apartments would be preferred. The difference between price and distance matching shows the (weaker) scale compatibility effect.

¹⁶⁰ Fischer, G, Hawkins, S, Strategy Compatibility, Scale Compatibility and the Prominence Effect, *Journal of Experimental Psychology*, vol 19 No 3, p 580-597

Shadke & Johnson (1989)¹⁶¹ conducted computer-based process tracing experiments to see whether people use different methods in choice relative to judgement. Their findings from the experiments were that choice and pricing involve totally different processes. Choice is faster than judgement in the form of pricing, which is characterised by greater attention to the payoff information. In pricing and rating, many respondents were found to generate responses by selecting a starting point and then making a series of adjustments on or near the response scale. They were "testing" their own feelings or judgements about specific responses. Shadke & Johnson's theory also supports earlier findings that the frequency of preference reversals should be greatest between rating and pricing and least frequent between rating and choice.

To make it easier to compare the different elicitation procedures, a figure has been drawn. It shows an attempt to categorise various elicitation procedures.

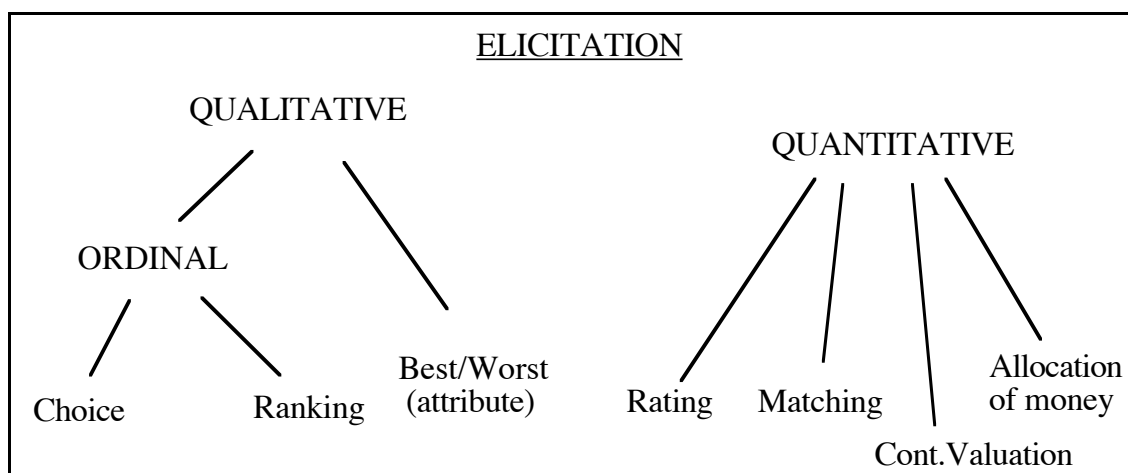


Figure 6.20 An attempt to categorise various elicitation procedures.

The categories of elicitation depend on the response mode respondents use. In choice, they only show the alternative they prefer – which alternative "is first" – an ordinal answer, as the ranking. In best/worst, respondents state the attributes that are ranked highest and lowest.

The two quantitative methods of rating and matching call for a higher degree of compensatory thinking about different attributes (and levels) in the alternatives. Contingent valuation and allocation of money is also quantitative, although they do not necessarily require compensatory thinking.

Slovic et al. (1990)¹⁶² wonder how the choice of a specific research method of elicitation can be justified. "At the very least we need to use multiple procedures (e.g. choice, pricing, rating) and compare their results. If they are consistent, we may have some basis for trusting the judgement; if they are not, further analysis is required."

¹⁶¹ Shadke, D, Johnson, E, Cognitive Processes in Preference Reversals, *Organizational behaviour and decision Processes* 44, p 203-231 (1989)

¹⁶² Slovic, P., & Tversky, A., Compatibility effects in judgement and choice. In R.M.Hogart (Ed.), *Insights in decision making*, (pp 5-27). Chicago: The University of Chicago Press, 1990

The reference level for judgement

The utilities used in RP and SP, logit and probit models are relative; one level of an attribute has a higher utility than the other. One level, the reference level, is then often set at zero. It can be set at any value, but this does not normally add any extra information. The utilities in the logit formula represent (about) quotients between effects, which makes it easier to understand the relativity.

In some kinds of SP experiments, for example the best/worst method, the question of what the reference is important.

Hogarth (1987)¹⁶³ points out that we make our judgements on the basis of *points of reference* or *cues*. The judgements are the results of a number of comparisons with cues. A decision rule based on references is the "ideal point model" which assumes that the decision-maker has an ideal representation of what the "perfect" alternative would be. Alternatives are then evaluated on the basis of their distance from this ideal representation.

The reference level people have in their minds is sometimes called an "anchor", but the word anchor is also used for psychological explanations in other contexts.

Think aloud protocol study

Think aloud protocol methods can be used to analyse how people think when they judge and choose alternatives. An application of think aloud protocols on stated preference interviews has been done at KTH Traffic Planning in a degree project 1996¹⁶⁴. The SP study used for this application is a study about day and night train services (see section 7.9). This degree project was too restricted to come up with very clear making findings on how people make their choices.

¹⁶³ Hogarth, R.M., *Judgement and choice*, Chichester, England: Wiley. 1987

¹⁶⁴ Nyström, T., *Tänka högt-metoden. Kan tänka högt-metoden öka Stated Preference förklaringsvärde?* (The think aloud protocol-method. Can the think aloud-method increase the explanatory power of SP?), degree thesis no.96-27, KTH Traffic & Transport Planning, 1996

6.3 Stated Preference practice

Stated preferences (SP) means that people have "stated their preferences" in interviews of various kinds. In accordance with this, "stated choices" means that the respondents have made choices which are supposed to reveal their preferences.

6.3.1 The CV, RP, SP and Conjoint concepts

In contingent valuation methods (CVM), people are asked more or less directly about their willingness to pay for an option. In figure 6.21, conjoint, contingent valuation (CV) and discrete choice methods are seen as partly overlapping applications of stated preferences. Other means of systematisation are also possible.

Revealed preferences (RP) is a method using which people's choices in real life have been studied to reveal their preferences. The statistical material that is needed can, for example, be collected using travel journals that people are asked to fill in.

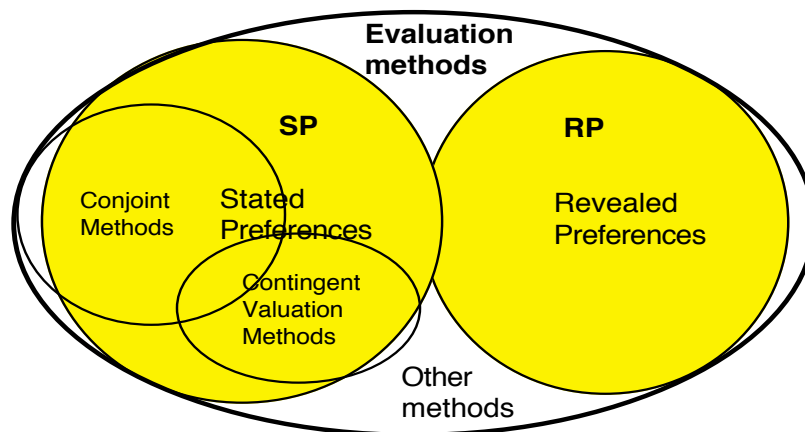


Figure 6.21 A possible classification of some preference evaluation methodologies for transport analysis. See text.

"Stated preference" is a broad concept, as it includes any type of preference judgement in any hypothetical situation. For example, consider the following question: "A new railway is being built from Stockholm to Eskilstuna. Will you use it instead of taking your car, when visiting friends in Stockholm?" The answers can be called "stated intentions", a type of stated preference, but not conjoint measurements. Hence, conjoint analysis is included in the set of SP techniques.

Morikawa (1989)¹⁶⁵ explains the term "conjoint analysis" as any *decompositional* method that estimates the structure of consumers' preferences using their overall evaluation of a hypothetical alternative represented by a set of attributes. Morikawa follows this broad

¹⁶⁵ Morikawa, T, *Incorporating Stated Preference Data in Travel Demand Analysis*, Dissertation, June 1989, MIT

definition, referring to Green and Srinivasan (1978)¹⁶⁶. The decompositional part involves estimating *part-worths* for the attributes. On the other hand, the *compositional* approach directly asks the respondent about the values of part-worths. Morikawa writes that it is generally accepted that, when it comes to the prediction of consumer behaviour, the decompositional approach is superior to the compositional approach because it is easier for the respondent to judge the preference for an alternative than to give an importance weight to each attribute. In this thesis, Morikawa's statement is not accepted without question.

Table 6.9 Classification of discussed methods.

	Conjoint methods	Other methods
Stated preferences (SP)	Decompositional. Based on alternatives or profiles (joined attributes).	Compositional. Examples: paired comparisons of attributes, ranking of attributes.
Revealed preferences (RP)	Analysis of alternatives chosen in reality. Decompositional.	?

Common SP practice takes the following form. The respondents are asked to consider product alternatives and to state their preference for each alternative. This can be done by ranking, rating or choosing between the alternatives. As the respondent continues to make choices or judgements, a pattern begins to emerge and, using complex multiple regression techniques, it can be broken down and analysed in terms of the individual features that make the largest contribution to the purchase likelihood or preference. The importance or influence contributed by the component parts is measured in relative units called "utils" or "utility weights".

In a full profile SP experiment, the respondents are asked to rank or rate all the combinations of products being tested at one time and the respondents are presented with the complete product. When a fractional factorial design is used, only a fraction of the total possible number of product combinations need to be tested.

6.3.2 Procedures for stated preferences and stated choices

Stated preferences (SP) mean that the respondents show their preferences in one way or another, while stated choices (SC) mean that people demonstrate more precisely how they would choose between alternatives. In a way, stated choice may be more closely related to a final transport model, the object of which is to predict choices (market shares and so on). In the same way, stated preferences may be very relevant when we are mainly interested in the weights or values respondents allocate to various attributes.

There are several ways (methods, techniques or tasks) of conducting an experiment.

- Ranking alternatives in a statistical design.

¹⁶⁶ Green, P.E., Srinivasan, E., Conjoint analysis in consumer research: Issues and outlook, *Journal of Consumer Research*, Vol.5: 103-23. 1978

Respondents are generally shown product combinations on sort cards which they are asked to put in order of preference. This is a preference task which is seen as a number of choices for the estimation of parameters.

- Rating of alternatives in a statistical design.

Respondents are asked to rate the alternatives on a scale (e.g. 1-10, where 1 is very bad and 10 is very good). This is also a preference task. It is often estimated by linear regression, although this has been questioned, but the rates can also be used to classify the alternatives and then estimate the parameters as if a number of choices had been made.

- Monetary valuation of alternatives in a statistical design.

This task has probably been tested somewhere. The task is equal to rating, but, instead of undimensional rates, monetary values are used. In this case, the (travel) cost may not be an attribute which is included in the alternatives. An assumed advantage over the standard rating task is that the scale problem in the rating task is reduced. The variation among people, the way individuals elicit money, is probably less marked, compared with the way various individuals elicit rates – but this hypothesis has not been tested. This should be a contingent valuation (CV) method.

- Choices between alternatives arranged in pairs – pairwise choice method.

Alternatives in pairs are widely used – in the computer-based MINT interview program used in many studies at KTH, for example.

- Choice of best and worst attributes within a statistical design.

Best/worst conjoint is a new elicitation method using which attributes rather than alternatives are elicited. It is described in a separate chapter.

Hensher (1994)¹⁶⁷ describes seven tasks to consider when practising the SP method.

Task 1 is the identification of the set of attributes. Which attributes should be included and which should be excluded? One way of preserving a large number of attributes is to divide the attributes into groups and to design a number of linked hierarchical experiments. A similar approach was tested at KTH by Schmidt (1995).

Task 2 involves selecting a measurement unit for each attribute. It is important to use well-defined attribute levels, such as 5 minutes' and 30 minutes' waiting time, instead of "short" and "long" waiting times.

Task 3 involves the specification of the number and magnitudes of attribute levels. One level may be the level currently facing an individual.

Task 4 relates to the statistical design where statistical design theory is used. A full factorial design contains descriptions of all the combinations, but in practice fractional factorial designs are used. One important property is that the design is orthogonal, which ensures that the attributes presented to individuals are varied independently of one another.

¹⁶⁷ Hensher, D, Stated preference analysis of travel choices: the state of practice, *Transportation* vol 21, No 2 May 1994, pp 107-134

Task 5 deals with the strategy of questions and the data collection method. The statistical design is reformulated in the form of questions and show cards, perhaps in the form of computer screen layouts. A rating, ranking or choice method must be chosen.

In Task 6, the selection of an appropriate estimation procedure is dependent on the data collection method and response mode, for example. The multinomial logit model has been used in the majority of stated choice applications.

Task 7 uses the estimated parameters to obtain choice probabilities. As has already been explained, these seven tasks come from Hensher (1994).

In studies in which the values of various attributes are in focus, Task 7 would instead involve the transformation of parameter estimates into some understandable measurements. If the estimate of any attribute is divided by the estimate for cost (for SEK 1), a trade-off between attributes and money is obtained. In this way, the valuations can be expressed in SEK and/or as a percentage of the fare or as an equivalent travelling time expressed in minutes (and perhaps hours).

At KTH, Division of Traffic & Transport Planning, we use software from the Hague Consulting Group for statistical design (Task 4), data collection (Task 5) and estimation (Task 6). The software also has Task 7 capability. The programs for Task 4 design, 5 interview and 6 estimation are called SPEED, MINT and ALOGIT. A handful of other software packages are mentioned in Hensher (1994).

Computer assisted self interviewing (CASI)

At the end of the 1980s KTH Traffic Planning conducted their first SP studies. These were made with cards describing various alternatives. The respondents had to sort the cards.

Around 1990 a few portable computers were bought and interviewing with pairwise choices with computer generated alternatives started. The first SP study I organised, in 1992 (see section 7.1) on the east coast main line, were made with a combination of a paper questionnaire and a SP computer interview. We carried one of these 5 kg "portable" computers and to make the electric charge last we had a lead acid MC battery that we put at the floor by the seat of the passenger. The computer was placed so as to allow both the interviewer and the respondent to view the screen. The respondents who wanted to do so, were invited to do the typing by themselves.

Later in 1992 I found 0,5 kg pocket computers that could run DOS, on the market. About four of these were used in my next study (section 7.2) with train passengers at the local railway Roslagsbanan. The small computers were handed out to the passengers and they were given a very short instruction. ("Please read the questions on the screen and press a digit and <Enter> when answering.") The battery life for our "Poquet" computers is two weeks.

Later we have complemented our interview tools with five 1,3 kg HP Omnibook computers. They have larger and more distinct, but still reflective, screens and no hard disks, which makes the batteries last 8 hours. Modern back-lit lap tops do not have the necessary battery time and most of them are still too heavy.



Figure 6.22 Self completed computer assisted interview (CASI) with pocket size computers on board a Swedish train. (MINT interview program runs in DOS.)

One CASI interview normally takes about 10-15 minutes and in trains we do about 100 interviews per day with 5-8 computers in use. (In February 1999 a KTH student managed to conduct over such 400 interviews in two days!) The answer data files can be saved on PCMCIA cards and from these cards we copy the results to a master computer, which can be one of the Omnibooks. Using an Omnibook in the field allows us to make statistics even in the field.

KTH comparison of stated preference elicitation procedures

In 1992-1993, a series of SP studies were supervised by Widlert at KTH to test different SP methods. The SP interviews were made on long-distance trains.

One interesting finding in these studies is that the use of very small hand-held "Poquet" computers (0.5kg) and self-interviewing produced results similar to those produced by the method used previously, when an interviewer was present and a computer with a larger screen was used. Lundin & Steen¹⁶⁸ reports the following results for the same SP experiment carried out with and without interviewer assisting (table 6.10).

¹⁶⁸ Lundin, A., Steen, M., *Metodstudier i stated preferences. Sp-metodens känslighet för olika utformning av datainsamling*, (Methodological studies in Stated Preferences. The sensitivity to various ways of collecting SP data, in Swedish), KTH Traffic & Transport Planning, Master thesis No.1993:6, TRITA-TPL-93-11-95, 1993

Table 6.10 Results (Parameters, *t*-values and valuations) for assisted and non-assisted computer interviewing.

Attribute	Portable computer with interviewer assisting the respondents.	Pocket computers, self assisted by respondents (CASI interview)
Cost (%)	-0,093 (8,6)	-0,088 (8,5)
Time (%)	- 0,085 (9,5)	-0,074 (9,2)
Frequency (min)	-0,0091 (8,6)	-0,0079 (7,9)
Modern coach	+0,36 (3,2)	+0,38 (3,7)
X2000-coach	+0,19 (1,8)	+0,29 (2,9)
Time value	0,91 % fare /% time	0,85 % fare /% time
Frequency	0,10 % /min	0,09 % /min
Modern coach	+3,9 %	+4,4 %
X2000 coach	+2,0 %	+3,3 %

Comparing the parameters of the two models shows no difference of any of the estimates on a 10% significance level. The so called scale differs a little but the value of time and frequency are very close. (The randomness seem to be somewhat larger for the CASI interviews, which can indicate they did their choices a little less consistent.)

Lundin & Steen concludes that the interviewers presence at the computer interviews did not have much influence on the results. They also mentions the big time saving there is by handing out small computers to many passengers at a time instead of sitting next to every person being interviewed.

Other degree projects tested different preference elicitation methods. The following methods were tested¹⁶⁹:

1. Ratings of alternatives on paper forms.
2. Ranking of alternatives by sorting cards.
3. Pairwise choices without individually adjusted price and travelling time levels on paper forms.
4. Pairwise choices without individually adjusted price and travelling time levels with computer presented alternatives.
5. Pairwise choices with individually adjusted price and travelling time levels and computerised.

¹⁶⁹ Widlert, S., *Stated Preference Studies - The Design Affects the Results*, 7th international congress of Travel Behaviour, Valle Nevado, Santiago, Chile, June 12-16 1994.

Tests were also conducted in which the travel costs and times in absolute differences in SEK and as a percentage of the fare were presented. When the cost was presented in SEK, it could then be calculated as a percentage of the fare.

The findings were that the elicitation procedure is of great importance for the relative importance of the attributes. Most frequently, the parameters for other attributes are divided by the parameter for travel cost, which produces the willingness to pay for the various attributes. The importance of the price attribute was found to be lower in computerised individualised interviews with pairwise choices. This involves the highest monetary valuations related to other attributes. This was followed by rating on paper forms. The difference in value for VOT (value of time) was as large as a factor of four for the extreme methods.

One reason Widlert identifies is that "people tend to simplify the task whenever possible". The relative number of lexicographic answers to the price attribute was lowest for individualised computer interviews. That means that the respondents appear to have used compensatory decision-making rules to a greater degree.

My comment to this is: Are we sure people do not use lexicographic rules when making their choice of travelling in reality?

Declines – people falling off when doing CASI interviews in trains

Decline is a comparatively small problem when doing CASI interviews in trains. People are in the train and often welcome the interviewer offering them something to do while travelling. Even though there are some declines:

- Refusal: The most common reason, mostly from old people and people working on board. I estimate that in average every tenth (or less) person refuses.
- Time: The respondent will debark the train at a nearby station. This reason is more common in local and regional trains, than in interregional trains.
- Sleep: The respondent was asleep or pretended to be asleep.
- Language: The respondent did not know Swedish well enough.
- Free tickets: This problem has been noted especially in first class where often railway staff travel with their free tickets. Also tourist tickets like "Nordturst" have caused falling off.

Regarding refusals from old people and other persons feeling uncomfortable handling the computer by themselves, they have often been offered assistance from the interviewer. Sometimes this has been necessary during the full interview, but often a good introduction has relieved their discomfort.

6.3.3 Practical conjoint methods versus stated preference methods

I agree with Morikawa's classification in which conjoint methods are a subdivision of SP methods, but I have noted that "conjoint" and "Stated Preferences" ("SP") are sometimes used as terms to describe competing methods. Some "indicators" of differences of these methods in practice will be mentioned:

- "Conjoint" is used by many marketing companies for evaluating various consumer products. "SP" is often chosen by econometricians and in transport studies. Marketing

companies use the terms "profile" or "stimulus" when econometricians use "alternative". In the same way, "part-worth" or "importance weight" correspond to "parameter" or "coefficient".

– "SP" is or should always be in accordance with random utility theory (RUT), while only some "conjoint" methods are.

– Conjoint practitioners often generate weights for each respondent for each feature. This is not so often done by SP practitioners, but it may well be done.

Hu (1997)¹⁷⁰ is one of several authors who have been found providing an introduction to conjoint analysis. He mentions a method with self-expressed utilities as the "compositional part" of a "hybrid conjoint model". The other part is a "decompositional part" estimated from full profile (alternative) evaluation. The decompositional part is more like ordinary SP methods.

Conjoint methods present their estimation results as:

1. Level utilities or part-worths and
2. Factor importance or attribute relative importance and
3. Profile or alternative utilities

The literature about these conceptions of conjoint methodology is of relevance to an understanding of the new method, best/worst conjoint, tested by me and discussed in this thesis.

6.3.4 Primary (hard) and secondary (soft) variables

A distinction between primary and secondary variables is recognised. The primary or "hard" attributes are those often used in transport models, such as travel cost, travelling time and waiting time. They are found to be fairly stable from experiment to experiment.

The secondary or "soft" variables are likely to affect travel behaviour, but their importance is difficult to quantify by studying people's revealed preferences. A small distinction in definitions is that *secondary variables* comprise the kind of socio-economic factors and transport system attributes that are seldom incorporated in transport models, while *soft attributes* comprise the kind of attributes that can be grouped into comfort, service or quality. Bates also feels that the secondary attributes are more incidental (for example, the clarity of announcements, the presence of escalators versus fixed staircases and so on).

Another interpretation of primary and secondary attributes is that people are more conscious and observant of primary attributes than secondary ones. They are more likely to be aware of their travelling time and the price they pay than of the existence of reading lamps or noise levels. Many secondary attributes can be seen as indicators of other concepts – for example, the concept of on-board comfort. They can also relate to latent variables such as convenience.

It was an early hope of practitioners that SP might be a powerful tool in the investigation of secondary and soft attributes. Many SP investigations have been conducted, not least

¹⁷⁰ Hu, Clark, Conjoint analysis, published on the Internet at huc@nevada.edu, UNLV Hotel College, 1997

about train travelling by KTH, to obtain appropriate valuations, typically given as a percentage of the fare paid. However, Bates (1993) and I feel that the valuations provided are often unconvincing when a number of attributes are added to a package of improvements – the valuations of individual attributes appear to be too high. This problem is addressed in a special chapter on package effects.

The so-called "error term" in the logit model contains a great deal of unexplained variance. Louviere¹⁷¹ feels that a good model, one which is able to make accurate predictions, must contain many variables. The unexplained variance is then transformed into explained variance. This means that secondary variables are important. Socio-economic and other personally-related variables identify variations between individuals and soft variables identify variance caused by the varying perception of soft attributes (comfort attributes and so on).

6.3.5 Unlabelled and labelled (ranked) designs

A ranked or labelled alternative is one which is defined by a "label", for example a specific mode (car, bus, train, air...).

The choice between car and bus is a choice between labelled alternatives, while the choice between a (blue) bus and a (red) bus is unlabelled. This is a choice between attribute levels, in this case a choice between colours of the buses, rather than between real transport alternatives.

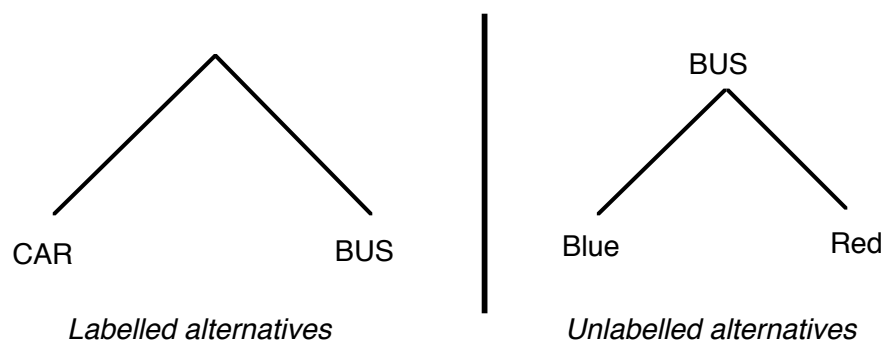


Figure 6.23 An illustration of labelled and unlabelled alternatives related to this example.

We can assume that the value of the colour is close to zero, for most respondents, but it may still be the reason for choosing one or the other bus. The only attribute that separates the utilities of the red and blue buses is the colour.

The choices respondents have to make in the Mint computer questionnaire used by KTH relate to alternatives in pairs. One pair of alternatives in a labelled, pairwise SP design is illustrated below.

¹⁷¹ Jordan Louviere at a stated preference course in Stockholm, June 1997.

CAR	TRAIN
Car travelling time is 3 hours Travel cost is SEK 200	Train travelling time is 2 hours Ticket cost is SEK 180 There is one train every hour

Figure 6.24 A labelled design (labels: CAR and TRAIN)

I have generally used pairwise unlabelled alternatives when interviewing train passengers. An unlabelled SP design is illustrated below. The levels of three attributes are presented randomly in alternative 1 or alternative 2, where both alternatives are designed to produce the same associations, in this case about the same type of train.

Alternative 1	Alternative 2
Travelling time is 3 hours Ticket cost is SEK 200 There is one train every hour	Travelling time is 2 hours Ticket cost is SEK 180 There is one train every two hours

Figure 6.25 An unlabelled design. Both alternatives relate to the same type of train.

A labelled alternative has alternative-specific parameters, while an unlabelled alternative is abstract in the sense of being an attribute mix. The alternative parameter(s) can be the parameter(s) of different modes.

The consequences of using labelled and unlabelled alternatives are discussed in greater detail in section 6.7.

6.4 Package effects – the value of added features

It is mostly of interest to improve trains and services using a package of measures and not just doing one thing at the time.

6.4.1 What are the "package effects"?

In this thesis, *package effects* are the phenomenon that measures regarding attributes often appear to be given a lower value when they are included in a package together with other attributes (packages of measures). The valuation of the package tends to be lower than the sum of the valuations of the included attributes. This appears especially to be the case when it comes to secondary attributes. The value of comfort attributes should perhaps be reduced by as much as 50% when about four of them are introduced as a package. On the other hand, the synergies produced by many improvements introduced at one time may lead in the opposite direction in a few cases.

Environmental economists have problems valuing the saving of one species of bird compared with saving a thousand species, for example.

In this thesis, around a hundred interesting attributes that could be valued by passengers are mentioned. There may be some willingness to pay for all of them, but all of them cannot be, or are usually not, investigated in a single study. In one SP "game", between three and ten single attributes are often investigated.

Methods for circumventing the problem of package effects have been proposed and tested. When a primary Swedish study about public transport standard was planned in 1987 by Widlert, Gärling and Juhlin¹⁷² they were aware of the existence of package effects. Therefore they included an experiment where packages of 3-4 measures were valued. Within the framework of my research, two studies have been conducted to test circumventing methods. Schmidt conducted one study in 1995/96 as a master's thesis under my supervision and in 1998 I conducted a second study. These studies produced somewhat contradictory results.

6.4.2 Findings

Monetary values for time, frequency and other hard variables have been acceptably consistent in the different studies¹⁷³. However, the valuations of soft variables such as comfort and on-board service variables have been less convincing, particularly when viewed as components of an improvement package.

Widlert et.al. found that the valuations of packages of attributes were so much lower than the sum of the included singular attributes:

¹⁷² Widlert, S., Gärling, T., Uhlin, S., *Värdering av kollektivtrafikens standard*, (Valuation of the standard of public transport, in Swedish), TFB Report 1989:2, ISBN 91-87246-39-2, June 1989

¹⁷³ Bates, J., *Reflections on Stated Preference Theory and Practice*, unpublished paper from John Bates Services

- Three timetable¹⁷⁴ related attributes: $\approx$ 20-50% reduction.
- Three station related attributes: $\approx$ 50 - 100% reduction.
- Four vehicle related attributes: $\approx$ 60% reduction

Rosenlind has in her degree project 1993/94¹⁷⁵ investigated timetable, coach types and on-board service. Her findings in short:

- Two timetable attributes + coach type: 10-15% increase (!)
- Two on-board service attributes: $\approx$ 30% decrease.
- Three area related service attributes $\approx$ 70% decrease.

In 1995 I supervised a degree thesis project about package effects described in section 7.3 and reported by Schmidt (1996)¹⁷⁶ after more than six months of studies. We investigated a number of circumstances that affected the package effect and they are reported below in Section 6.4.3.

Part one in mine and Schmidt's study showed a much lower package effect for (three) comfort attributes than previous studies suggested. The attributes were high and reclining seats, air conditioning and toilets in suburban trains and the package effect was only 4-20% decrease.

A study for London Underground (Coopley et al., 1993¹⁷⁷) concludes that, when it comes to package effects, 1) no general conclusions about non-linearity effects could be drawn, 2) interaction effects between aspects cannot account for the scale of the "package effect", 3) no significant differences were found between within-mode and between-mode experiments, 4) the relative valuations of a set of quality attributes were unaffected by the presence or absence of fare in the SP experiment. The most successful endeavour to reduce the package effect appeared to be an explicit and consistent definition of the soft variables.

Sælensminde (1995, 1996)¹⁷⁸ has shown that packages of attributes of accessibility (for cars), traffic safety and environment were given a lower value than the attributes receive when they were valued individually. The average reduction for accessibility when valued in a package of two was 26% and the reduction in a three-attribute package was 47%.

¹⁷⁴ They called it "service factors" which is in line with the meaning of service in English.

¹⁷⁵ Rosenlind, S.; *Tågresenärers värderingar av trafikering, vagntyper och service*, (Passengers' valuations of traffic services, coach types and on-board service, in Swedish), KTH Traffic Planning, Master thesis/ examensarbete 94-1, 1994

¹⁷⁶ Schmidt, L., *Värdeminskning vid värdering av Tågkoncept – Studie av komfort, service och tidtabellspaket med Stated Preferences-metoden (Value reduction when evaluating train concepts – A study on comfort, service and timetable factors using the stated preference method)*, KTH Traffic Planning, TRITA-IP AR 96-44, 1996

¹⁷⁷ Copley G, Terzis G, Bates J, Sheldon R, Goulcher A & Weston G, *Use of Stated Preference Methods to Determine London Underground Passenger Priorities*, PTRC Summer Annual Meeting 1993, seminar D

¹⁷⁸ Sælensminde, K, *Pakkeeffekter og budsjettpåminnelse*, Arbeidsdokument av 29/12-95 O-2187 Met-LOKTRA. TP/0934/1995

Sælensminde, K, *Interaksjonseffekter ved verdesetting av fremkomlighet, trafikksikkerhet og miljø gjennom hypotetiske betalningsvillighetsstudier*, Arbeidsdokument av 18/12-96, O-2013/ O-2270, TP/1075/96

In 1997 Jones¹⁷⁹ presented an interesting paper addressing the packaging problem, at the European Transport Forum (PTRC). He reports that packaging has been found to require scaling factors of the order 0,3 - 0,7. Jones' paper will be referred to also further down.

From the studies mentioned here I have noted that the package effect seem to increase with the number of attributes included in the package. It is also reported to be less for primary attributes, that is attributes regarding timetable.

Two of the studies reported in this thesis have shown that the package effect can be small or even non-existing some times. The InterRegio study reported in section 7.3 included a package of new trains with better comfort and an improved timetable; faster and more frequent trains. The value of this package was equal to the sum of the two factors: The sum of 8% and 16% equalled the package value; 24%. This result is similar to Rosenlind's result reported above. A small package of timetable and coach does not show a package effect.

The other study that contradicts the hypothesis of strong package effects is the extensive "package study" 1998 investigating a greater number of timetable, comfort and on-board service attributes, reported in section 7.15. It showed that many, but not all, of the attributes investigated separately in earlier studies, received as high or almost as high values when evaluated in packages of 5-7 attributes.

6.4.3 Reasons

There are many reasons for package effects. I will present my view but also mention explanations given by other researchers. The diagram below is my own structure of the most important reasons for the value reduction most often found for packages of measures/attributes.

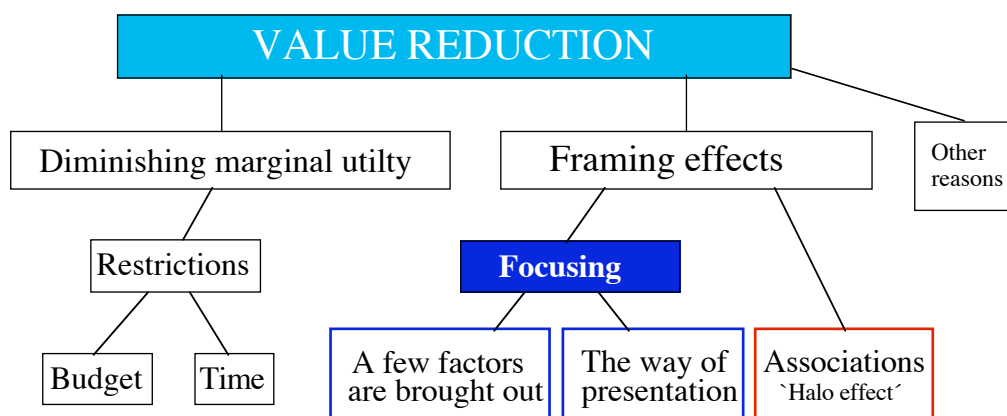


Figure 6.26 Some reasons for package effects (value reduction) in SP studies

¹⁷⁹ Jones, P., *Adressing the "Packaging" Problem in Stated Preference Studies*, Transport Studies Group, University of Westminster, European Transport Forum, September 1997

I have sorted the reasons into decreasing marginal utility, where the most obvious reason is budget restraints and framing effects.

Diminishing marginal utility

People do not have the money to pay for the sum of a greater number of improvements. The decrease in marginal benefits can be related to time as well; we may not have the time to watch a video film, listen to a radio programme and read a book. (Jones means that there should be a distinction between diminishing marginal benefits for further improvements and budget constraints. Regrettably I have not considered this distinction in the model above.)

In the theory of economics, there is a concept which decreases marginal benefits. This means that the consumption of twice the amount (of one commodity) is not worth twice as much as the first amount. The traveller cannot simultaneously be involved in every conceivable activity on board – reading, discussing, playing, eating, listening to music, watching films and so on. If he appreciates "consuming" several of them, it is therefore likely that the benefit of being able to satisfy each one diminishes with the number. It is therefore likely that the value of the qualities of the train that facilitate these activities (or consumption) diminishes with the number of (positive) qualities.

Budget restrictions

The idea of budget constraint is that the respondent cannot afford to pay for the full set of improvements when offered them in one package. They therefore offer a lower price for full implementation, than for the individual attributes/improvements.

Respondents may understate their restricted budget. Sælensminde (1995)¹⁸⁰ found that an explicit reminder of people's restricted budget caused them to give the included attributes (travelling time, frequency) a lower value. For example, a budget reminder reduced the valuation of travelling time by 12-32%. In the same study, Sælensminde studied package effects and he concluded that these and the budget reminder may be two sides of the same phenomenon (Sælensminde used a transfer price method).

Framing effects inclusive focusing

Framing effects are related to the experimental situation – for example, the presentation and description of alternatives and attributes. The psychological effect of framing is described in Section 6.2.2. It is related to the situation in which questions are put and the description and formulation of the questions and response alternatives.

Focusing: the focus is placed on the attributes that are included in the experiment. If people have not thought about these attributes before, they will probably do so when asked. A third reason, which is classified here under framing, is associations. People may make other, and wider, associations than those intended by the experimenter.

At a seminar, Bates¹⁸¹ put forward an intuitive explanation that has to do with focusing: The respondents may envisage; "so these are the improvements that can be made and I

¹⁸⁰ Sælensminde, K, *Pakkeeffekter og budsjettpåminnelse*, Arbeidsdokument av 29/12-95 O-2187 Met-LOKTRA. TP/0934/1995

¹⁸¹ SP seminar in Copenhagen arranged by Prof. Holmberg, Lunds University. (1995??)

support improvements in general". Most respondents/passengers are not experts and are not aware of the greater number of possible improvements that can be made and could have been included in the SP interview.

The way of presentation

The way of presenting attributes can affect not only the valuation of singular attributes but also the package effect. Schmidt¹⁸² and I have shown that, if we describe a package with dispersed attributes, it will be rated more highly than it is when it is presented as consolidated attributes.

- Seatbacks can recline
- Less vibration than in this train
- There is air conditioning

Example of dispersed attributes.

- Reclining seat backs, less vibration than in this train and air conditioning

Example of consolidated attributes:

Over-associations and suggestions

One reason or part of the package effect may be the following. When respondents are presented with an alternative in which a soft attribute is included, this attribute may be seen as an indicator of an even better measure. For example, chairs with adjustable seatbacks in the train may be interpreted as a comfortable seat in general. Adjustable seatbacks may also be interpreted as an *indicator* of a latent attribute "good comfort". The association

¹⁸² Schmidt, L., *Värdeminskning vid värdering av Tågkoncept – Studie av komfort, service och tidtabellspaket med Stated Preferences-metoden (Value reduction when evaluating train concepts – A study on comfort, service and timetable factors using the stated preference method)*, KTH Traffic Planning, TRITA-IP AR 96-44, 1996

may even cover a comfortable train in more respects than the opportunity to adjust the angle of the seatbacks.

As other terms are lacking, this effect will be called "*over-association*". Jones describes a similar effect (or the same effect) which he calls 'Halo effect': Improving one attribute can appear to increase the value ascribed to others.

A few attributes are brought out

This view is supported by the ideas of Tourangeau (1987)¹⁸³ (referred to in Wärneryd, 1990¹⁸⁴). Tourangeau feels that attitude answers may be better understood if one takes the underlying cognitive structures into consideration. He uses the term *script* for an organisation of knowledge, conceptions and feelings that are closely related. When an attitude question is answered, these scripts are activated. Various scripts can be activated by various formulations of questions relating to the same item. Some questions may activate certain scripts more effectively than others. As I understand it, questions about various attributes (for example, various comfort attributes in trains) may activate the same script or scripts. Wärneryd feels that the discussed problem is reduced for subject fields in which the respondents are better informed and to which they are more committed.

Preferences of any complexity or novelty are often constructed – not merely revealed – in the generation of responses to judgement tasks. This may be true, especially when people have less prior knowledge. One relevant question for the valuation of train attributes is the degree to which people in general are informed about and committed to various versions of passenger trains. (Probably the great knowledge of and commitment to various versions of private automobiles, especially among Western-European men, does not have an equivalent when it comes to trains.) Wärneryd refers to a number of studies which show that respondents' answers become unstable when people know less. One solution is to argue the respondents into answering "don't know". (This is in contrast to what SP experimenters often want – getting respondents to take all the attributes into account, not being lexicographic, for example – because they think it is the right thing to do.)

Other related explanations

The "interaction" effects as such are not yet mentioned. Jones explains these like: the combined value of certain attributes is less than their individual values because in part they are meeting the same need. In part I have touched on this explanation when describing the result of time constraints and it is also related to over-associations. For example lower levels of the attributes "noise" and "vibrations" may meet the same need but they may also be associated with each other.

On the other hand, when two attributes fulfil different needs the package effect can be smaller. What I mean is, when attributes have different dimensions or inherent qualities their values could be summed. My example regards timetable improvements in combina-

¹⁸³ Tourangeau, R Attitude measurement: A cognitive perspective in Hippler et al. Social information processing and survey methodology, Springer Verlag, NY 1987

¹⁸⁴ Wärneryd, Bo, att fråga, SCB Förlag ISBN 91-618-0382-0, 1990

tion with improved coach types. Both studies reported above (Rosenlind¹⁸⁵ and Kottenhoff¹⁸⁶) showed no package effect for attributes fulfilling different needs. If this conclusion would be the case even for secondary attributes in combination has not been tested.

Jones mentions that a consumer surplus effect can add a value to whatever attribute: Most respondents would pay some additional amount for the existing public transport service, without any enhancements. Each attribute value is inflated, as is the overall package value, as it includes both the "real" value of the improvement and the consumer surplus.

Jones also mentions a few reasons that he sorts under "artefacts of the SP designs". I very much agree on the existence of SP artefacts, and much of chapter 6 is elaborating on psychological issues related various artefacts. Below three "artefacts" are put forward.

The influence of decision-making rules

The use of judgement or decision-making rules other than maximising utility may cause a package effect. For example, the MNA rule, maximising the number of attributes with greater value, could cause this. Think of a number of relatively unimportant attributes. Let us say that they are all worth about SEK 1, if the evaluation is to be made using an ideal method. Assume also that we use a cost attribute with a price difference of SEK 2.

If people use MINA, they simply count the number of attributes. This means that each attribute has the same value as the price, namely SEK 2. If a number of other attributes were only presented as a package (e.g. comfort package or service package) this package could be counted as one attribute and this would lead to an underestimation in comparison with individual attribute presentation.

Discrimination instead of valuation

One logical explanation is that respondents are good at *discriminating* the levels of an attribute from one another, which does not in itself ensure that the respondents value the levels very differently. This is pointed out in a report on comfort in cars by Alm (1989)¹⁸⁷. This hypothesis will be applied to SP choices in two examples.

- Example I Level 1. There are no reading lamps.
 Level 2. There are adjustable reading lamps at each seat.
- Example II Level 1 All the seats in the train are positioned face-to-face.
 Level 2 All the seats in the train are positioned front-to-back.

In Example I, the "discrimination effect" is more likely to occur for some attributes for the following reasons. Few people think that the existence of reading lamps is negative. Instead, they may value them as positive for the people who want to read. So the only

¹⁸⁵ Rosenlind, S.; *Tågresenärers värderingar av trafikering, vagntyper och service*, (Passengers' valuations of traffic services, coach types and on-board service, in Swedish), KTH Traffic Planning, Master thesis/ examensarbete 94-1, 1994

¹⁸⁶ Kottenhoff, K., *Evaluation of passenger car interiors, German InterRegio cars, Norwegian ICE and regional X10-trains*, KTH Traffic & Transport Planning, TRITA 93-10-93 (no.86), 1993

¹⁸⁷ Alm, Irma, *Transportabel komfort – komfortabel transport* (in Swedish), VTI report no 347, 1989, ISSN 0347-6030

valuations that could result for level 2 are neutral or positive in relation to level 1. Most of the respondents are likely to be able to discriminate this.

In Example II, level 1 is preferred by some respondents and level 2 by other respondents. For each group, it is possible in the same way to discriminate which of the levels is better. However, people may be aware that other people may have opposites. This makes it less probable that people use discrimination, or make the assumption that other people may benefit from the attribute.

From the experimenter's angle, the results from Example I can only be expected to be quantitative. How highly are reading lamps valued (or considered – discriminated)? In Example II, the experimenter may not know qualitatively which of the two levels respondents choose. (The odds or relationship between levels 1 and 2 in Example II only give the value difference between the two levels, not the value of each level.)

Within or between mode SP/RP exercises

Attribute levels are often lower in between mode than within mode SP exercises. The values are even lower in RP studies than in corresponding SP studies. Both these circumstances were used by Wardman¹⁸⁸ in his interesting study, where he achieved very low values of individual attributes regarding rolling stock improvements.

How to proceed?

There are a few measures that I assume will reduce the package effects. These measures have probably different degree of theoretical underpinning, practicality and effect on the results. Things to try are:

- Conjoint (SP) designs that allow the estimation of interactions.
- Interviews with SP experiments in more levels; individual attributes and package levels. (This is done in the studies presented in sections 7.8 and 7.15.)
- A more careful description of the attributes and their levels and an appropriate way of presentation. One thing by this is to reduce the focusing effect.
- A combination of different SP valuation methods in the same study. The results can then be compared.

As a simplified solution one could also use is to rescale the estimated attribute weights by multiplying with a factor less than 1. In such cases on-board comfort attributes could be multiplied by a factor of, say 0,4 - 0,8. This solution may be a practical for consultant works but is not used in this thesis.

¹⁸⁸ Wardman, M., Whelan, G., *Rolling stock quality improvements and user willingness to pay*, ITS working paper 523, Leeds, March 1998

6.5 The dependence of valuations on travelling time and travel cost

In this thesis valuations are mostly presented as per cent of the fare or ticket price. It can be questioned if this is reasonable. In this section a few reasons are presented as well as the results of estimations I have made to test the valuations' dependence on cost and time.

Another reason for testing the dependence, then to justify, is that it may be practical to know how the value of specific attributes vary with time and cost of the journeys.

One of my hypothesis is that the willingness to pay for improvements increases with the price level. This can be justified in two ways:

1. The people who buy expensive journeys are the ones that have already made a choice between a high price and the type of journey bought. Those people who had the lower willingness to pay are not included among those with a high price level.
2. The customer makes relative comparisons.

6.5.1 About people making relative comparisons

When comparing two alternatives with different prices, the reference price level is important. People are probably more indifferent to the difference in price between SEK 1,000 and 1,010 than they are between SEK 20 and 30.

It is also probable that various persons *differ* more about the importance of an SEK 10 price difference around the level of SEK 1,000 than around the level of SEK 20. The variance of the valuation is probably larger at higher monetary amounts.

The models used often presume that the value of one marginal SEK is the same, irrespective of the level.

Frisch (1993) quotes a "% versus absolute" problem from Kahneman and Tversky (1994)¹⁸⁹.

A. Imagine that you go to purchase a jacket for \$125. The jacket salesman says that the jacket you wish to buy is on sale for \$120 at the other branch of the store which is 10 minutes away. Would you drive to the other store?

B. Imagine that you go to purchase a calculator for \$15. The calculator salesman says that the calculator you wish to buy is on sale for \$10 at the other branch of the store which is 10 minutes away. Would you drive to the other store?

Many respondents demonstrated framing effects to these types of problem and, when they were asked whether the problems should be treated differently, most of them agreed that they should.

The S-shaped value function for gains and losses (figure below) has been found in psychological experiments¹⁹⁰ about decisions made in conditions of uncertainty and risk.

¹⁸⁹ Kahneman, D, Tversky, A, Choices, values and frames, *American Psychologist* 39 (1984), pp 341-350

¹⁹⁰ Kahneman, D, Tversky, A, Prospect theory, *Econometrica* 47, 263-291 (277), 1979

In *prospect theory*, outcomes are expressed as positive or negative deviations (gains or losses) from a neutral reference outcome, which is assigned a value of zero.

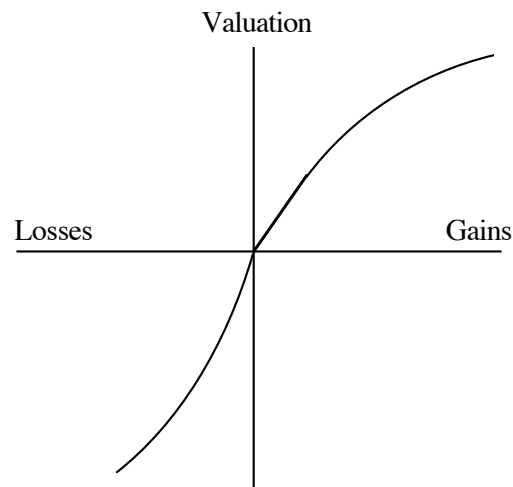


Figure 6.27 A hypothetical value function from "prospect theory", Tversky and Kahneman (1981)¹⁹¹

The curve is steeper for losses than for gains and concave above the reference point and convex below it. That means that if we, for example, think of the value of money, the subjective value of a loss of SEK 10 is higher than a gain of SEK 10 (when we start at the reference point) because of the gradient. The difference in subjective value between gains of SEK 100 and 200 is higher than the difference in value between gains of SEK 1,100 kr and 1,200. The same is true of losses.

I mean it is reasonable to assume that a customer is prepared to pay more for goods of which he/she receives more. If the travelling time is longer, the willingness to pay more for positive attributes increases. Likewise, when the travelling time increases, the travel cost (most often) also increases.

According to the above, the appreciation of certain factors, especially comfort attributes on board, should increase with the length of time travelled, which consequently corresponds to the price through the distance fare.

¹⁹¹ Tversky, A, Kahneman, D, The framing of decisions and the psychology of choice, *Science* vol 211 Jan 1981

Relationships

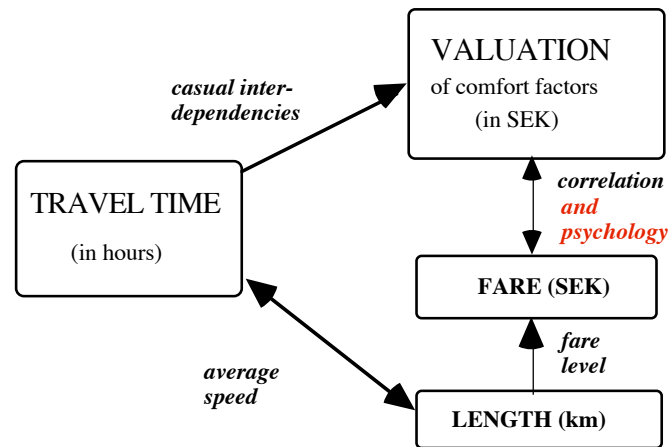


Figure 6.28 There are relations between travel time, travel length and fare and the valuation of travel attributes.

Heteroscedasticity in taste variation

If taste variation is accepted, the utility of a specific attribute differs from individual to individual. The distribution of utilities for some attributes may be more or less normal. Is it then likely that the variation, the standard error, is of the same magnitude for attributes with different mean utilities? This situation is illustrated in the next figure.

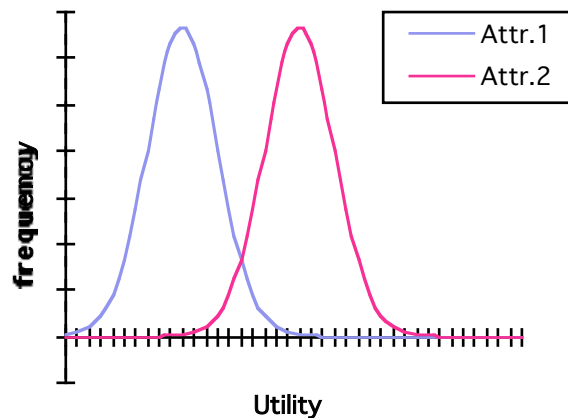


Figure 6.29 Illustration of two equally distributed attribute utilities

It is more likely that the standard error is proportional to the mean value itself, as shown by the next figure.

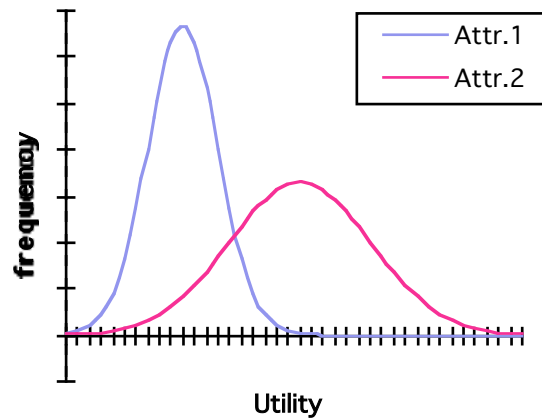


Figure 6.30 The distributions of two attributes: where the size of the "errors", the variance, increases with the utility.

Accepting this idea for the price attribute would mean that the variance of the utility for the price attribute will increase with increased price level. That would also mean that the assumption of identically distributed error terms would likely be easier fulfilled for relative than for absolute price parameters.

6.5.2 About SP methodology and valuation dependencies

Many of the observed time and price dependencies are related to the way studies are designed and valuations are estimated.

How to vary the presented price attribute in SP experiments?

When evaluations are obtained using the SP method, the price is varied either in absolute terms or as a percentage of the price. These variations may then be presented by IP as an absolute or a percentage variation. So, there are two possibilities to present the prices:

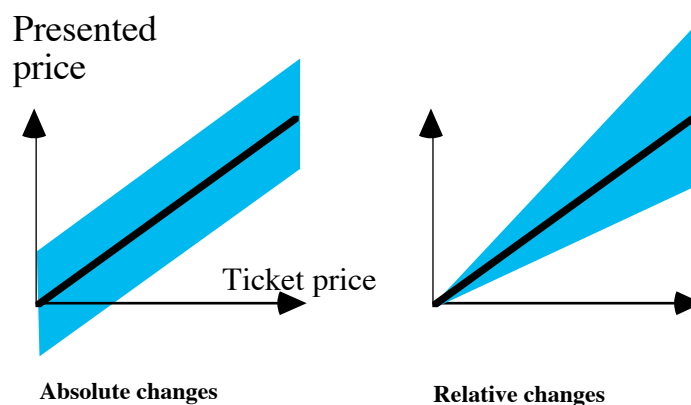


Figure 6.31 Absolute and relative price variations/changes

A third option that I have used is to vary the price with one absolute and one relative part. This leads to the absolute part dominating at low ticket prices and the relative part dominating at higher price levels.

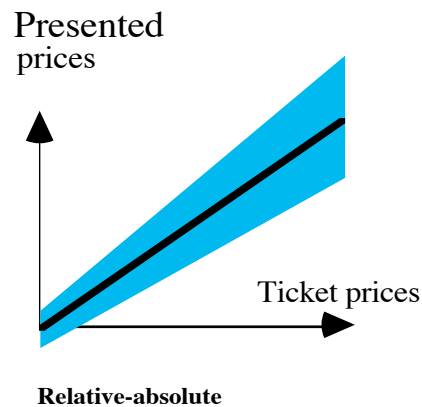


Figure 6.32 Combined relative and absolute price variation

Here is an example of four types of ticket and three ways of presenting the price variations. We can imagine a reduced price level:

Type of ticket	Reference ticket price	Absolute price variation	Relative price variation	Relative plus absolute
Price variation	-	-SEK 25 kr	- 10 %	-5 % - SEK 10
Regional ticket	SEK 25	SEK 0	SEK 22.50	SEK 14
Long dist. ticket	SEK 250	SEK 225	SEK 225	SEK 228
Monthly season	SEK 1,000	SEK 975	SEK 900	SEK 940
Yearly season	SEK 25,000	SEK 24,475	SEK 22,500	SEK 23,740

Table 6.11 The values presented for IP for different ways of constructing price variations

From the above table, it is obvious that *absolute variations* provide variations that are too large for the people who travel a short distance on a regional ticket. On the other hand, the variations are much too small for the people travelling on a yearly or monthly season.

Relative variations are good for levelling out the discrepancies between the people who travel by train on a monthly season or a yearly season and those that pay cash for the ticket. Since the season-ticket holders have bought a season, this results in a (somewhat) lower price than a ticket for cash. As a result, the price variations are also (somewhat) lower for them – not higher as it appears in the table.

The last alternative in which relative and absolute variations are *combined* is based on the idea that relative price variations produce too small a change at low price levels. This is especially relevant for the attributes that are thought to be evaluated as "SEK per journey". At higher price levels, the combination mainly works as a relative price fluctuation. One advantage is that the size of the percentage variation can be adjusted to those with high prices. In the above example, 5% was, for example, set in lieu of 10% as in only relative variation.

Empirical results

In KTH's SP interviews with train passengers using portable computers, the respondents enter their own ticket price for the actual journey. This is used in the pairwise choice interview as the reference level. The price presented on the screen is then lowered or raised (often by about 10%) to create various levels for the cost attribute. The various price levels may be presented:

"Ticket price is RAISED to SEK 450" (1)

"Ticket price as today SEK 400" (2)

"Ticket price is LOWERED to SEK 350" (3)

when the respondent entered SEK 400 as his actual ticket cost. The respondent will probably see this as differences in losses, as in the prospect theory. This would mean that an SEK 50 price difference would be given a lower value at high price levels than at lower ticket price levels.

The different ways of varying the price attribute in the SP experiments may be combined with different ways of evaluating the models. There are at least five different ways to combine the variation and estimation principle:

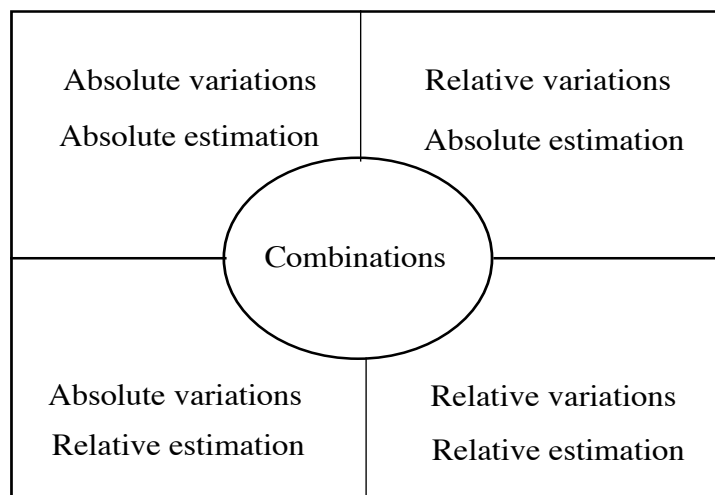


Figure 6.33 Five different ways of varying the price attribute in stated preference experiments.

The assumptions mentioned so far can be tested. This has been done by checking a previous KTH study and by making own complementary assessments of a few studies.

Lindh and Widlert presented the following results from an SP study of trains (1988/89).

Table 6.12 Estimation result for the ticket price parameter in absolute and relative estimations (Lindh & Widlert)

	Short	Medium	Long journey
<u>Absolute estimation</u>			
ticket price (SEK)	-0.0590 (t=14.9)	-0.0219 (t=9.6)	-0,0184 (t=8,0)
<u>Relative estimation</u>			
relative price (%)	-0.0779 (t=17.5)	-0.0759 (t=11.9)	-0.0822 (t=10.8)

According to Lindh and Widlert's explanation, the above table shows that the interviewees perceived the price as relative rather than absolute. This is apparent both from the fact that the relative estimates are constant for various lengths of journey (when the ticket price should have had different levels) and from the fact that the t-values are higher in the relative estimation.

My comment on the Lindh/Widlert results is that the price changes were created relatively in the interview design and that this probably supports relative decision-making and facilitates relative estimation.

Own assessments

Two studies have been analysed so far.

- Space comfort study east coast line 1992 (reported in section 7.1).
- Space comfort study on suburban Roslagsbanan 1992 (reported in section 7.2).
- InterRegio study 1993 (reported in section 7.3).

The following table shows the parameter weights and calculated values in per cent of the respective fares for the interregional and a suburban comfort studies. The absolute fare levels were very different in SJ interregional trains and in Stockholm's suburban trains. (The SJ fare was about 0:50 - 1:00 SEK/km, corresponding to normal fare levels at SEK 100-400, while the suburban fare was based on a zone fare for single journeys and monthly cards. 2/3 of the travellers used monthly cards and less than 20% used single fare payment. The rest had school tickets/cards. For passengers travelling 30 km in each direction 20 days a month with the suburban train the fare should have been about 7:50 SEK/journey or 0:25 SEK/km.)

Table 6.13 Comparison of estimates from Interregional and regional passenger studies.

Attribute description (for attributes included in both studies)	Interregional Parameter	Value (%)	Suburban Parameter	Value (%)
Price (% of respondents' ticket price)	-0,0564	–	-0,0906	–
10 cm less legroom	0,0405	- 7%	-0,0556	- 6%
10 cm more legroom	0,0260	+5%	0,0387	+4%
Face-to-face, occupied	-0,253	- 4%	-0,29	- 3%
Face-to-face, free opposite	0,089	+2%	0,34	+4%

These empirical results support the notion that people make relative valuations. An hypothetical comparison of a one hour journey in the two situations/trains reveals great differences in absolute valuation: The fare in the interregional train is assumed to be SEK 75 and in the suburban train SEK 7:50. This indicates about *ten times higher* absolute valuation levels ($\approx$ willingness-to-pay) in the interregional train with high fares.

One can guess that attributes that express needs which are dependent on the travelling time, e.g. resting, listening to the radio, or reading, should be possible to express in SEK/hour. The valuation of other attributes ought not to vary with the time travelled. This relates to attributes associated with embarking or disembarking. This may include other station attributes. In this case, the appreciation as SEK per journey can be discussed.

As argued for in the preceding text there are reasons for assuming that the valuations also depend on the fare level.

There are several ways of testing these assumptions by estimating the time and cost dependence from the choice response data:

1. Different levels of aggregation: segmented into different time and/or price intervals.
2. Create and estimate separate parameters for the constant and the time and price-dependent parts of the estimations.

One of the SP experiments in the InterRegio study has been estimated using four different methods. They differ as the price attribute has been evaluated relatively or absolutely, new time and price dependent parameters, for a number of included attributes, have been created and limits in terms of travel cost per hour have been introduced.

Table 6.14 Conditions and resulting t- and r^2 -values for three models and a reference model.

Method/ model	Price parameter	New parameters	Cost limit	t-value for price	r^2 -value
Reference model (201)	Relative (%)	No	No	16.9	0.140
IRR252	Relative (%)	Yes	No	17.1	0.159
IRR251	Absolute (SEK)	Yes	No	4.7	0.092
IRR253	Absolute (SEK)	Yes	Yes SEK 200/h	16.9	0.148

From table 6.14, it can be seen that:

- The introduction of new time- and price-dependent attributes somewhat increased the r^2 -value, as well as the t-value for the price attribute. The 252 model is better than the usual 201.
- Switching from relative estimations of the price to absolute ones (model 252) works very poorly with these interview data. The t-value drops dramatically, as does the r^2 -value. One explanation is that travellers with a monthly season ticket and an annual season ticket (SEK 25,000) have an extremely disparate taxation level, which does not fit in with an absolute estimation of the price attribute.

– Absolute estimations of the price attribute work better when a price level cost limit at SEK 200/travel hour is introduced; model 253. The t-value of the price attribute again becomes high, but the degree of explanation for the whole model is still somewhat lower than the best (252).

I presume that the t-values for the parameters mirror the degrees of explanation for the respective attributes. A high t-value shows that the parameter is statistically separate from zero. At logit estimations made, the spread of the standard deviations are not that large – the deviations are relatively similar. It may thus be possible to re-evaluate a high t-value as high parameter value (or low parameter value and an even lower standard deviation).

One consequence of splitting a previous factor into several new ones is that the t-values of each of the factors probably diminish. If one strictly demands t-values above 2.0, new split factors easily end up below this level. It may therefore be more reasonable to look at the sum of the t-values that belong together with a certain attribute of origin (e.g. type of seat).

The t-values for three types of parameter are shown below:

1. Attribute per journey; "value; SEK/journey"
2. Attribute * time; value SEK/travelling time
3. Attribute * ticket price; value SEK/ticket-SEK (%)

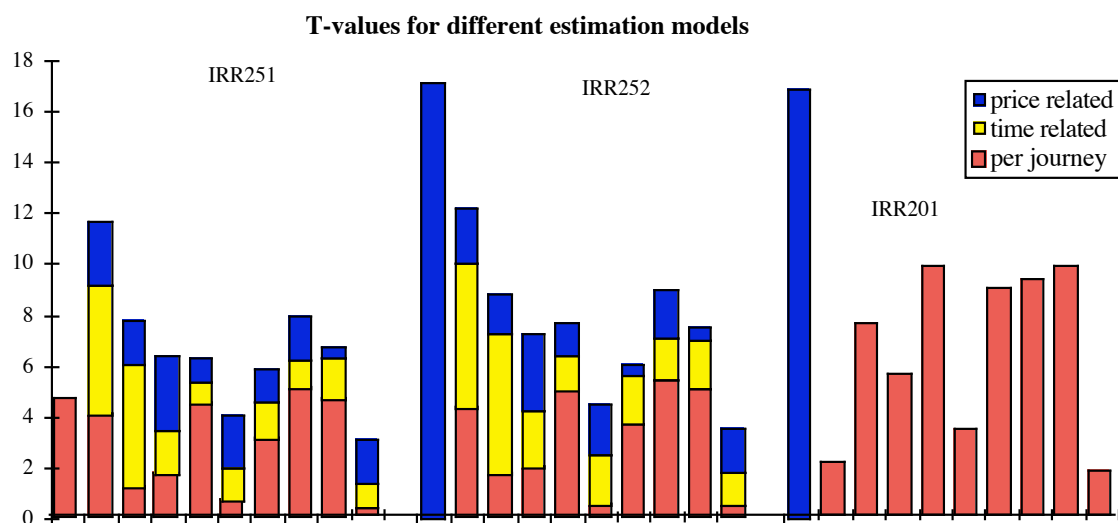


Figure 6.34 T-values for three different estimation models for the same SP interview data. The staples represent the size of the T-values for various attributes and levels, in the same order for all three models. The first staple in all three models is the T-value for the price attribute parameter.

One way to express the results is to use a linear function:

$$\text{Value (SEK)} = k_{\text{trip}} + k_{\text{time}} * \text{time(hrs)} + k_{\text{price}} * \text{ticket price(price*100SEK)}$$

where k is the parameter for the attribute divided by the price parameter: $k = p / p_{\text{price}}$

By in the usual way dividing the different parameters by the parameter for price one gets values in SEK, SEK/hour and SEK/100SEK. These values are shown in the columns two to four in the diagram below. In column five, the last one, an example is given of

accumulated values of different factors for a three-hour train journey, which costs SEK 200.

Table 6.15 that shows valuations for attributes depending on journey, travelling time and ticket price level. The fifth column shows an example for a journey with 3 hours travelling time and a ticket price of SEK 200.

Attribute	k_{journey} (SEK)	k_{time} (SEK/hour)	k_{price} (SEK/100SEK)	$k_r + k_{\text{time}} * 3 \text{ hrs} +$ $k_{\text{price}} * 2 (\text{SEK} 100)$
Mandatory seat reservation	-26	+4	+12	$-26+12+24=$ SEK 10
Seat reservation possible	-16	+6	+12	$-16+18+24=$ SEK 26
This interior (New IR coach)	+2	+2	+5	$2+6+10=$ SEK 18
This interior and recliner chairs	+17	0	+4	$17+0+8=$ SEK 25
Smoke-free with smoke-corner	+3	+2	+1	$3+6+2=$ SEK 11
Read/talk-departments	+7	+2	+4	$7+6+8=$ SEK 21
Individual fresh air-vents	+22	+3	+1	$22+9+2=$ SEK 33
Air Conditioning	+19	+4	+3	$19+8+6=$ SEK 33
10cm legroom	+7	+0	+3	$7+0+6=$ SEK 13

The dependence for the value of 1dm of legroom is illustrated in the diagram below.

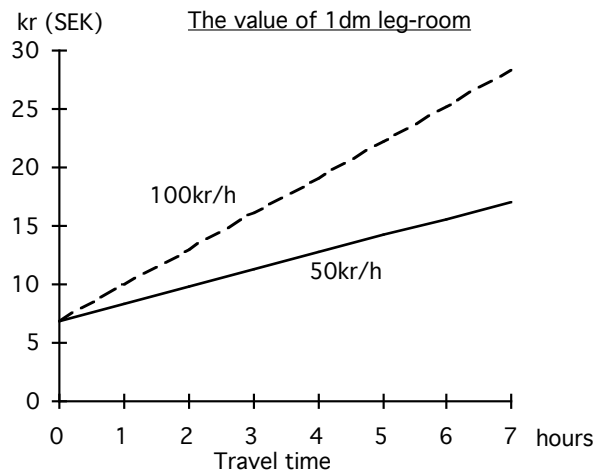


Figure A visual presentation of the dependence of valuations on travel time and travel cost levels.

The value of more space for the legs is always positive and it increases with the travelling time. The above figure may be interpreted as follows: the value "is greater" for those people who travel long distances. Another interpretation, and one that I prefer, is that the value, relatively speaking, is higher for the people who travel a short distance. In the cases in which the straight lines cross the y-axis for a positive value, the value is the greatest, from a relative point of view, for the short-distance travellers. If the line crosses the y-axis at zero, the relative willingness to pay is independent of travelling time.

Below, in figure 6.35, are shown valuations in SEK, dependent on travelling time in hours and fare-level, for many attributes.

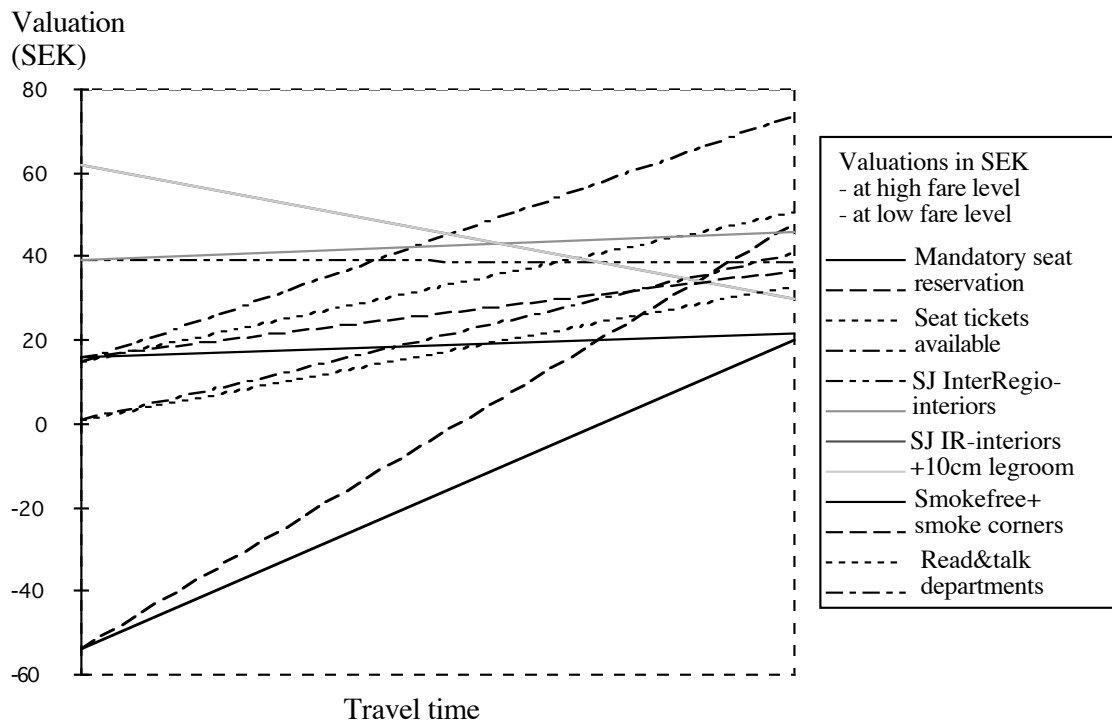


Figure 6.35 Graph showing how the value of various factors in a study varies with travelling time and fare-level. Many, but not all, factors have a higher value for those passengers that have a longer travelling time.

For the 3h/SEK200-journey exemplified in the table about 70-80% of the summarised attribute-values stem from the time and price terms. This indicates that time and price dependence plays a big role.

Shortcomings by presenting valuations as per cent of the fare

There are potentially a few shortcomings or problems by presenting valuations simply as per cent of the passenger's ticket prices. Three of these are:

1. It presupposes that the values for all attributes are correlated with the price level.
2. There are shortcomings when the services are subsidised.
3. There may be problems to recalculate the values when the fare level and/or fare structure differ or is changed.

The first problem may be overcome by avoiding to present attributes which are inappropriate to relative valuation. To select these attributes we must test the price dependence, by for example the presented method, or we can motivate our selections by casual arguments. None of these methods will give the final precision, for one thing because the valuation generating methodology, the SP interview and estimation models, itself influences the noticed relationship, as implied in the foregoing text.

The second problem, with subsidised train services, can be problematic. The easiest way to get around this problem is to divide the relative valuation figures by the cost covering rate. On the other this may lead to a bothersome conclusion; that subsidised services must be run with the cheapest standard level. If there are good arguments for subsidising rail services do these include justification for comfort, on-board service and quality levels? If yes, the relative valuations should be possible to use for at least ranking of the benefit of different measures.

The third problem shows up for example when two public transport regions have different fares. Imagine we want to use the relative valuations obtained in one region, with low fare level, in another region that has a much higher fare level. Is the resulting value of the measures much higher in the second region? Or should we recalculate the values into absolute values before transferring them?

When the valuation figures are to be used for socio economic assessments, the values must be recalculated into absolute values in monetary terms (e.g. SEK). This may cause different values for the same measures for train services or companies with differing fare levels.

Summary of the findings about price- and time dependence

The findings can be summarised like:

- Price variations and estimations ought to be made in the same way in order to obtain good clarity.
- Constructing the SP game price variations with a relative and an absolute part provides intuitively correct alternatives to consider for IP.
- One workable way of assessing time and price dependence has apparently been reached: Each standard factor is split into three; one "normal" (per journey), one time-dependent (per hour) and one price-dependent (per SEK 100 ticket price) part.
- A great part of the valuation of many attributes seem to be time and/or cost dependent but more theoretical considerations and empirical research is welcome.

In short, there are good reasons for relating valuations to the price but there are also shortcomings. The shortcomings regards problems with insufficient confirmations and doubtful values when services are subsidised or unreliable values when fare levels are changed. A few pro-reasons are of theoretical nature and other reasons are of practical nature: It is easy to evaluate and represent the passengers' valuations in per cent of the price. They can be used easily for the type of cost/benefit comparisons proposed in this thesis.

6.5.3 Dependencies related mainly to travelling time

Three other aspects will be mentioned. It regards the valuations dependence on travel experience, the travelling time concept and if the value-of-time is affected by the number of events.

Valuations' dependence on frequency of train travel

The travel experience can be assumed to modify the travellers' valuations. In section 8.4.1 it is shown that commuters often has high valuations, especially for many comfort attributes.

As usual the valuations in thought are a result of both the weight for the attributes and the price weight. The parameters for the various attributes are divided by the parameter for price. Hence, low price-parameters lead to high monetary valuations of other factors. The estimation-result in the diagram below comes from the InterRegio Study (section 7.3).

Why would the time-values be higher for those that travel farther, a longer distance or for a longer time? One explanation may be that long journeys are made more seldom than shorter ones. Since they are made more seldom, the person's yearly budget is not affected as much by one unit of something (here time). For this reason I have tried to estimate different price-parameters for groups that go with different frequency by train.

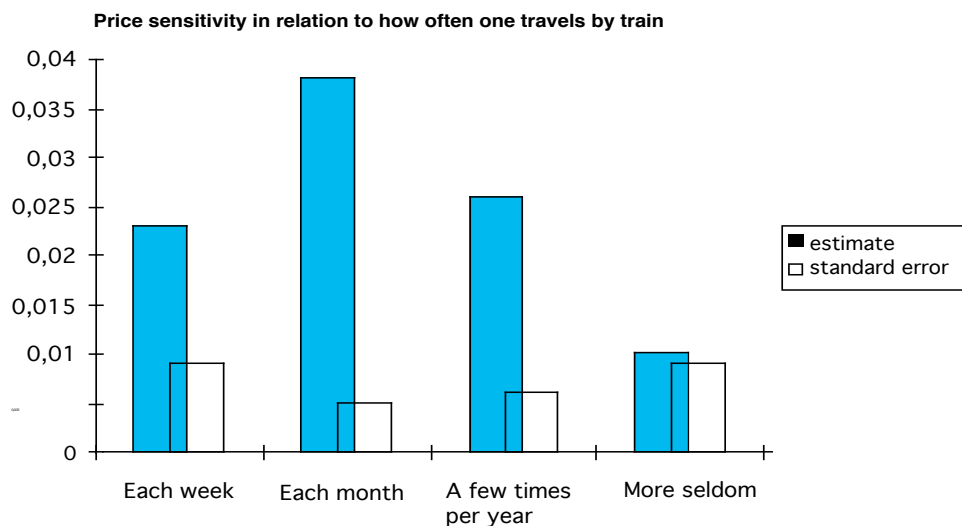


Figure 6.36 Valuations in relation to how often one travels by train. (See text)

The figure may also be used as an indication of the non-train-travellers' valuation of train, for those that go by train more seldom than a couple of times a year, are almost non-users. When other attribute weights/ parameters are divided by the price parameters shown in the diagram, the result is that seldom travellers have higher monetary valuations.

To sum up: Commuters, that is people who travel very often by train, show medium weight for the price attribute. At the same there is some indication that people who travel seldom by train reveal lower price parameters and thereby show higher willingness to pay.

How does one consider the travelling time in the train?

Time spent in train is not as negatively weighted as time in car, bus and plane, according to some models. Time on the go onboard regular trains is experienced only half as negative, according to the Transport Council's prognostic model from 1990³, as time on the go in other means of transport. Here an hour on a regular train was evaluated to SEK 40-80/h,

while the time on a railbus coincided with the valuation of time in car and bus, which was SEK 90-190/h. The difference may stem from better comfort, service etc. on the train. In order to be clear I shall bring up two plausible interpretations:

1. Comfort is a factor that co-varies with travelling time. Hence a negative experience can be added to (negative “essential valuation” of) travelling time. In this case the basic level for travelling time is lower. One interpretation is that it represents the travelling time-valuation for train. A higher valuation comes from increased discomfort.
2. Good comfort (and service) turns some of the travelling time into useful time. The useful part of the travelling time is in this case subtracted from a negative “essential valuation” of the travelling time.

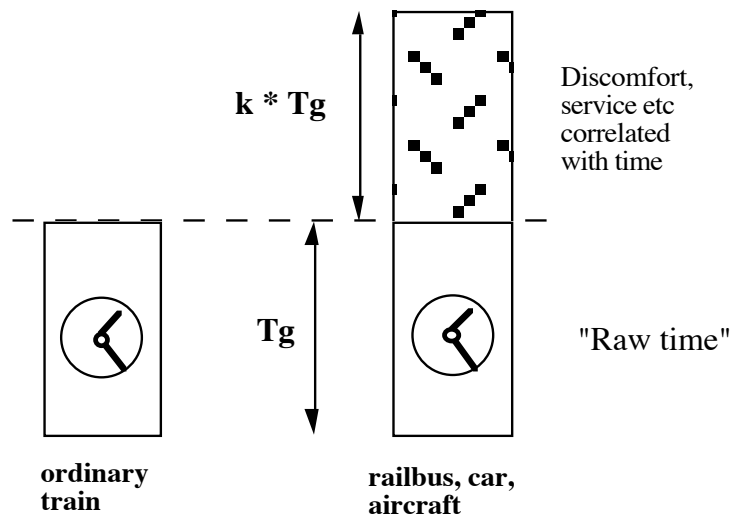


Figure 6.37 Interpretation 1 of time-valuation: Lacking comfort and service may be experienced negatively in the means of transportation that have these shortcomings and is therefore added to a valuation of “raw-time”. One may take the position that this negative experience correlates with the raw-time or the basic travelling time valuation.

For the second interpretation the expression “killing time” seems favourable. Within the travels field the term “time killers” is sometimes used for various activities one may offer. These make the time useful, healthy or fun.

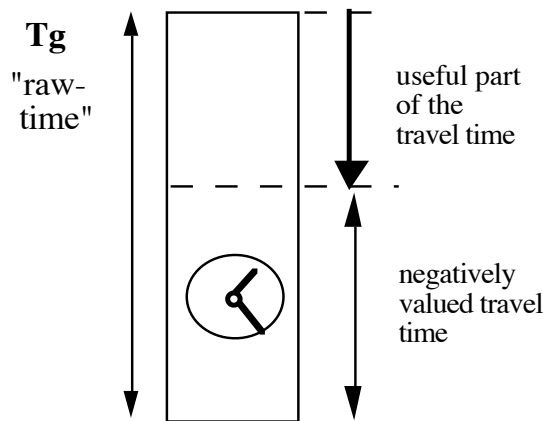


Figure 6.38 Interpretation 2 of time-valuation: Good comfort (and service) turns part of the travelling time into useful time, or make it valued as such.

If the first interpretation would be correct, the part that exceeds the “raw-time” would consist of e.g. discomfort in (the other) means of transportation. It is likely that comfort is valued in accordance with travelling time. It is confirmed by e.g. the comfort in vibrations, that it is time dependent. (ISO2631, see section 4.4). “Discomfort” in cars, buses and aeroplanes is in such a case (negatively) worth ca SEK 100/hour, heavily rounded. It is more than the pure travelling time sacrifice for private travellers, but less than the travelling time sacrifice for business travellers on a journey. Is this reasonable?

From this interpretation you may draw the conclusion that it matters not much having a short travelling time on the train, because the valuation of time on the train is so low. If the second interpretation is correct – that useful travelling time may be subtracted – one should offer trains with good service and many optional activities. This interpretation is used by Hensher¹⁹² in the formula for the business journeys' time valuation.

The time may be experienced differently dependent upon the number of events

An assumption based on experience is that the view of the travelling time is related to how many times the train stops on its way. Generally, a bit more, I think that the time-view, or value-of-time, is dependent upon, among others, the number of events per time unit.

What happens when the train stops at a station is e.g.: forces of retardation and acceleration, sometimes extra noise and sometimes new people coming into one's preserve. If this happens ten times during a journey in lieu of three, it may be experienced as a longer journey.. -"The journey was two hours and ten stations long." Because of this one can have different travelling time weights for direct trains, and such that stop more frequently. Results from the study in the spring of 1998 (section 7.15) show that the value of few stops may be in the same order as 10% travelling time (for passengers interviewed on-board an X2000 train).

The hypothesis should be further tested.

¹⁹² Hensher has developed a formula for the valuation of business journeys; the productivity onset, used by the Swedish transport authorities.

6.6 Other elicitation and evaluation methods

In this section some other elicitation and evaluation methods will be shortly mentioned. They are the Best/Worst, listings and factor analysis. The first two are seen as alternatives to standard Stated Preference methods in some cases. They are mentioned because I have used them in a few field studies and because I aim at penetrating them further in the future.

6.6.1 Best/worst conjoint

The best/worst method (B/W) is described by Louviere and Swait (1996)¹⁹³. It is a "new measurement and scaling model and associated conjoint task involving choice of the most and least attractive (important, etc.) attribute levels in profiles. That is, respondents choose the two attribute levels which are, respectively, "best" and "worst" on the response dimension. The method also permits estimation of separate attribute effects for each attribute independently of its partworths, an important advantage not possible with traditional additive conjoint and choice models. Because of the separability made possible by this new conjoint method, we also envision the use of this new model as an interpretative aid to standard (choice) conjoint techniques".

The best/worst choice task is attribute-based. This means that the respondents make their judgements by comparing attributes. As is the case for other attribute-based choice strategies, this may be simpler than making a trade-off judgement with a compensatory strategy like the weighted additive rule. One question about the B/W method is whether it can be used in accordance with the random utility theory (RUT)¹⁹⁴. A related question is whether the judgements respondents make in a B/W task could be used as though they had made an alternative-based choice, ranking or rating using compensatory rules.

In B/W, the respondent has to compare aspects or attributes with one another.

BEST	DESIGN LEVEL/ ALTERNATIVE	WORST
X	Attribute1, level 1,2 ... or j	
	Attribute 2, level 1, 2 ... or k	
	Attribute3, level 1,2 ... or l	X
	Attribute 4, level 1,2 ... or m	

Figure 6.39 Respondents have to select one best and one worst attribute for each design level. In this example, for design level A, aspect 1 is marked as the best and aspect 5 as the worst.

¹⁹³ Louviere, J, Swait, J, *Best/Worst Conjoint: A New Preference Elicitation Method to Simultaneously Identify Overall Attribute Importance and Attribute Level Partworths*, working paper revised Dec 1995 and Nov 1996

¹⁹⁴ Jordan Louviere at Stated Preference Course, Portland, June 1996

The attribute levels presented to respondents belong to a statistically determined design which can be the same as for other SP methods. That means that an orthogonal fractional design can be used.

A B/W choice situation is described in figure 6.40 to illustrate the method. The respondent is shown one design level, one alternative, at the time. This is exemplified by a train alternative with four attributes, in this case extra services which are supposed to be valued, telephone, air conditioning, radio and café, by this particular respondent on this journey. The respondent is supposed to reveal his high value for café by picking this attribute instead of any of the other attributes.

BEST	TRAIN ALTERNATIVE i	WORST
	There is no passengers' telephone	X
	There is air conditioning	
	There are no radio/music outlets	
X	There is a café in the train	

Figure 6.40 The respondent has marked that the existence of a telephone is the best and the non-existence of a café is the worst in this alternative.

It is not completely clear to me how the method should be formulated. For example, what should the respondents judge – what comparisons should they make? How should these judgements be evaluated in a statistical model?

Hogarth¹⁹⁵ mentions a compensatory decision model, "the ideal point model", which assumes that the decision-maker has an ideal representation of what the "perfect" alternative would be. An alternative is evaluated by its distance from the ideal point on different dimensions. The ideal point model is algebraically similar to the linear model if the distances from the ideal points are evaluated in a linear manner. This model may be a good starting assumption for considering a solution to the unanswered formulation problem in best/worst conjoint.

Another way of tackling the problem of best/worst formulation and evaluation is reformulating. The problem can be reformulated to produce a similar problem that can be interpreted by the researcher in a known context.

The question to put in the reformulated case is: *Given that you are going to travel by train for a similar purpose as now, which train would you choose if all the trains differed in only the mentioned respect (equivalent equipment, timetable and so on)?*

¹⁹⁵ Hogarth, R.M., *Judgement and choice*, Chichester, England: Wiley, 1987

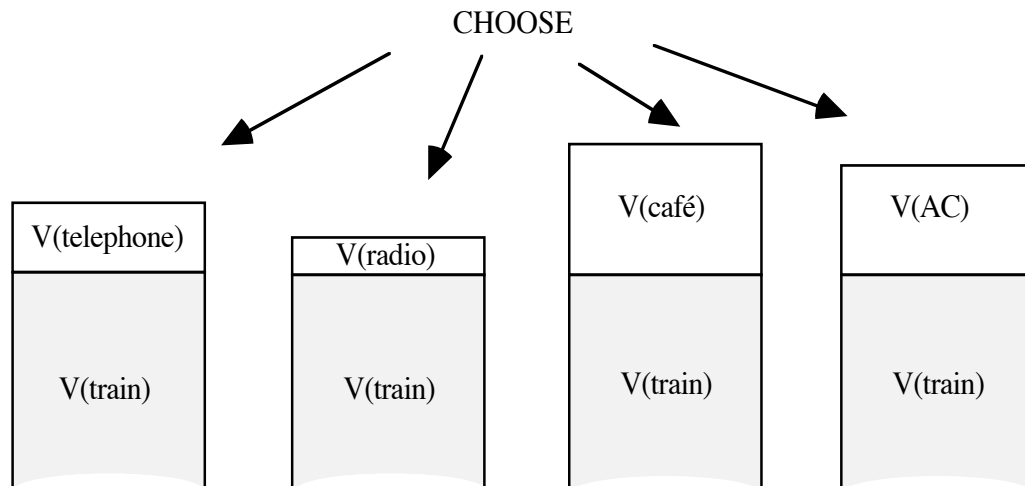


Figure 6.41 A reformation of the former choice problem. The respondent has to choose between alternatives (trains) that differ in only one way. V in figure means value.

When we estimate the taste weights (parameters) in the reformulated case, we estimate the differences between the above alternatives.

The best/worst method has been examined by use in the studies presented in sections 7.10, 7.11, 7.14 and 7.15. It should be further examined, analysed and explained in subsequent work.

6.6.2 Listings

Attitudinal studies often use importance and fulfilment ratings for attributes. This is described in many textbooks on marketing research¹⁹⁶. There are guidelines for appropriate response scales, which are often category ratings.

One aspect which appears to have been less dealt with is what to evaluate – what formats should the attribute descriptions have. This is in contrast to stated preference/conjoint studies in which unambiguous and well-defined attribute levels are compared. It should be possible to use the same unambiguous definition for attributes and their levels in more direct forms of attribute/level elicitation. The following is an example of attributes which are described on scaling level 3; interval described attributes – attribute shifts.

We can request the respondents to choose one attribute; the for him/her most important, i.e. highest valued, measure. If we assume that the respondents choose the alternative with the highest utility for them, we will obtain a frequency distribution for choosing among the various measures/ attribute level shifts.

¹⁹⁶ Zikmund, W.G., *Exploring Marketing Research*, Oklahoma State Univ., The Dryden Press, 1994

– Please indicate which of the following measures would be the most important for you for a journey like this one.

1. Your travelling time is reduced from 3.50 to 3.30 (hours and minutes).
2. Your ticket price is reduced from SEK 300 to SEK 250.
3. The legroom at your seat is increased from 10 cm to 25 cm.¹⁹⁷
4. The coffee trolley is replaced by a restaurant car, with hot and cold meals, wine & beer and coffee.
5. Frequency of 10 min delays is reduced from one in five to one in ten journeys.

We can also let the respondents rank all measures. This ranking can be transformed to a number of pairwise choices and thereby we can make use of Thurstone's methods.

Thurstone's methods

Thurstone¹⁹⁸ showed that pairwise choices from all the included attributes produce a preference scale that is approximately accurate. A requisite is that the valuation of each attribute is about normally distributed among respondents.

An excerpt from Thurstone's own summary of the method of paired comparisons (for social values) now follows:

"The stimuli whose magnitudes are to be measured are presented to the subject in paired comparisons. For each comparison he decides which of the two is stronger. It is assumed that each of the stimuli has an unknown mean magnitude for the group and that there is a standard error of observation for each stimuli (sic). Every judgement is assumed to be the result of four discriminable factors, namely, the two stimulus magnitudes and the two standard errors of observation. The proportion of judgements are (sic) expressed in equation (1) as a function of these four factors. The experimental data consist in (sic) the observed proportions of judgements, and from these data the best-fitting scale values of the stimuli as well as their respective observational standard errors are determined.

$$k - a = c_{ka} * \sqrt{s_k^2 + s_a^2} \quad (1)$$

"

The precision of the method has been simulated by me in Excel. I found that the resulting attribute parameters (utilities) are quite linearly related to the given input utilities, at least if the anticipated standard errors are within "medium size".

When using just the first choice, the frequencies for the respondents first choices, the precision and linearity is lower. Attributes with lower assigned utility are being underestimated relative the ones with higher assigned utilities. This may be adjusted by anticipating the distribution of the attribute shifts.

¹⁹⁷ The respondent's real legroom must be known, by the interviewer making measurements, for example.

¹⁹⁸ Thurstone, L.L., *The measurement of values*, University of Chicago Press, 1959 (spec. pp 67-81; reprinted from Journal of Abnormal and Social Psychology, XXI, 1927)

Various forms of listing methods have been tested in the studies presented in sections 7.14, 7.15, 7.16 and 7.17.

6.6.3 Factor analysis

Using factor analysis, it is possible to detect personal underlying "factors" or dimensions that control a person's preferences, for example. The factor analysis does not group people. Instead, one person can hold a number of these new underlying dimensions.

Factor analysis can be used to group a number of variables into fewer variables. It has been tested on attribute listing data. The resulting factors may reveal latent attributes or needs. For example, attributes have been grouped together under a factor which I interpret as being associated with reading. The attributes under this factor can be reading lamps, face-to-back seating, low noise levels and so on.

Factor analysis has been tested in the studies 7.14 and 7.15.

6.7 Summary and discussion of judgement and choice theory, SP practice and train evaluations

All scientific models are simplifications of reality which make the world and its processes easier to understand. In this light, statistical models, like the random utility theory and logit modelling, may be relevant and good for the purpose of this thesis. The concept of utility is the basis of idea that every attribute (or attribute level difference) can be given a value. My hope is that the valuations obtained from SP interviews will agree with travellers' true preferences – preferences in reality.

However practising stated preference methodology has made me interested in psychological findings about judgement and choice.

Psychological findings

Psychologists have studied the way people make judgements and decisions. They focus on what people actually do, not the outcomes of decisions. I have included some of their experiences, because some of the problems associated with the outcome of stated preference experiments are related to the way people make their choices.

Individuals have difficulty making choices precisely in accordance with utility maximisation. People often do not maximise the outcome of their decisions because this is too complicated, at least when the stakes are low. They are not totally "rational". Instead, they may approach rational decision-making using the concept of *bounded rationality*¹⁹⁹ which holds that, because of limited information-processing capacity, people's choices reflect strategies that are "reasonable", given their goals and inherent limitations. One such limitation is limited computational skill. Instead of optimising, people are thought to "satisfize"; they choose an alternative that is good enough in relation to their aspirations.

Another observed problem is that people may construct preferences while conducting an SP experiment. They show preferences they do not have or know of beforehand.

Framing – the way information is presented – and focusing – respondents focus their attention on the included attributes – can help to explain why outcomes that should be similar sometimes differ in different studies. In my opinion, framing and focusing may play a role in explaining package effects (Section 6.4).

Decision research on risky decisions should be considered when dealing with valuations of (train) delays. There is a great deal of knowledge that can be used, but in my studies delays have not been investigated in depth.

When attempting to understand how various SP methods work, the compatibility effect in judgement and choice can provide some guidance. Some SP methods require like pricing quantitative responses, while others like choice ask for qualitative responses. These methods involve different judgement processes.

One comment on the choice of elicitation procedure is that, when we are interested in the monetary, or social, valuations of attributes, a quantitative procedure might be most

¹⁹⁹ Hogarth, R M, Judgement and choice, pp 62-66 (from chapter 4: Combining information for evaluation and choice), John Wiley & Sons

adequate, but, when we want to predict the choices, between travel modes, for example, a choice-based procedure might work more effectively.

It is probable that the reference levels people bear in their minds, about trains, for example, affect their judgements. The way in which this takes place should be considered when interpreting the outcomes of studies. The reference level for judgement is of special interest when understanding the new best/worst method described in brief in section 6.6.1.

About modelling and SP practice

A paradigm that is often found is that a good model makes good predictions. Model errors are primarily due to unobserved variables²⁰⁰. My view is that a good model should have causality between the variables it includes and the predictions it makes. If, for example, a model which includes both travelling time and travel cost makes accurate predictions when validated, it may not explain the relative importance of time and cost, if these variables are correlated. We should be interested in the relative strength of many, in this case attractiveness, factors. This is especially the case when we tap the models for parameter figures and use them to describe the value of various measures.

Improved train design and on-board service have attracted many new customers to the new *X2000* and *Kustpilen* train services. In the case of the *Kustpilen*, the number of travellers has increased by about 200%. This cannot be explained by standard demand models including only price, time, frequency and the number of interchanges. Lindh²⁰¹ has calculated that in this case a standard model of this kind could only explain an increase of around 40%. The rest may be associated with the high comfort and quality levels of the new train sets.

Another explanation is more reason-based. Before the introduction of the *Kustpilen*, people did not have any good reason for changing behaviour – using the train instead of the car or bus, but, when the *Kustpilen* was introduced, it was easier to justify a change in behaviour. After having tested the train (*Kustpilen*), it was possible to justify the use of it for oneself and for others.

Stated preference studies in which respondents rate, rank or choose alternatives may be difficult, or at least time-consuming, to conduct, especially when the number of attributes is more than about four. So it would be pleasing to find alternative methods which can handle more attributes quickly and easily, resulting in utility weights of sufficient precision.

Many market research studies have used vague attribute descriptions, such as, "What is the most important factor for you when choosing the train, the *cost*, the *travel time* or the *comfort*?". By tradition, stated preference studies have carefully *specified the levels* of the included attributes. This makes the importance of the attributes easier to compare. The point is now; if the attributes were more precisely defined (also) in methods other than traditional SP experiments, might this not make some of these other methods more

²⁰⁰ Talvitie, A, Things planners believe in, and things they deny, *Transportation* 24: 1-31, 1997. This view is taken by Talvitie in his article and it a main messages from Jordan Louviere about stated preference modelling.

²⁰¹ Lindh, C, Kottenhoff, K., The value and effects of introducing high standard train and bus concepts in Blekinge, Sweden, *Transport Policy*, 1995 Volume 2 Number 4

trustworthy? Can one use methods that are easier and quicker than traditional SP, like ranking well-specified attribute level differences? I have tested similar methods in my latest SP studies (see, for example, sections 7.15, 7.16 and 7.17).

Discussion of alternative-based stated preference estimation

It is important to understand the role of unobserved variables in revealed and stated preference models. If we have an alternative which contains many unknown circumstances, we can say that the utility of that alternative is the sum of a large number of stochastic variables. The fixed part of this unknown utility is captured by constants in the model (or as bias in the observed attribute parameters). The unobserved attributes each have some kind of distribution, contributing to the error term of the alternatives. In certain circumstances, the sum is more or less normally distributed.

Are there then any good reasons for anticipating that the random part, the ε term, is more or less normally distributed? Yes, one reason is the central limit theorem which states that the sum of a large number of randomly distributed variables will be normally distributed²⁰².

All the unobserved effects (unobserved attributes, taste variation between them, socio-demographic factors, measurement errors and so on) can be seen as a number of stochastic variables. These unobserved stochastic variables may vary for different alternatives and the sum of them may be more or less normally distributed, even if the variables themselves are not normally distributed.

It is hard to understand these circumstances and simplifications of reality in the prerequisites of the logit model or believe that they are fulfilled.

The first doubt relates to the distribution of the observed and unobserved attributes in a choice model. A standard logit model will make the most accurate predictions when all the individuals have similar taste weights for the observed attributes, in relation to the size of the random component. Is it likely that we will have respondents with similar values for all the observed attributes in one model, but with different values for the unobserved attributes?

When evaluating train concepts, many comfort- and service-related attributes are included in the evaluations. It is likely that many people care very little or not at all about many of these attributes when they make choices, while others care a great deal. I have checked some best/worst interviews to see how frequently an attribute is taken into account. I have found that many attributes were never considered. A normal figure was that about 20-30% of the respondents did not find an attribute important enough to react to it. It was never judged as best or worst.

In one of my interviews, people were asked to distribute SEK 100 in three experiments; firstly among 11 attributes, then among seven other attributes and lastly among four attributes. Using this method for attributes such as a fax machine or conference compartment, it was revealed that the majority allocated SEK 0 to these attributes. When it

²⁰² I am told that every year there are new findings that indicate that more types of distribution can be added together and that the sum approaches the normal distribution very effectively.

came to timetable and price attributes, fewer people allocated zero and the distribution of allocations approached the normal curve to some degree.

The second doubt relates to the prerequisites for the logit model when it is used to estimate the outcome of stated preference experiments with unlabelled designs. This is what is most often done when train attributes relating to comfort and on-board service are involved.

The situation is different for labelled and unlabelled alternatives, as is illustrated by the following figures. My example is a choice between two train alternatives which will be compared with choices between modes.

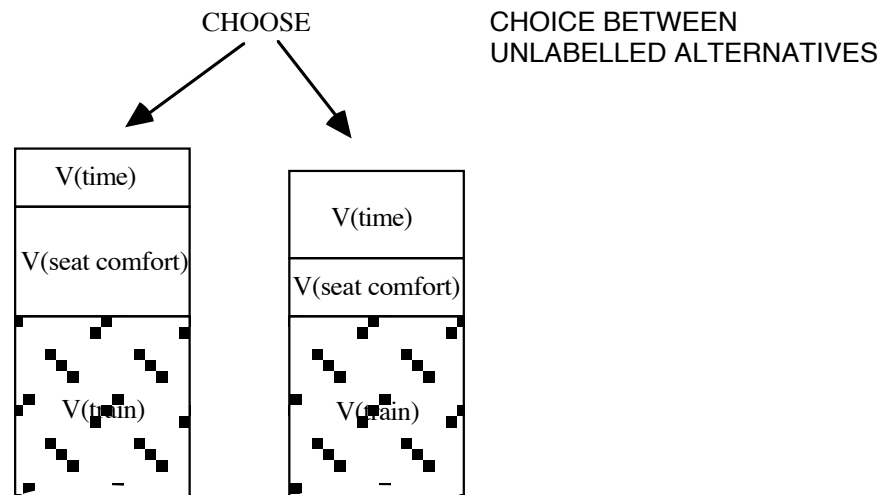


Figure 6.42 An individual's valuation of two equal train services, where only two attributes, the seat comfort level and the travelling time, differ, results in a choice between unlabelled alternatives. The difference in valuations is produced by varying the description of the alternatives; the levels of comfort and time.

The respondents compare attribute differences when choosing one of the two train alternatives. Is the extra time a smaller or greater sacrifice than the reduced seat comfort in the other alternative? In this unlabelled case, the train service is the same in all other respects. The two alternatives the respondents have to judge do not differ in more than a few respects. There is a strong covariation between them. A labelled example now follows. In this example, it is assumed that the car alternative is preferred, because its sacrifice pile is the smallest.

In a labelled design, like the one in figure 6.43, there is variation in all parts: the respondents' various weights for the observed parts (time and comfort) and for the unobserved parts, partly revealed by (market share) constants (in this case a train constant and a plane constant). The various patterns for the car, train and plane piles are there to show that there may be different unobserved variables and variance among the labelled alternatives. So, in this example, little is observed and there is a large "random" part, giving a wide distribution.

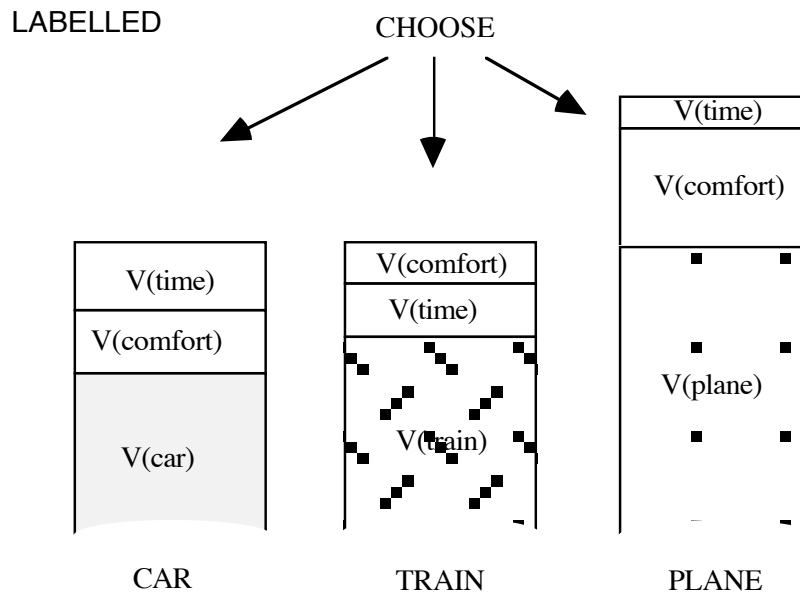


Figure 6.43 Choice between labelled alternatives (car, train, plane). An individual's valuation of three modes, where comfort and time are explanatory variables.

Summary: A *labelled* alternative, such as "car", includes many features or attributes and triggers many different associations among respondents. The same holds true for its competing alternative, such as "train". In the other case, comprising *unlabelled* alternatives, only some of the attributes distinguish the alternatives from one another – one train from the other. It is hard to believe that the respondents will value the two identical parts (the identical trains) differently with a Gumbel-distributed error term separating them. The reason for choosing one or the other alternative lies in the investigated attributes and their distribution.

The second doubt leads to the question of how the values of the investigated attributes are distributed among individuals in the population of interest. This will probably influence the outcome of unlabelled stated preference experiments.

What happens to the SP results if people do not maximise their utility?

We do not want the results of an SP study to be "wrong" – and what do we mean by wrong? One definition could be that the choices predicted by a model based on SP estimates should predict the same choices we can observe in reality. This is a difficult task because there are many factors that influence real choices that are different in a SP interview. For example, do people in real situations often not have the same information as is given in an interview? Probably not all potential train travellers know as much about the comfort attributes inside the train as is presented in an interview.

A question of the greatest relevance is the decision strategies people use in reality and whether they use the same strategies when answering an SP interview (SP "game"). It is possible that people maximise utility more in the game than in reality, or the opposite.

Earlier research by Widlert²⁰³ at KTH – and probably many others – presumes that the extent to which the lexicographic rule in SP games is used is a measure of the quality. An interview with a low rate of lexicographic answers has worked better than one with a higher rate. However, what if people use the lexicographic or other strategies in reality?

Widlert demonstrates that lexicography can lead to parameter values that are too high or too low. If the reason for lexicography is to simplify the task, the effect is that the importance that is used for sorting is increased in relation to the other attributes. The respondent gives too high a weight to these attributes. The result is an overestimation of the attribute in question.

The opposite effect occurs if the respondent sorts lexicographically because one attribute really is that important. Imagine a situation in which one attribute is precisely that important that it results in lexicographic sorting. If we then increase the importance of that attribute by widening the range of the levels, we obtain exactly the same answers to the experiment – there is no opportunity for the respondent to show that the attribute is even more important now. The result is an underestimation of the attribute in question.

Lexicographic sorting has often been found for the price attribute. If the result is that the price parameter is underestimated, due to the second effect described above, the trade-off with other attributes will result in too high a willingness to pay.

SP experimenters have used the amount of lexicography as a measure of quality. They suspect that people have not maximised their utility, as the normative theory of utility maximisation requires.

As has previously been reported, Payne's computer simulation with various decision-making rules showed that the lexicographic strategy (LEX) produced almost the same accuracy as the reference, weighted additive rule ($WADD \approx$ utility maximisation), but with only 30-35% of the effort. The other rule that performed well in some cases was the equal weight (EQW)²⁰⁴. Contrary to LEX, it performed less well when dominance was not possible. A combined strategy that always performed well was Elimination By Aspect followed by utility maximisation of the rest of the alternatives.

Perhaps we can conclude that "people appear to maximise their utility even if they use other decision-making rules". The choices in which respondents have not succeeded in maximising their own utility will increase the randomness. The dispersion will probably be greater, but whether this severely affects the average parameter estimates is an open question.

The package problem

The willingness-to-pay values obtained from many SP studies are suspected of being too high. This suspicion is especially strong in the case of secondary or soft attributes.

²⁰³ Widlert, *Stated Preference Studies – The Design Affects the Results*, KTH (1994), submitted to the 7th International Conference of Travel Behaviour, Chile, June 1994.

²⁰⁴ In newspapers, when judging consumer products, for example, the judgements are sometimes based on points for a sum of attributes. The weakness of this evaluation is that it often does not take any attribute weights into account; how important are the various attributes?

– When secondary attributes are part of packages, the value of the package is lower than the sum.

Some of the reasons suggested by me and other researchers:

- The use of decision-making rules other than additive value maximisation. The lexicographic rule can lead to higher WTP, if the price parameter is underestimated.
- Focusing and framing. The focus is placed upon the attributes included in the experiment. If people have not thought about these attributes before, they will probably do so when asked. Psychologists have found that preferences may be constructed in the generation of responses (Section 6.2.2). People's ability to *discriminate* will be a sufficient tool for conducting the experiment. This may cause an overestimation of the importance of these attributes.
- Compatibility effect. The use of stated choice, instead of, for example, rating. Choice is a qualitative, ordinal method which could prioritise the qualitative attributes in relation to the quantitative ones. The various qualitative comfort attributes would then have a relatively higher weight than the quantitative price attribute. Not all the findings mentioned in the section on compatibility effects support this hypothesis, but the theory itself may do so. The findings made by Widlert also support the hypothesis that choice is the method that produces the highest preferences/valuations for attributes other than price. Lexicography (for the price attribute) is the lowest for choice, which is often interpreted as goodness. It could also be interpreted as a deviation from what people do in reality – they may well be lexicographic in their real choices, given the included attributes. The SP choice method has fooled them into considering more attributes than they normally do and than some other method would do.
- Standard choice models include explaining attributes as they are in reality, not people's perceptions about them, even though we know that the perceived attributes are what people compare. Not even people's attitudes are explicitly included in standard choice models. A few models including latent perceptual and attitudinal attributes have been developed in the past year, see the report by Ben-Akiva et al.²⁰⁵. These models pay more attention to the choice process and they can strengthen the explanatory power.
- The secondary attributes can be seen as indicators of other latent attributes. For example, the three attributes of noise, shaking and vibration can be indicators of the same attribute as "restlessness" or "unease". The total value of these three attributes may therefore be difficult to add up.
- Taste variations among individuals may produce biased results. Lindqvist et al.²⁰⁶ have shown that an estimation procedure in which the attribute parameters are normally distributed produces other results. In their study, the difference in the value of time was about $\pm 50\%$ in comparison to the standard logit estimation method. It would be interest-

²⁰⁵ Ben-Akiva, M., Walker, J., Bernardino, A., T., Gopinath, D., A., Morikawa, T., Polydoropoulou, A., *Integration of choice and latent variable models*, draft revised in May 1998, MIT, for presentation at AMA ART Forum '98, Keystone, Colorado

²⁰⁶ Algers, S., Bergström, P., Dahlberg, M., Lindqvist-Dillén, J., *Estimating the value of time by means of a mixed logit model*, KTH, Transek, Uppsala University, work in progress, 1998

ing to test this mixed logit estimation on other interview data, especially with secondary attributes.

The conclusions I draw from previous studies are that

- the package problem increases with the number of attributes or measures included
- the combined valuation of timetable and comfort improvements instead reveals that a package of this kind is very attractive. It receives a value that is as high or even higher than the included factors receive separately.

The latter finding may be contrary to the frequently mentioned assumption that people value time savings less highly if the comfort level is increased, at least in the experimental situation. In this case, people's "wishes" overrule the theoretical idea of interactions.

Sampling and representativeness

When interviewing train passengers, one investigates their preferences. However, what about the preferences of other groups or segments, like the people who currently choose to use their car? Their valuations cannot be secured by interviewing people who have already chosen the train. I have however segmented groups who claim that they seldom use the train or claim that they more frequently use their car for "this type of journey". Smaller or greater differences between different segments have been found.

The question of sampling in this section is somewhat different. If different types of passenger are represented in the passenger interviews, how great is the sampling problem? I hypothesise that it is not very serious for many of the comfort and service-in-train attributes I have investigated. When I have segmented my interview data for various groups, I have often found moderate variations in estimates. In this thesis, the average value for the whole population on board is generally presented, so the question is how the average is affected by a moderate sampling error. Representativeness then refers to the average valuation for (Swedish) train passengers.

Figure 6.44 illustrates a hypothetical situation in which a sampling error would lead to a fairly low estimation error of the average value. It illustrates that average values level out variations. In this hypothetical case group 1 has 1.5 times higher valuation than group 2, and a moderate sampling error does not affect the estimated average valuation very much.

For other types of study with other aims, the sampling problem may be very serious. When the respondent group is very inhomogeneous in terms of the investigated attributes, the sampling errors can be large. If, for example, one group dislikes an attribute that the other group likes, the estimated average value will be specious.

We may also be interested in the valuations by specific groups and in these cases representativeness is an important issue.

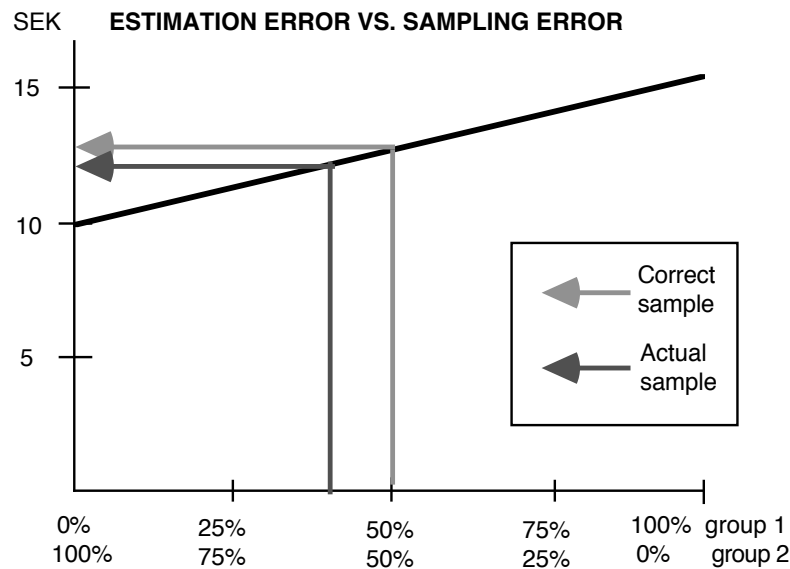


Figure 6.44 Illustration of how estimation errors can be small, even when there are sampling errors.

How to proceed?

As already mentioned, models are simplifications of reality. The assumptions for the random utility theory and logit modelling may be well fulfilled for revealed preference studies and stated preference studies of labelled alternatives, such as mode choice. However, there might be a problem with unlabelled alternatives, which I have noticed. There are also other problems, like the package effect.

As I see it, there are few good alternatives to stated preference methods and the way we have used SP at KTH is accepted practice.

Today's SP methodology, its relations to psychological findings and certain shortcomings should be further investigated. Until we have even better alternatives for estimating valuations, we should use and trust the practical methods we have.

Swanson²⁰⁷ has looked outside the field of transport to seek evidence for the validity of stated preference and recommends the same sources I am inclined to recommend: Conjoint research in the general market research and experimental economics and psychology. As a matter of fact Swanson also points to the importance of framing and reference points, the preference reversal phenomenon and Prospect theory as knowledge which have direct bearing on how SP tasks should be designed.

²⁰⁷ Swanson, J., *Factors affecting the validity of stated preference*, Seminar paper with summary on the Internet, <http://www.aetransport.demon.co.uk/SeminarD.htm>

6.8 Classification of travelling standard attributes

Travelling standard is a measure of attractiveness. Interest here focuses primarily on the traveller's experience of standard. A timetable does not represent a travelling standard, but several relevant attributes can often be derived from it: travelling time, departure frequency and number of changes. In addition to them, there are other attributes which are classified under the following headings. comfort, on-board service and quality fulfilment.

The classification primarily includes concepts and attributes that are related to the design of trains. Some conceptual factors, which are indeed important, are not included, especially those belonging to the concepts of safety, accessibility, marketing and information. Socio-economic factors are not considered here.

Main classification of train related travel standard attributes

The main classification²⁰⁸ can be seen in figure 6.45. Within the sectors of timetable, comfort, service and quality it is possible to find at least a hundred of sub-topics which are likely to influence the travellers.

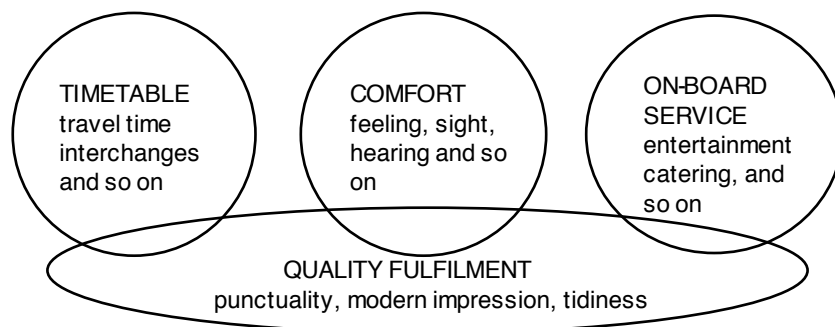


Figure 6.45 Diagram of different travelling standard attributes. For the notions of timetable, service, comfort and quality, a further breakdown into factors/attributes is necessary.

A more detailed structure has also been drawn up. Its outline can be seen in figure 6.46. The frequently used concepts of frequency, travelling time, distance and interchanges have their own circles. The three concepts of comfort, on-board service and quality fulfilment will be further divided in the three diagrams that follow (figures 6.47, 6.48 and 6.49).

²⁰⁸ Many other classifications have been proposed. This one is used by the Railway Group at KTH. (Traffic safety is missing in this one.)

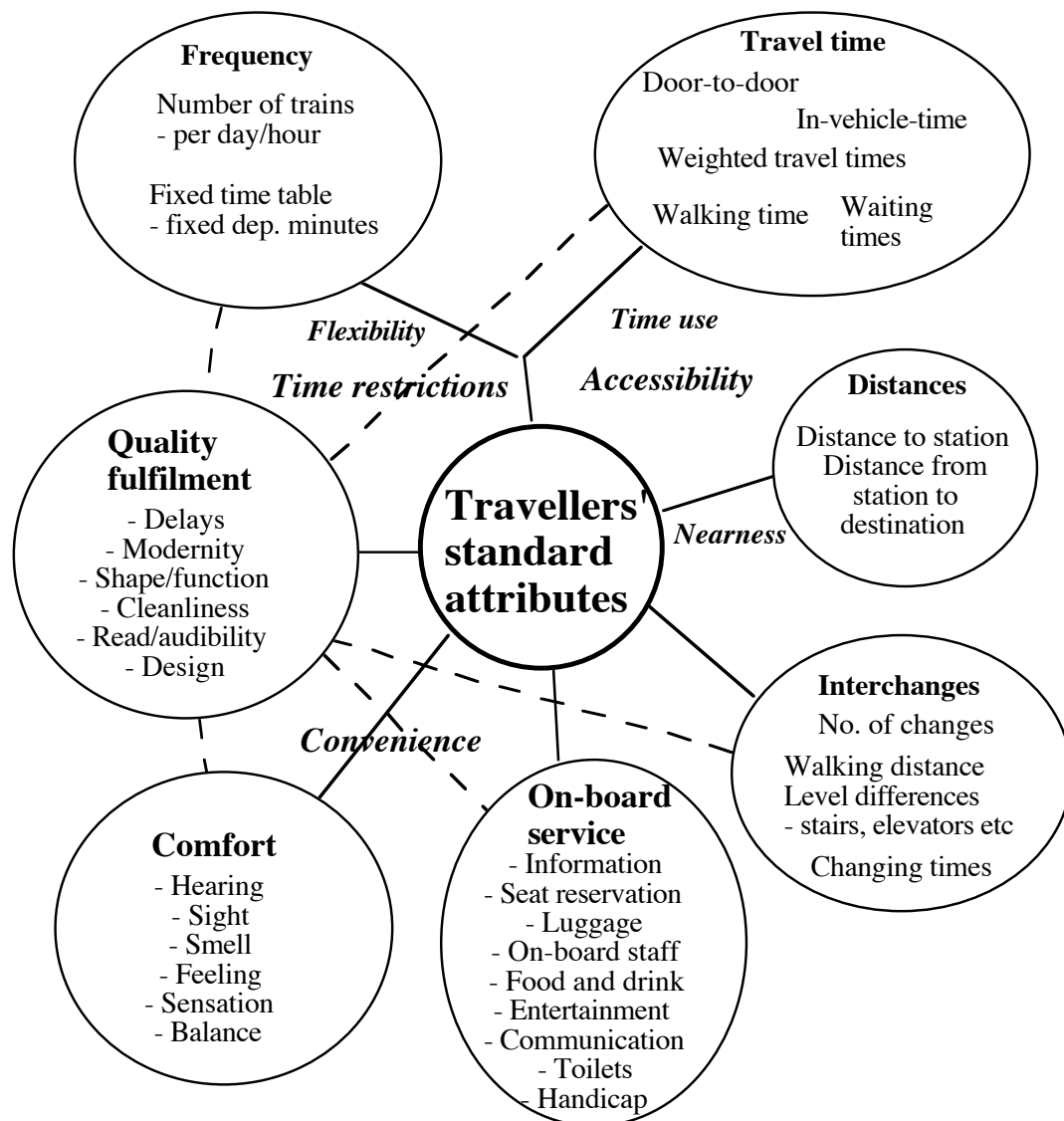


Figure 6.46 Proposed classification of traveller's standard/attractiveness attributes

Section 6.4.3 included some reasoning about primary and secondary, hard and soft attributes. In the above main structure, attributes that are more like primary or hard attributes have their own circles while the attributes that are thought of as secondary or soft have been grouped and listed below the concept headings in the circles.

The concepts of comfort, on-board service and quality fulfilment will now be further discussed and developed. Under each of these concepts, about 20-40 detail level, soft attributes are indicated and shown. All these detail level attributes and, of course, others can be used in stated preference interviews.

On-board comfort

According to the dictionary *comfort* means convenience. Johansson²⁰⁹ has defined comfort as a human being's sense of well-being during a journey. The fact that the train arrives on time may be a comfort determinant (a factor that impacts on the sense of well-being.). This type of comfort is called organisational comfort by Johansson. In this thesis a factor of this kind is classified under quality fulfilment. The comfort when changing trains, "transfer comfort", is not considered comfort in this project.

In a VTI-study of the comfort-concept, Irma Alm²¹⁰ has discussed this from a psychological point of view. She holds that comfort ought not to be used in the way that for example Johansson uses it. "It is likely that comfort may be one of the variables that determines this satisfaction, but it is unlikely that comfort would be the only factor that determines it." She defines comfort as "an above all positive emotional reaction to external objects or external events and partially as a cognitive comparison between points of reference and the objects in question...". In this project it suffices to use the word comfort as a heading for a number of factors according to the following reasoning.

During a journey by (e.g.) train, one is fed with sensory stimuli of various kinds. They affect comfort. The comfort concept in this thesis comprises the impressions that have their foundations in physically describable sources or causes, i.e. often in the technical design of the train. A handsome, friendly ticket collector may make a positive impression, but this type of impact is not intended.

The impressions may be classified as:

- hearing impressions
- balance, i.e. vehicle movement impressions
- sight impressions
- tastes and odours
- tactile, i.e. physically mechanical, sensations
- sense, i.e. psychological experiences

The vehicle qualities that produce the impressions have been classified under the following categories.

²⁰⁹ Johansson, B., *Komfort i kollektivtrafik (Comfort in public transport, in Swedish)*, Chalmers University of Technology, Dep. of Transportation and Logistics, Report 9, September 1989, ISSN 0283-3611

²¹⁰ Alm, Irma, *Transportabel komfort – komfortabel transport*, VTI rapport nr 347, 1989, ISSN 0347-6030

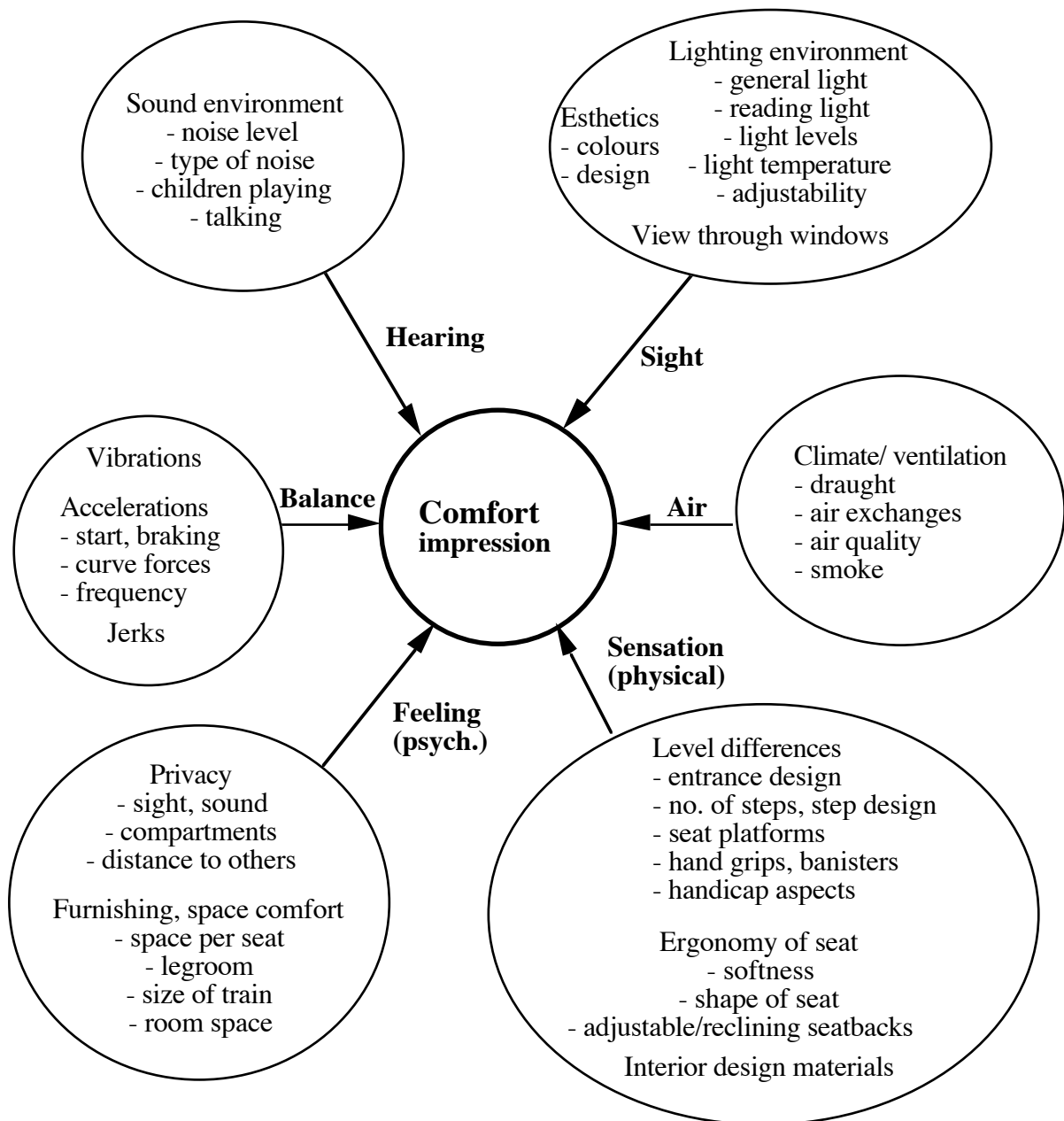


Figure 6.47 Structure of (on-board) comfort related attributes

On-board service

It is difficult clearly to distinguish comfort from service. Both influence the experience of well-being. The dictionary defines service as someone seeing that you get what you need. I hold that service in this context is the devices and services that are not necessarily offered to passengers at all times or in all vehicles, but that the transport company chooses to provide or sell. In this definition, the following subdivision has been made.

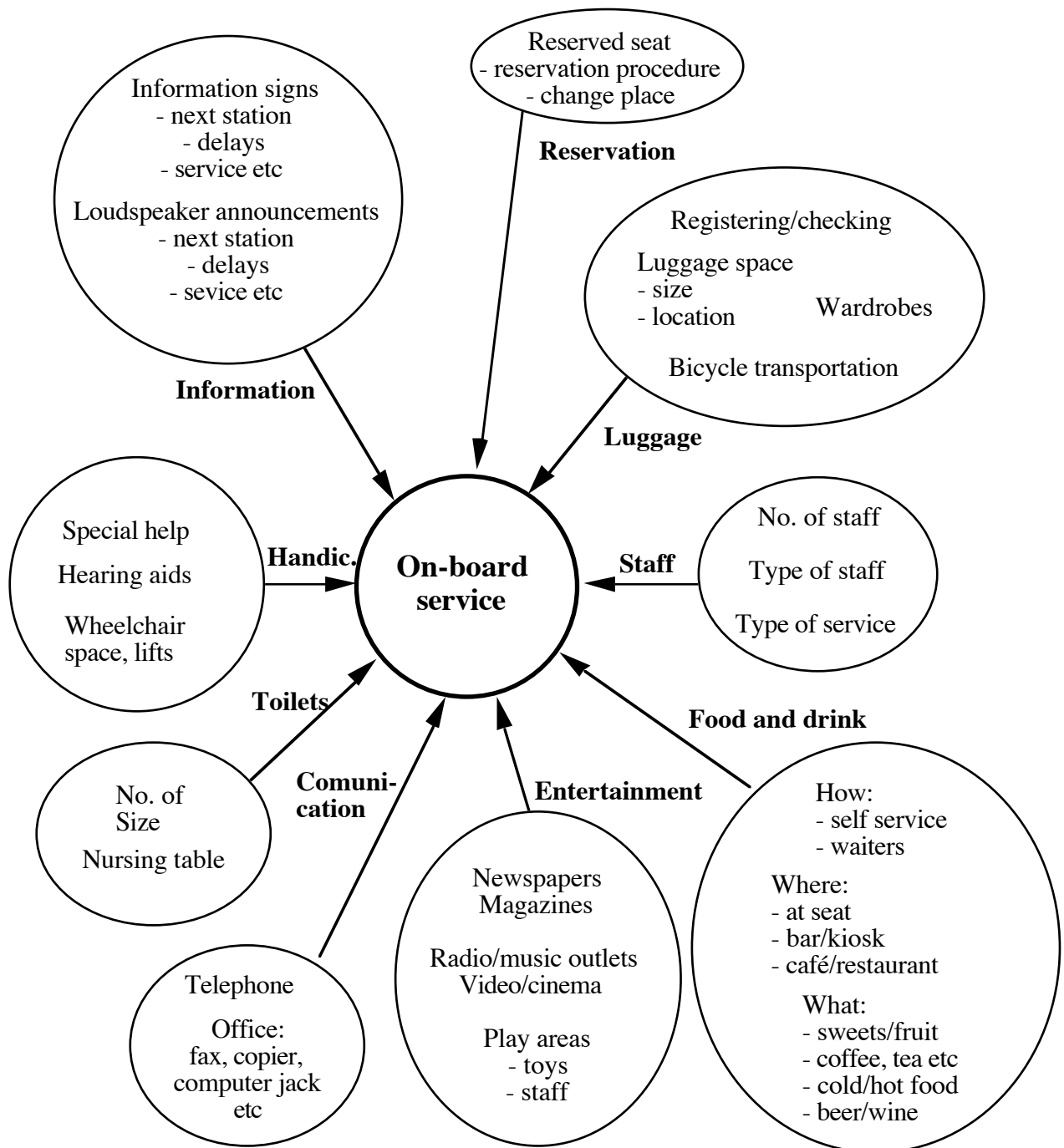


Figure 6.48 Structure of on-board service attributes

I suppose the most readers would automatically assume that staff, information and seat reservation are included in on-board service or influence the service. Food and drink, luggage, entertainment, communication, toilets and facilities for the disabled are also headings for service attributes. This suggests that service can be provided not only by human beings but also by hardware like telephones or music outlets in the trains.

A transport company may provide a great deal of service prior to the journey, e.g. at the station. These services have not been included in the above compilation as this project centres on vehicle related attributes.

Quality (quality fulfilment)

There are a large number of definitions of quality. According to the dictionary, it means inner value. One also attaches to quality "pertaining to nature, qualities or inner worth", as opposed to quantity which means "pertaining to quantity".

Earlier definitions specified product-related measurable qualities such as durability and strength. Nowadays, the quality concept has developed beyond definitions of a technical nature. A new definition of this kind is "appropriate for its use". Most of the definitions in the later years are based in one way or another on the customer's appreciation or experience of quality, e.g. Swedish standard or international standard:

"Quality is an aggregation of features in a product or service that enables it to satisfy explicit or implicit needs."

Warsén&Göthlin²¹¹ take as their starting point the customers' position and mention the following quality dimensions: dependability, competence, availability, accommodation, communication, credibility, security, comprehension and manifestation. The list pertains to the quality of service, not the quality of physical products.

In 1993 the resource working party suggested a more subjectively-oriented definition: "Quality is neither an objectively certifiable or permanent nature in a phenomenon. Quality is a judgement about this phenomenon, stated by an interested party - at a certain point - based on a subjective assessment of its value for him or her."

One may regard quality in a normative way and compare the features of a product or a service with an acceptable minimum level. This may be extended to reasoning about whether what people want is what they should have, but this question has not been developed any further.

Quality in this project is *an indication of the degree to which one gets the product or service one may reasonably expect*. This comprises what may be held to be a reasonable expectation based on the type of journey, competing vehicular services and the general quality level and standard in Swedish society. One expects trains to arrive and depart according to the stated timetable, for example. Good quality here means that the product comes up to expectations. Many factors influence expectations; one's own experience, marketing and image. The project definition of quality is a relative concept which is determined by the expectations the customer has and how well the activity comes up to these expectations.

The quality need not be explicitly stated for travellers to have a right to expect good service - one does not need to promise that the train will be cleaned, the upholstery will be intact and the personnel be pleasant. Further examples of shortcomings in quality include: loose, rattling structural parts - especially irritating in night-coaches - headphone outlets containing programmes with white noise and crackling and so on. The producer of a service can estimate what the customer may reasonably demand, even if this estimate does not always coincide with the customer's view of quality.

²¹¹ Warsén, L., Göthlin, L., *Utformat för kvalitet – Kundens uppfattning om design, kvalitet och kollektivtrafik*, (Designed for quality, in Swedish), TFK report 1993:3

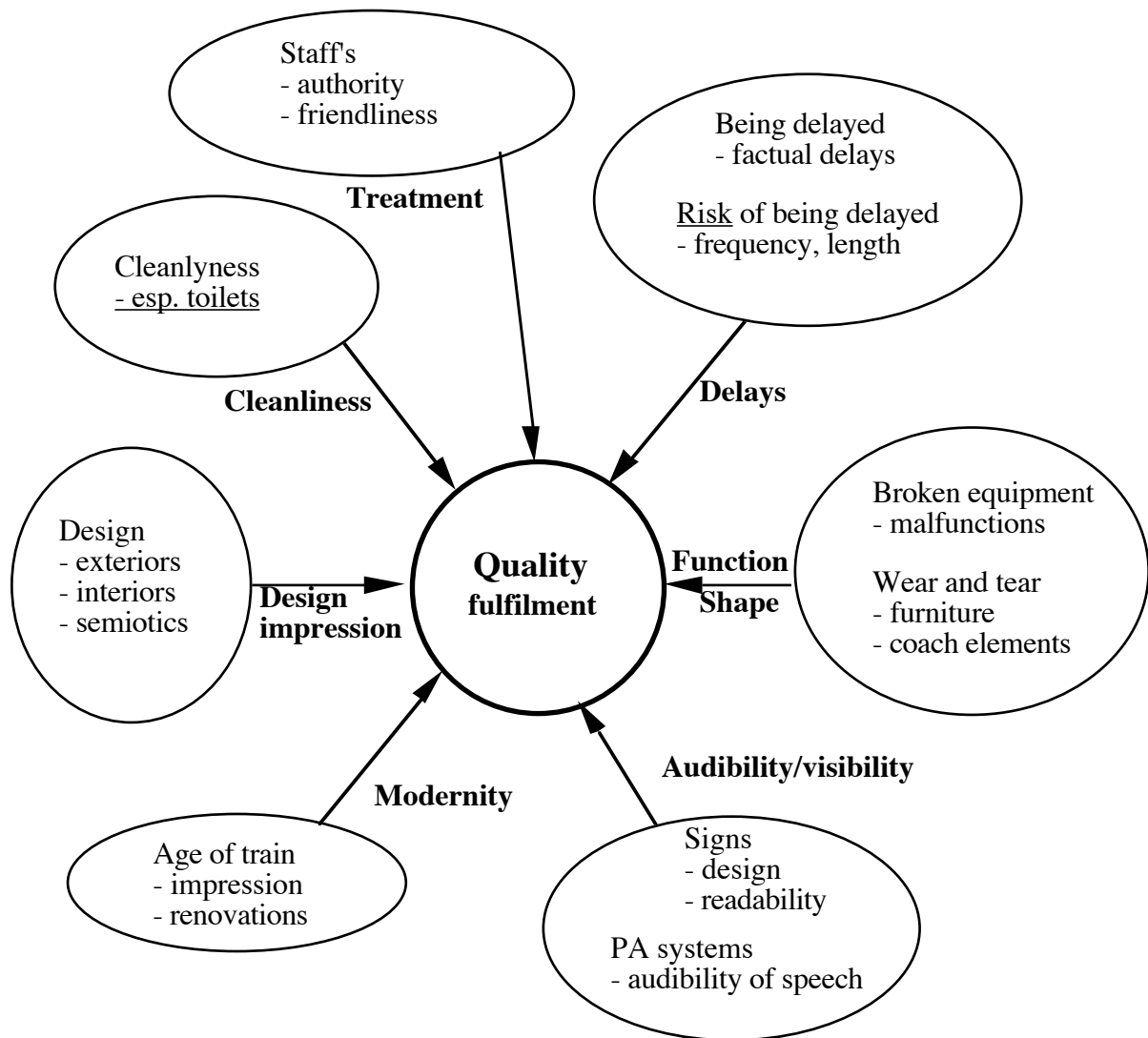


Figure 6.49 Structure of quality fulfilment attributes

There is a minor difference between the terms "quality satisfaction" and "quality fulfilment". The first one describes the passengers' satisfaction with a state that is included in the other term: The quality is satisfactory if the requirements or expectations are fulfilled.

The project definition of quality harmonises with the definition of quality defined by SJ. It states: "Quality is to continually and to the full extent satisfy the agreement that SJ has made with its customers - and what the customers are paying for". SJ mentions that punctuality is the customer's foremost demand. Other examples of quality factors mentioned by SJ are:

- Accessibility and service - to be there, friendly, quick, correct answers and so on.
- Well-made beds, soft terry, correct clock-display, working lamps and hot water in the shower, as well as smooth traction in the bogie, important for the night train.
- Novelty/ modernity - new, fresh station environments and rolling stock.

When structuring rolling stock features, the quality concept is used in a more product-oriented sense, where durability and life span are included under quality, for example.

Alternative structuring of travelling standard attributes

In the work conducted so far and in my licentiate theses²¹², train-related attributes are sorted into four categories with the following headings: transport standard (later: timetable), comfort (later: on-board comfort), service (later: on-board comfort) and quality (later: quality fulfilment).

Many other structures for travelling standard attributes have been proposed and used. One example is the structure created by Holmberg (1977)²¹³. He used safety, convenience and accessibility as the main classes in his structure. Most separate attributes were classified under vehicle, which corresponds to the image presented by me. One striking aspect is that information is classified under convenience - mental. Holmberg's structure illustrates that there many other effective ways of dividing the concept of travelling standard.

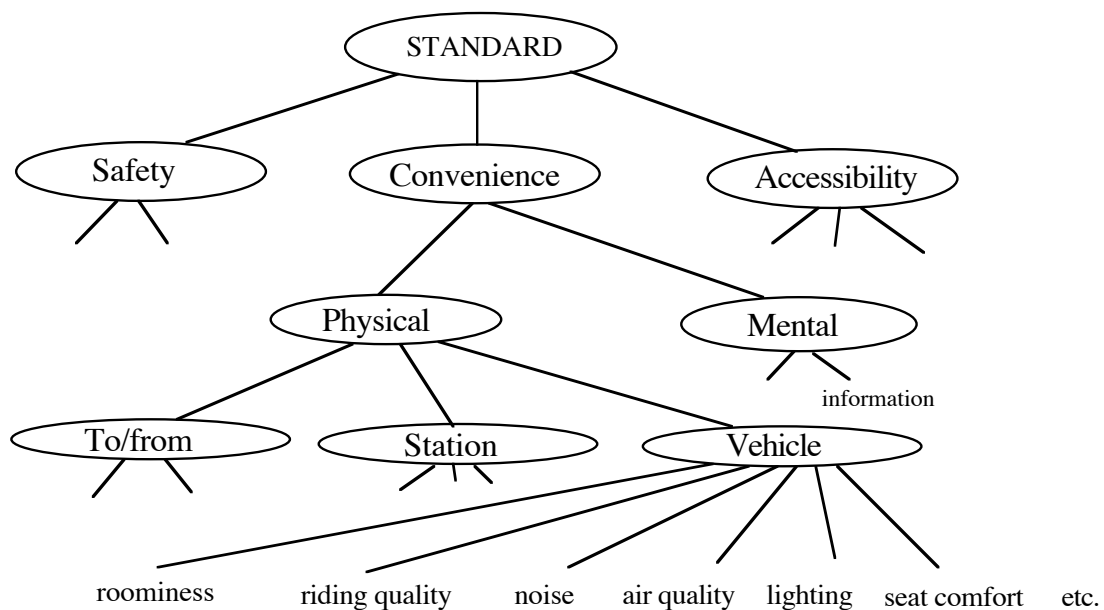


Figure 6.50 Classification of travelling standard in public transport used by Holmberg (1977)

An even more effective structure than mine and Holmberg's should be justified by some theoretical or practical reasons.

The classification in this thesis has been made to obtain a practical structure for a large number of attributes that could affect passengers. This has not been done to reduce, for example, all comfort-related attributes to one new attribute "comfort". However, a proposal of this kind was made back in 1973 at a TRB conference. Demetsky²¹⁴ sums up the

²¹² Kottenhoff, K., *Framtida Persontåg – fordonsegenskaper för ökad attraktivitet och effektivitet*, (Future Passenger Trains – Vehicle concepts for increased attractiveness and effectiveness, in Swedish), Licentiate thesis, Traffic & Transport Planning KTH, TRITA-IP FR 94-3, 1994

²¹³ Holmberg, B., *Standard i lokal kollektivtrafik – metoder för mätning och beskrivning*, Nordiska institutet för samhällsplanering, R 1977:1

²¹⁴ Demetsky, M.J., Attitudinal data, in *Behavioral Demand Modeling and Valuation of Travel Time*, TRB Special Report 149, printed 1974

conference discussion about attributes like temperature and seating arrangements: "These hierarchical (among attributes) and degree measures must then be interpreted in terms of broader characteristics, such as comfort, wherein there might be direct trade-offs between temperature and space as opposed to indirect trade-offs between temperature and travelling time".

Morikawa developed some models, presented in his thesis (1988), and in a paper written in co-operation with Ben-Akiwa and McFadden²¹⁵ about incorporating comfort and other psychometric data in logit models. Morikawa refers to data from a study in the Netherlands about mode switching rail – car. This study included subjective rating data for six latent travel characteristics: *relaxation* during the trip, *reliability* of the arrival time, *flexibility* of choosing departure time, *ease* of travelling with children and/or baggage, *safety* during the trip and an *overall* rating of the mode. The first five are also called *perceptual indicators*.

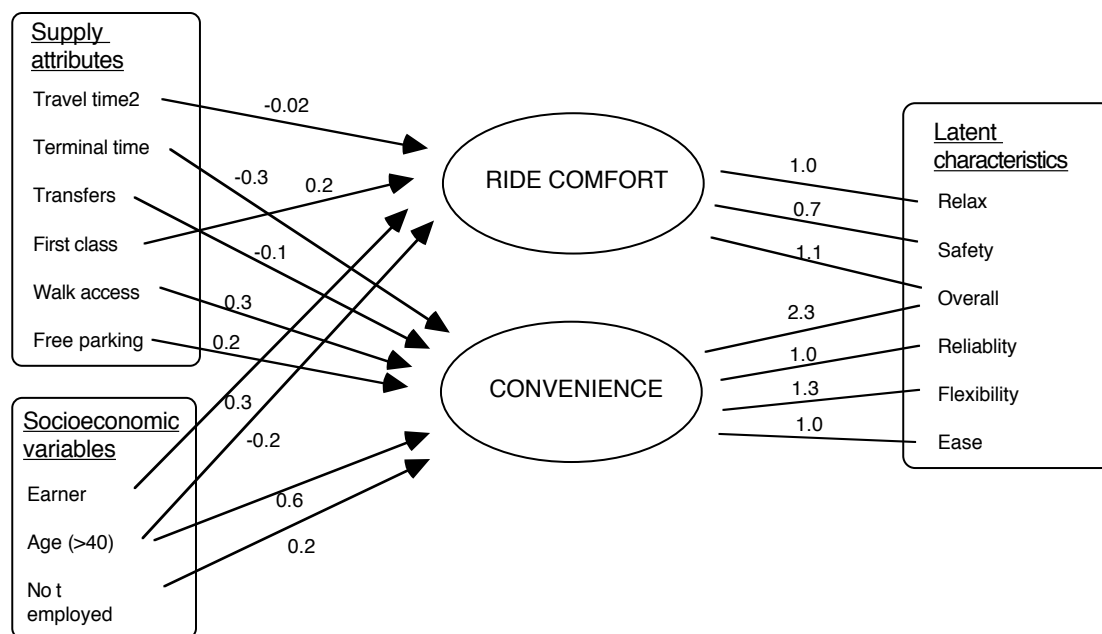


Figure 6.51 Morikawa's structure including two latent variables and six perceptual indicators.

In addition to these perceptual indicators, two latent variables called *ride comfort* and *convenience* were specified. They were measured in terms of the differences between car and train riding. The figure is a simplification of the correspondence between observable variables and latent variables. The estimated correlation coefficients are also shown.

²¹⁵ Morikawa, T., Ban-Akiwa, M., McFadden, D., *Incorporating Psychometric data in econometric travel demand models*, July 1990

7. Summaries of SP studies included in this thesis

A number of stated preference studies have been conducted within the framework of this project. Most of them are presented in separate reports, in Swedish or English. A few of the small interview studies have not been published before.

This chapter (7) presents the results of the studies, one by one, while Chapter 8 contains a summary of passengers' evaluations of the investigated attributes.

Table 7.1 Studies performed within the framework of this thesis.

No.	Study	Date and comments
1.	Study on the Ostkustbanan 1992 about train comfort and legroom ²¹⁶	The SP study was conducted in October 1992
2.	Study of comfort in new suburban trains	December 1992. Published in the same report as above.
3.	Evaluation of German InterRegio coaches in Sweden in 1993, Norwegian ICE trains, regional X10 trains and Swedish InterRegio cars in 1995	Two SP studies; 1993 ²¹⁷ and 1995 ²¹⁸
4.	Train or bus (coach) with train interiors?	March/Aug. 1994 ²¹⁹ ²²⁰
5.	The value of travelling in (small) compartments	Not published before
6.	The (negative) value of changing trains	Not published before
7.	Travelling by train in tunnels and over bridges	Nov.1995, not published before
8.	Study of train concepts and package effects (value reduction when evaluating train concepts)	Supervising L. Schmidt, degree thesis ²²¹ at KTH 1995-96
9.	The value of night and day train services	March 96, not published before

²¹⁶ Kottenhoff, K., *Resenärers värdering av inredning och utrymme i fjärrtåg och lokaltåg*, KTH Traffic Planning, TRITA-IP, AR 94-11, 1994

²¹⁷ Kottenhoff, K., *Evaluation of passenger car interiors*, KTH Traffic Planning, TRITA-TPL 93-11-96, 1993

²¹⁸ Kottenhoff, K., *Utvärdering av tyska och svenska InterRegio vagnar 1993 och 1995*, (Evaluation of German and Swedish InterRegio coaches, in Swedish), KTH Traffic Planning, TRITA-IP AR 95-34, 1995

²¹⁹ Kottenhoff, *Tåg eller buss med tåginredning - en jämförelse i Blekinge mellan tåg (Kustpilen) och rymliga bussar (Kustbussar)*, KFB report 1994:14

²²⁰ A PTRC paper is also presented

²²¹ Schmidt, L., *Värdeinsknning vid värdering av Tågkoncept - Studie av komfort, service och tidtabellspaket med Stated Preferences-metoden*, KTH Traffic Planning, TRITA-IP AR 96-44, 1996

10.	Are wide trains profitable?	Supervising P. Båge, degree thesis ²²² at KTH 1996/97
11.	Evaluation of BrainTrain	Spring 97, not published before
12.	Evaluation of the value of the new train services on the Svealandsbanan.	Supervising L. Segerman, degree thesis ²²³ , 1996/97
13.	SP interviews within the project "Establishing new train communication - the example, the Svealand Line"	Spring 97 spring 98, to be published as a PhD thesis by O Fröidh about year 2000
14.	Interviews about train travel, via the Internet.	Supervising K. Törnström, degree thesis, 1997/98
15.	Evaluation of InterRegioMax (B20), a high-capacity test coach with more seats	May-June 1998 ²²⁴
16.	Evaluation of a large number of timetable, comfort and on-board service attributes.	Spring 1998
17.	Evaluation of German double-decker trainset on trial in Sweden	Dec.1998

The studies are summarised below to present the valuation figures they produced and to comment on methodological issues. In most cases, the valuations of the attributes have been estimated as a percentage of the actual ticket price (or fare level). The reasons for this have been explained in Section 6.5.

The presentation below contains short summaries of the 17 studies. For many of them, only one of a number of estimated models is presented.

Most of the studies were performed on various main lines in Sweden and a map of Swedish rail lines is included in the appendix.

²²² Båge, P., *Är breda tåg lönsamma – En värdering av olika sittplatsarrangemang med fyra metoder*, KTH Traffic Planning, master's thesis number 97-53, 1997

²²³ Segerman, L., *Resvanor i den nya Svealandsbanans sträckning. Allmänhetens kunskaper om och värderingar av olika trafikutbud.*, degree thesis 97-51, KTH Traffic and Transport Planning, 1997

²²⁴ Kottenhoff, K., *Utvärdering av SJ's experimentvagn B20. Resenärers kvalitativa och kvantitativa preferenser av högkapacitetsvagn "IRmax" på olika linjer*, KTH Traffic & Transport Planning, TRITA-IP AR 98-68: 1998

7.1 Study of train comfort and legroom on the Ostkustbanan in 1992

This was my first SP study. The main reason for conducting the study was to investigate passenger valuations of reduced seating space/legroom.

Name of study and main purpose	Train passenger valuations of interiors and space in trains on the Ostkustbanan (East Coast Line) To evaluate the comfort of various train interiors To investigate the value of legroom To find groups of travellers with a lower valuation of space
Places and dates	Ostkustbanan Stockholm-Gävle-Sundsvall/Östersund and regional line Gävle-Ljusdal One week in October 1992
Type(s) of train/bus	Passenger coach B7. Open saloon, about 1980 Passenger coach B2. Compartment like 3+1 seats, ~1986 Passenger coaches from 1960 Inter-regional EMU X12 with 2+2 seating in open saloons Regional EMU X10 with 2+3 seating in open saloons
Methodology	Background and opinion questions on paper questionnaire SP experiment (MINT) on a (heavy) portable computer
Number and type of respondents	Mostly second class (90%) inter-regional and regional passengers. No of interviews 269 . Response rate $\approx 9/10$.
Studied attributes and attribute levels	1. <u>Price</u> : as now/reduced by 10% minus SEK 10/increased 10% plus SEK 10 (presented for respondents in SEK) 2. <u>Legroom(cm) to the seat in front or the knee of the opposite passenger</u> : as now/5 cm less for half of the respondents and 50% for the other half/increased by 25% plus 10 cm 3. One, two or three <u>seats side by side</u> 4. <u>Seating</u> : face-to-back/face-to-face, the seat opposite is free/face-to-face, the seat opposite is occupied 5. <u>Train type</u> : You travel by loco-hauled train/motor coach train with improved comfort (one example given)
Methodological results	Reduced legroom obtains higher valuations than increased legroom.

Other SP results and comments	The interviews were conducted using a combination of paper forms and assisted computer interviewing.
	Regional commuters have higher (relative) valuations for comfort attributes than other groups.
	A passenger group with significantly lower relative valuations for legroom could not be identified.

Like most of the other studies, this one included a computerised SP interview, but the ordinary background questions were asked using paper forms. A 5 kg computer with a heavy extra battery was used for the computerised questions.

In addition, as in all SP studies, a large number of result models have been estimated. I have chosen not to present all the figures in this summary. The model below shows the main estimation results. The table presents estimated parameter values, estimated standard deviations for them and valuations calculated as a percentage of the fare. Other researchers often publish the t-values instead of standard deviations. However, in this case, we are primarily interested in valuation levels, not in whether the parameter differs from zero.

Table 7.2 Main estimation results for 220 respondents.

Attribute description	Parameter	Stand.dev.	Value (%)
Price (% of respondents' ticket price)	-0.0564	0.0027	–
10 cm less legroom	0.0405	0.0041	- 7%
10 cm more legroom	0.0260	0.0043	+5%
Three seats side by side (instead of two)	0.404	0.079	- 7%
Single seat (instead of two)	-0.116	0.071	- 2%
Face-to-face, occupied	-0.253	0.100	- 4%
Face-to-face, free opposite	0.089	0.092	+2%
You travel on an EMU trainset ("motorvagnståg")	-0.052	0.129	-1%
EMU with some extra comfort equipment (various)	0.075	0.117	+1%

A number of questions were designed to identify "budget" passengers with less willingness to pay. One of them was about the role of discounts. More than three-quarters of the passengers had some type of discount ticket. The majority of them claimed that their discount had influenced their choice of travelling by train. The models segmented for different groups produced similar results – it was hard to find passenger segments that had substantially lower valuations for legroom, because of the generally lower weight for legroom.

Figure 7.1 shows the result of estimating the legroom value for segments of legroom distances. These differences in legroom depend on the type of seating, the height of the interviewed persons and the different ways/styles of sitting in a seat. A potential decrease in legroom creates a higher response/higher valuations than an increase. Similar curves were constructed using other methods of estimation and curve fitting, for example, using an exponential parameter for legroom.

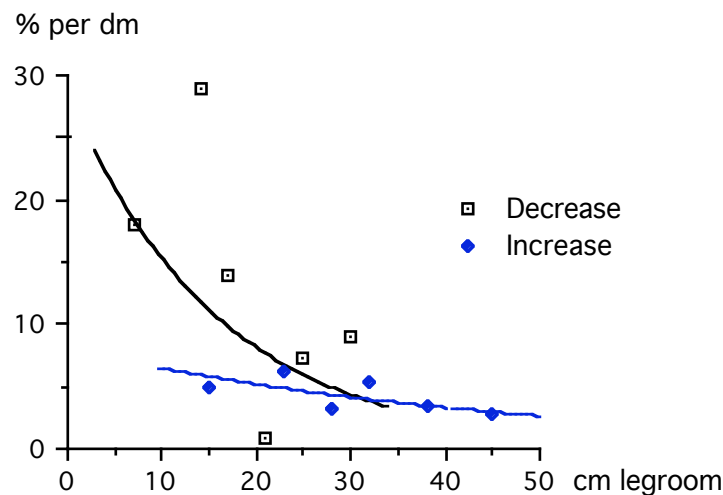


Figure 7.1 The value of a 10cm (1dm) increase or decrease in legroom in relation to the respondents' actual legroom (in cm).

Face-to-face and non-facing Sitting in *non-facing* (face-to-back, as in a bus) or *face-to-face* seats has no significant value on average, but people are different! Up to 50% of travellers prefer to sit in non-facing seats when travelling alone.

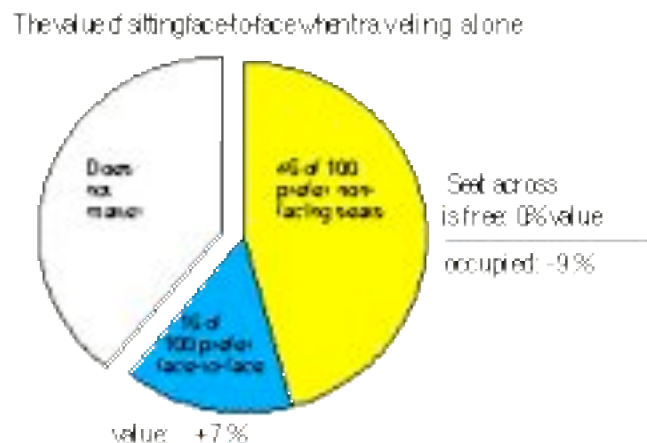


Figure 7.2 The value of sitting face-to-face, when travelling alone, divided into segments of those who prefer non-facing or facing seats.

Almost 50% of train travellers prefer to sit in non-facing seats when travelling alone. The non-facing travellers place a negative value on sitting face-to-face when the seat across is taken. For one-third of the respondents, the seating arrangement did not matter.

Those who claim to prefer to sit in non-facing seats set the value of sitting face-to-face at minus 9% of the ticket price, when the seat across is taken. If the seat is free, they have no negative view of sitting face-to-face. Those who prefer sitting face-to-face, a minority when travelling alone, set the value of sitting in non-facing seats at minus 7% of the ticket price.

The Ostkustbanan study also included a number of other, non-SP-related, results and two of them are summarised here.

As one way of evaluating privacy, a question about having other travellers next to or opposite was asked. The majority of the interviewed (Swedish) travellers said that they preferred to sit alone if they could.

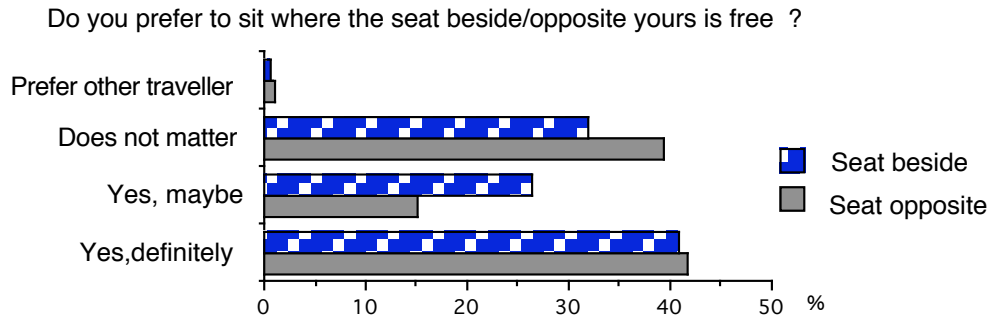


Figure 7.3 A question about peoples' feelings about privacy at their seat.

In this study another approach, than utility questioning, was tested; to ask what people want to do at their seat. A question with multiple-choice alternatives produced the following results:

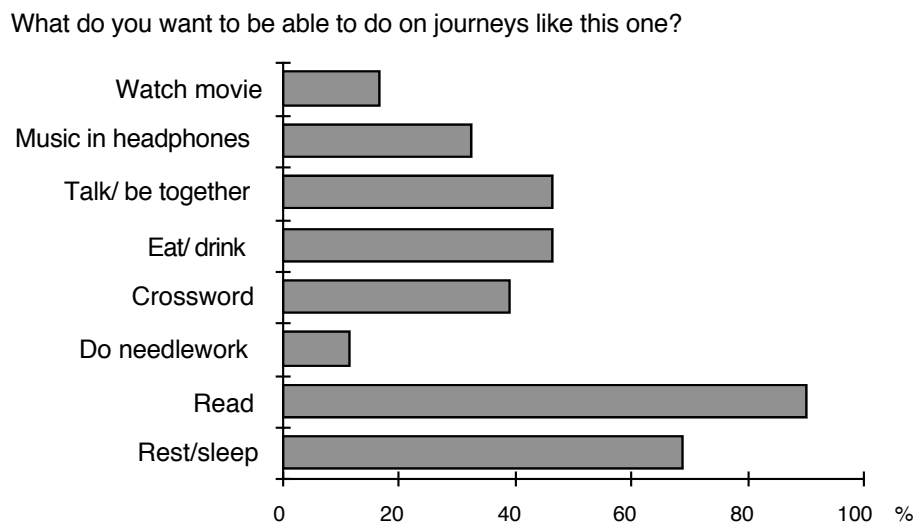


Figure 7.4 Percentage of travellers who said that they wanted to be able to do certain things in their seats

The answers to this question can guide the design of the seat and its surroundings. For example, it appears to be very important that seats are designed for reading and resting.

7.2 Study of comfort in new suburban trains

The Roslagsbanan (Roslag Line) narrow-gauge suburban railway received new rolling stock at the beginning of 1990s. The new coaches were quite densely furnished and had only face-to-face seating. A few cars were therefore converted with sections of face-to-back (bus) coach seats and more legroom. Stockholm Transport asked for a study. The study was conducted using pocket-size computers that were handed out to passengers on the train.

Name of study and main purpose	Valuation of standard in new local train coaches on the Roslagsbanan suburban line To evaluate the comfort of the new coaches To investigate the value of legroom and experimental type of seating
Places and dates	Roslagsbanan Stockholm Östra-Lindholmen-Kårsta/Österskär Two weeks in December 1992
Type(s) of train/bus	Loco-hauled, aluminium, narrow-gauge passenger coaches delivered around 1990. They have face-to-back seating with approx. 150 cm per seat bay. Interviews were made in converted coaches with a small number of face-to-back bus seats with higher seatbacks.
Methodology	Background and opinion questions, as well as SP experiment (MINT) on small portable computers (Poquet)
Number and type of respondents	Local/ regional commuters and school passengers. No of interviews 339. Response rate $\approx 8/10$.
Studied attributes and attribute levels (where attributes have the same numbers, different numbers of respondents answered different versions of the interview)	1. <u>Price</u> : as now/reduced by 5-10%/increased by 5-10% (presented for respondents in SEK) 2. <u>Legroom (cm) to the seat in front or the knee of the opposite passenger</u> : as now/reduced by 1-2 cm for half the respondents and 50% for the other half/increased by 10 cm 3.1 Seat with ordinary low seatback 3.2 Seat with high seatback (not reclining) 3.3 Seat with high reclining seatback 3.3 Seat with high seatback that can be turned for travelling forwards 3.1 New coach with face-to-face seating 3.2 New coach with face-to-back seating 3.3 Old coach (face-to-face)

	4.1 You sit face-to-face, other person opposite
	4.2 You sit face-to-face, empty opposite
	4.3 You sit face-to-back
	4.1 –
	4.2 Electronic sign shows ** NEXT STATION **
	4.2 Curtains in the coach
	4.3 Reduced lighting, but individual reading lamps
	4.3 Less noise and shaking
	4.1 You sit face-to-face, heading forwards
	4.2 You sit face-to-back heading forwards
	4.3 You sit face-to-back, heading backwards
Methodological results	Reduced legroom obtains higher valuations than increased legroom.
Other SP results and comments	These interviews are KTH's first CASI interviews, conducted using pocket-size computers which were handed out to passengers. Some attributes were evaluated by segments that were too small (too few respondents) to be reliable

Some of the main results are presented below. A few of the attributes that were investigated received too few responses, because they were programmed into only one or a few interview computers. The valuations of these attributes are not presented below.

One very interesting result is that the valuation of 10 cm legroom is about the same in this study comprising local or regional passengers as it was for the passengers in the long-distance trains on the Ostkustbanan in the previous study. This result supports the use of relative valuations; % of the fare.

Table 7.3 Main estimation results. The number of respondents varies for the different attributes because of interview variants. The number of respondents is shown in the column for standard deviation. Each respondent produced eight responses.

Attribute description	Parameter	Stand.dev./ n o. of resp.	Value (%)
Price (% of respondents' ticket price)	-0.0906	0.0067/200	–
10 cm less legroom	-0.0556	0,0091/200	- 6%
10 cm more legroom	0.0387	0,0083/200	+4%
Seat with high backrest	0.64	0.12/120	+7%
Reclining seat (with high backrest)	0.69	0.19/50	+7%
Face-to-face, occupied	-0.29	0.19/50	- 3%
Face-to-face, free opposite	0.34	0.14/85	+4%
This new type of coach	0.73	016/85	+8%
Less noise and shaking	0.68	019/55	+7%

All the older passenger vehicles on the Roslagsbanan have had face-to-face seating. The passengers' preferences were found to be only about 30% for face-to-face, 35% for face-to-back and the rest were indifferent. Models were estimated which showed that the passengers who preferred face-to-face were willing to pay to sit that way and the "face-to-backers" were willing to pay for their favourite furnishing alternative, as in the previous Ostkustbanan study.

The results of this study provided strong support for converting the interiors of the new Roslagsbanan vehicles, but for some reason this has not yet been done.

7.3 Evaluation of German InterRegio coaches in Sweden in 1993 and Swedish InterRegio coaches in 1995

This summary is based on two studies and two reports. The first study was made in 1993 when SJ borrowed a set of four InterRegio coaches from Deutsche Bahn. A report was written in English, to enable the Germans to read it as well. The evaluation result was used by SJ when the company created its own InterRegio concept. Another SP study was conducted in 1995 when these coaches had been in service for a while.

The idea behind the InterRegio concept is to have a high-quality train product for intermediate distances, without having to buy new vehicles. Older InterCity coaches were converted, in Germany and then subsequently in Sweden.

The first study also included two other train types; Norwegian ICE trains (four-coach EMUs) and Swedish regional two-coach EMUs.



Figure 7.5 CASI interviewing on board the Norwegian ICE

Name of studies and main purpose	1. Evaluation of passenger coach interiors – German InterRegio coaches, Norwegian ICE and Swedish regional EMUs (X10, GLAB) 2. Evaluation of German and Swedish InterRegio passenger coaches (1993, 1995)
Places and dates	German IR: Gothenburg-Karlstad 17-23 Oct. and Stockholm-Västerås 26-29 Oct. 1993 ICE: Gothenburg-Ed(-Oslo), 17-23 Oct. 1993 X10: Gothenburg-Halmstad, 17-23 Oct. 1993 Swedish IR: Gothenburg-Karlstad, 24 May 1995
Type(s) of train/bus	1. Converted German coaches as InterRegio concept, Norwegian four-coach trainset "ICE" and Swedish X10 two-car EMUs with 2+3 seating 2. Converted Swedish coaches as InterRegio concept
Methodology	Background and opinion questions as well as SP experiment (MINT) on small portable computers (Poquet and HP Omnibook); CASI interviewing A few qualitative association questions were added in 1995
Number and type of respondents	German IR 93: 326 + 310 respondents, mixed inter-regional business + private travellers Response rate $\approx$ 90% Norwegian ICE: 142 respondents (response rate 80-90%) X10-GLAB: 104 respondents (response rate 80-90%) Swedish IR 95: 175 respondents, mostly private inter-regional travellers
Studied attributes and attribute levels	"Coach with this type of interior" - "Coach with SJ's standard interiors" Many other attributes were studied and some of them are commented on in the text.
Methodological results	The free association questions help to obtain an intuitive understanding of valuation results
Other SP results and comments	Values were fairly stable from the 1993 SP study to the 1995 SP study. A package of timetable and comfort attributes received the same value as the sum of the two separate attributes.

The valuations with parameter and standard deviation figures only constitute an extract from this very rich study. The main reason for the study was to investigate the value of the

InterRegio concept. So the number of respondents is lower for the interviews on board the Norwegian ICE and the X10 trains.

Table 7.4 Main valuation results. In this table, parameters from different SP experiments are summarised.

Attribute description	Parameter	Stand.dev.	Value (%)
Price parameter 1993 game 2 (relative, %)	-0.079	0.0067	–
.....ditto game 3, German IR coach	-0.084	0.0046	–
Price parameter 1993 game 2 (relative, %)	-0.086	0.0070	–
.....ditto game 3 ICE train	-0.082	0.0055	–
Price parameter 1993 game 2, X10 train (rel., %)	-0.150	0.012	–
Price parameter game 2, 1995 (relative, %)	0.079	0.0090	–
.....ditto game 3, Swedish IR coach	-0.085	0.0066	–
German IR coach interior on Karlstad line (1993)	0.539	0.089	7-8%
German IR coach interior on Västerås line (1993)	0.155/0.332	0.092/0.117	2-4%
Swedish IR coach interior on Karlstad line (1995)	0.680/0.783	0.128/0.169	8-9%
Norwegian ICE (1993)	0.760	0.180	+9%
Swedish X10-GLAB (1993)	0.250	0.150	+2%
All the valuations above in comparison to standard coaches on line			
10 cm extra legroom in Swedish IR coach	0.094	0.125	+1% (95)
Reading saloons and "talk corners":	0.676	0.092	+8% (93)
	0.593	0.122	+8% (95)
Smoke-free train with smoking corners	0.330	0.089	+4% (93)
	0.629	0.123	+8% (95)
Telephone, fax and shielded work place (for a smaller fee)	-0.047	0.121	-1% (93)
	-0.281	0.170	-2% (95)
Free coffee and tea in each coach	0.546	0.127	+6% (93)
	0.497	0.169	+6% (95)
Music/radio outlet at each seat, as well as video at a few seats	0.342	0.124	+4% (93)
	0.218	0.169	+3% (95)
Mandatory seat reservation	0.215	0.093	+2% (93)
	-0.107	0.121	-1% (95)
Seat reservation needed in half the train (in comparison to no seat reservation)	0.701	0.092	+8% (93)
	0.770	0.125	+10% (95)
Air conditioning with cool air in the summer (X10)	0.762	0.149	+5% (X10, 93)
Air conditioning with cool air in the summer (IR)	0.914	0.098	+11% (IR,93)
Individually adjustable fresh air at all seats (X10)	0.449	0.149	+3% (X10, 93)
Individually adjustable fresh air at all seats (IR)	0.880	0.097	+10% (IR,93)
Dimmed lighting with individual reading lamps (in X10 type train)			+8% (93)

The number of observations in the estimation models differs for the different coaches and lines on which interviews were made. Two examples are the Norwegian ICE, where there

were about 725 usable observations, and the German InterRegio on the Västerås line in 1993 with about 1550 observations. For some analyses, the observations in 1993 from the Stockholm-Västerås and Göteborg-Karlstad line were merged. (These merged data were called IRR and were used in the analysis described in Section 6.5 relating to cost and time dependence.)



Figure 7.6 Interior in the Swedish InterRegio coach.

A package factor including both timetable attributes and comfort was created. The description of the attribute levels and the valuation results are presented in the next table.

Table 7.5 Results from addition of timetable and comfort attributes.

Results from Karlstad line	1993	1995
Standard SJ coaches	+16%	+17%
MORE trains; every second hour , faster (-10%)		
Coaches with this NEW interior	+8%	+8%
Today's timetable		
Coaches with this NEW interior	+23%	+25%
MORE trains; every second hour , faster (-10%)		

The travellers' valuation of a better timetable is about twice as high as their valuation of the new InterRegio coaches. When these two attributes were presented together as a package, the valuation of this package was about equal to the sum of the two attributes evaluated individually. This happened both times; in 1993 and in 1995.

7.4 Train or bus (coach) with train interiors?

In 1992, a new train concept, the Danish "IC/3", a multiple unit train, known in Sweden as the "Kustpilen", replaced old rail coaches and buses (130 km) in the county of Blekinge (Karlskrona-Kristianstad) in southern Sweden. The new train was combined with improvements to the timetable and lower fares. Eighteen months later, a new parallel bus/coach service with comfort comparable to that on the new train was added. The bus service aimed to increase the service frequency as a complement to the train and is included in the same timetable. Four bus departures a day were introduced. The "Coast Buses" (KUSTBUSSEN) and the "Coast Train" (KUSTPILEN) form a systematic service with one departure every hour and the buses generally stop at the railway stations.

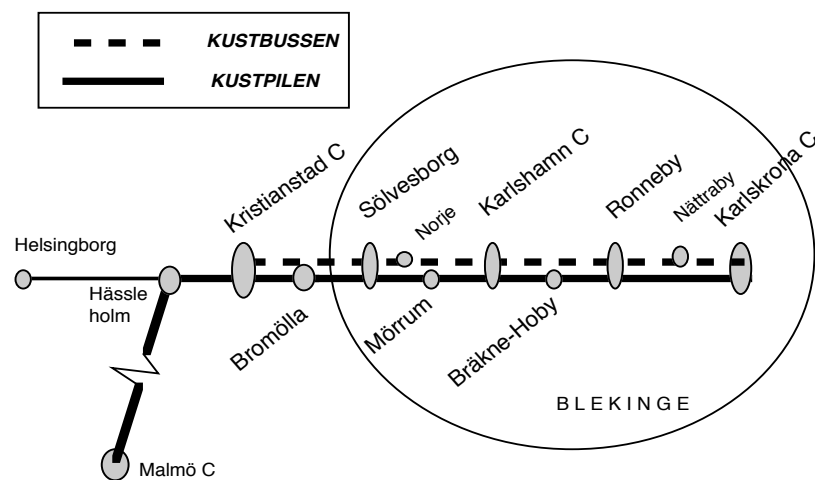


Figure 7.7 The transport system with Kustpilen and Kustbussen in southern Sweden.

In other mode choice projects, buses and trains differ more than they do in this study. Differences that were neutralised in this study:

1. Price level (completely neutral in the experiments, about the same in reality)
2. Travelling time (the same, even in reality)
3. Frequency
4. The location and number of stops
5. The comfort level and size of the seats in buses and trains
6. Comfort measures like noise and vibration levels, ventilation, music outlets, reading lamps and so on

The buses are about as spacious inside as 2nd class trains. The "Coast Bus" and the "Coast Train" both have a high standard, with air conditioning and music outlets at each seat.

There were still a few differences, such as the size and standard of WCs. In the buses, it is easier to look out of the windows, especially forwards, but it is easier to walk around in the train, which is larger.

Name of study and main purpose	The value and cost of trains and buses (coaches) with train interiors. To investigate whether a roomy bus has the same value for passengers as a train and to compare cost levels for train and bus services.
Places and dates	Interview 1: March 16-17 and 23-25, 1994 Interview 2: August 9-10, 1994
Types of train and bus	Train: Kustpilen, Danish IC/3 trainsets for Blekinge regional transit authority Buses, interview 1: 12 m "Kustbussen" bus/coach with 26 seats, 12 m bus/coach with 40 seats and standard bus with 50 seats Buses, interview 2: 14.5 m "Kustbussen" bus/coach with 40 seats
Methodology	CASI = computer assisted self interviews Background and opinion questions as well as SP experiment (MINT) on small portable computers (Poquet and HP Omnibook)
Number and type of respondents	250 + 216 passengers (March, August) = 466 44% of the interviews on Kustpilen (train) and 56% of the interviews on Kustbussen (bus/coach)
Studied attributes and attribute levels	1. Price: lower, as now, higher 2. Travelling time: shorter, as now, longer 3.1 Kustpilen 3.2 Kustbussen (2+1 seats side by side) 3.3 Coach (bus) with extra legroom (10-15 cm more) 3.4 Standard tourist coach (bus) 3.4 SJ train with modern coaches 4.1 No food and drink on board 4.2 Food and drink at your seat (coffee, beer, sandwiches)
Methodological results	People who have chosen one mode are biased towards it; their valuation differs from that of the people who have chosen another mode. Even so, people who had chosen the bus valued the Kustpilen train more highly than their high-standard bus.
Other SP results and comments	The results of the interviews in March and the interviews in August corresponded very well. Cost calculations are presented briefly in Section 10.6.1

As has already been mentioned, the standard factors/attribute levels differed very little in this study. The levels for a number of factors are given below.

Table 7.6 Standard attribute levels for Kustpilen and Kustbussen

Factor/attribute	Level for Kustbussen	Level for Kustpilen
Vehicles	High-standard coaches	High-standard trains (IC/3)
Travelling time (Karlskrona - Kristianstad)	110-115 min	105-114 min
Stops	At railway stations	At railway stations
Seats side by side	2+1	2+2
Seat pitch	77-87 cm	102 cm
Noise level inside	70-75 dB(A)	70-73 dB(A)
Lateral acceleration	< 2m/s ²	Approx. 1 m/s ²
Reading lamps	Yes	Yes
Individual ventilation	Yes + AC	No, but AC
Music outlets	Yes	Yes



Figure 7.8 "Train interior" with two-plus-one seating in Kustbussen

The travellers' valuations were investigated using stated preference interviews on board the high-standard buses and trains in March and August 1994. In all, almost 500 passengers were interviewed. About half these interviews were carried out on board trains and buses respectively. This time, SP data were collected from train and bus passengers using portable (0.5 kg) computers and pairwise choices from randomly-selected train and bus alternatives. The data were analysed using A-logit.

More than 18 different models were estimated to analyse the valuations of different segments. In this thesis, the main results from one model are presented in full, with parameters and standard deviations (see table 7.7 below).

Table 7.7 Main valuation results for all interviews (1,867 observations)

Attribute description	Parameter	Stand.dev.	Value (%)
Price parameter (relative, %)	-0.056	0.003	–
Travelling time (min)	-0.036	0.003	-06%/minute
Standard modern long-distance coach (bus)	-1.235	0.13	-22%
Bus with extra legroom (10 cm extra)	-0.858	0.11	-15%
The "Kustbussen" with 1+2 seating	-0.996	0.11	-18%
Standard SJ train (all in comparison to Kustpilen)	-0.563	0.15	-6%
Catering on board	0.410	0.083	+7%

The main valuation results show the aggregated valuations for bus and train travellers in Blekinge.

Preference for train

Forty-seven per cent of the subjects said that they used the train most frequently, while only 13% most frequently chose the bus. Many of the others often used both the train and the bus. Another question related to the mode, bus or train, people normally preferred for longer journeys.

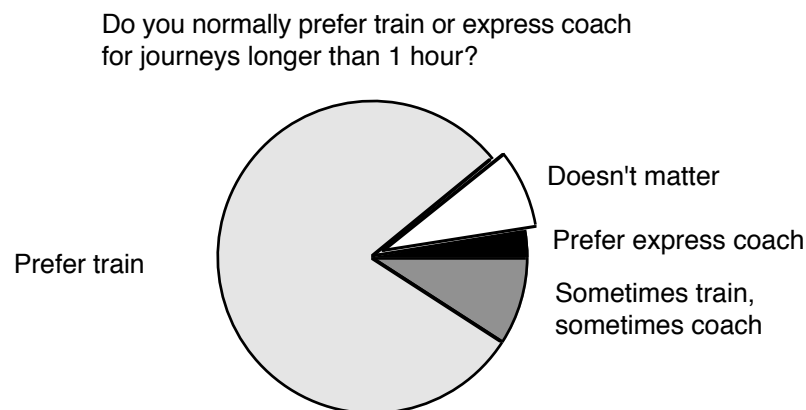


Figure 7.9 Preferences for train and bus concepts.

More than 75% of the people interviewed preferred the train; 70% of the bus passengers normally preferred the train for longer journeys. In August, a question was asked; "Why was the Kustbussen (bus) chosen for this journey and not the Kustpilen (train)?" Eight of 10 said that the bus departure time was more convenient. Only 5% gave the comfort of the Kustbussen as the reason, even though it is one of the most comfortable buses ever built.

Table 7.8 Estimated values from two studies.

Attribute and level	March 94	Aug. 94
Express coach. compared with KUSTPILEN	- 30%	- 30%
Express coach with spacious legroom (10-15 cm extra)	- 17%	- 20%
SPACIOUS express coach (extra legroom and three seats side by side)	-14.5%	
Special express coach "Kustbussen" with (2+1) wide seats - " -		- 23%
Standard SJ train with modern coaches- " -	- 16%	- 13%
Buffet on board	+ 5%	+9%

In table 7.8, the SP values for the various bus alternatives and standard "SJ trains" are presented in relation to the Kustpilen train, which explains why the figures are negative. These figures correspond to a 50/50 mixture of bus and train passenger values.

Train passengers were more negative about the bus alternatives. Taking only train passengers into account, the value of a "modern long-distance bus" is 46% of the fare below the value of the "Kustpilen" train. Their valuation of the roomier buses was about -34%.

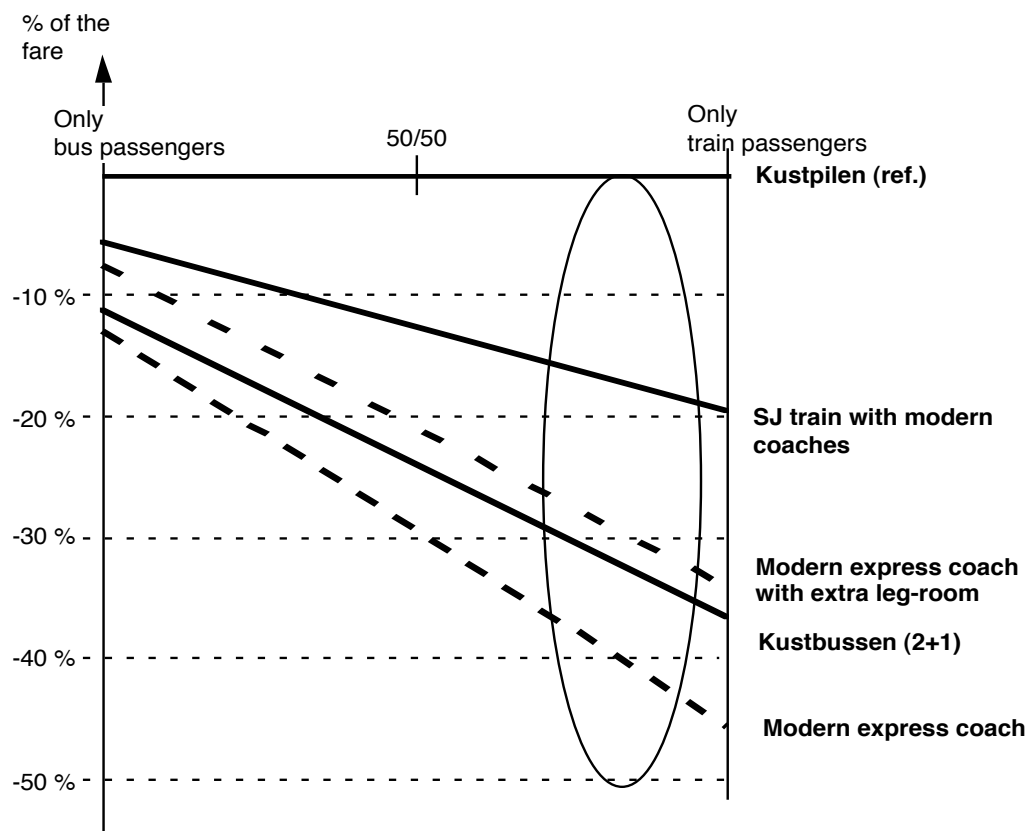


Figure 7.10 Average value of bus and SJ train in relation to the Kustpilen for different mixtures of bus and train passengers

Train passengers valued bus alternatives more negatively than bus passengers did. When they had the chance to choose, most people, say 80%, are like train passengers. So an ellipse is drawn around the valuations at the 80% train-passenger level. A modern express coach is here valued about 40% lower willingness-to-pay than the KUSTPILEN. The standard SJ train is in between; valued 20-25% more positively than the bus alternatives.

Buses with a higher comfort level, "train interiors" or more legroom, are valued up to 10% more highly than standard modern express coaches.

PS. Inertia – sticking with the mode you have chosen

Afterwards, in 1998, the inertia of sticking to the mode people actually use was estimated. A new parameter was created. It was set at one of the alternatives presented on the screen, on the left and right side respectively, and was equivalent to the mode passengers were travelling in. The two possible modes were bus and train. All the variants of buses in the SP experiment were "bus" and both SJ trains and the Kustpilen were calculated as "train".

The estimation result was:

$$\text{Inertia parameter} = 0.459 \text{ (} t = 5.1 \text{)} \approx 8\% \text{ of the fare or } 12\% \text{ of the travelling time}$$

This can be interpreted as meaning that there is extra resistance to changing from bus to train or from train to bus, which is approximately equal to an extra charge of 8% of the fare or a 12% increase in travelling time. In this model, the difference in value between train and bus increased by 2% (fare).

If we take the natural exponent of -0.459, this gives us a ratio of $0.63 = 0.63/1$. This corresponds to a share of 39% ($= 0.63/1.63$). All else being equal (hypothetically), the inertia effect would produce a share of 39% for the new mode instead of 50% if the new mode was as good as the old one. This is an 11% lower share or 22% fewer passengers than would have been the case without inertia. (It is difficult to say whether the Kustpilen is the new or the old mode in Blekinge. It is a train, which was the former main mode on this stretch, but it is a very different train, like a new mode.)

I conclude that there is an inertia effect, but that it does not change the results to any great degree and it is difficult to interpret the effect of the inertia.

7.5 The value of travelling in (small) compartments

In connection with investigations in the project of the space efficiency of various interiors, it was noted that Swedish passengers' valuations of travelling in compartments was missing. A small study²²⁵ was therefore initiated.

Name of study and main purpose	The value of travelling in compartments To investigate compartments as an alternative or complement to open saloons in passenger coaches
Places and dates	Stockholm-Sundsvall, January 18-19, 1994
Type(s) of train/bus	InterCity loco-hauled train
Methodology	Stated preference interviews on small portable PCs
Number of respondents	137 InterCity travellers
Studied attributes	See result table (7.8)

The valuation results of this minor study are presented below in table 7.8.

Table 7.8 Main valuation results

Attribute description	Value (%)
Travelling time (+5%, 0, -5%)	1%/0% time
Compartment for six persons, instead of open saloon	-4%
Compartment for four persons, instead of open saloon	-4%
Automatic coffee dispenser	+5%
Catering at your seat	+11%

The results of this study were reported without explicit parameters and standard deviations.

Two other questions were asked about where people preferred to sit when they travelled alone or where they preferred to sit when travelling with someone else:

Table 7.9 Preferences for travelling in a compartment or open salon

Where do you prefer to sit when you travel	Alone ?	Accompanied ?
In a compartment	16%	44%
In an open saloon	51%	30%
It does not matter	33%	26%

²²⁵ This study was conducted as a joint venture by Stina Rosenlind and me. It was never published.

Table 7.10 shows that the people who prefer compartments are not at all willing to pay so much to travel in a compartment as those who prefer an open saloon are willing to pay for one.

Table 7.10 Valuations for travelling in a compartment segmented on preference for compartment or open salon

VALUATION (% of price) of travelling in a compartment	All those who prefer compartments...	All those who prefer open saloons ...
... when travelling alone	+5%	-10%
... when accompanied	+1%	-14%

The conclusion from this study is that a significant number of travellers prefer compartments, at least when travelling accompanied, but their willingness-to-pay for this option is much lower than the opposite groups' willingness-to-pay for their alternative; the open saloon. In Section 10.2, it is shown that compartments are not beneficial on average.

7.6 The (negative) value of changing trains

A small study²²⁶ about changing trains was conducted on the Ostkustbanan. This is a line on which most passengers do not normally need to change trains. Seventeen of the 190 interviewed passengers had changed trains on the journey in question and 27 of them were going to change. If we assume that a few of them are the same persons, about 20% had to change trains.

Name of study and main purpose	Passengers' valuation of changing trains and having radio outlets at the seats
	To estimate the value of two attributes that were missing at the time
Places and dates	Stockholm-Sundsvall, February 5-6, 1994
Type(s) of train/bus	InterCity loco-hauled train
Methodology	Stated preference interviews on small portable PCs
Number of respondents	190 InterCity travellers
Studied attributes	See result table (7.11).

The valuation results from this minor study are presented below. (As in the previous study, parameters and standard deviations are missing.)

Table 7.11 Main valuation results

Attribute description	Value (%)
Travelling time (+7%, 0, -5%)	0.8%/time
Interchange on same platform. The other train is there.	-9%
Interchange to another platform. Other train in five minutes.	-13%
Radio outlets. You can use your own headphones	+2%
Radio outlets. Rent headphones for SEK 20 or use your own	+1%

Those people who travelled by train "often" (at least once a month) were less negative about changing trains, -8% to -11%, compared with those travelling "less often" (less than once a month), -11% to -16%.

No difference in the valuation of interchange was found for journeys longer or shorter than three hours. This shows that the absolute willingness to pay (in SEK) for a journey without interchange increases with the travelling time.

A significant difference was found in the valuation of travelling time. Those people travelling for three hours or less valued a 10% reduction in travelling time as a 4% lower price, while those with longer travelling times valued 10% of the travelling time as 10% of their ticket price.

²²⁶ This study was conducted as a joint venture by Stina Rosenlind and me. It was never published..

7.7 Travelling by train in tunnels and over bridges

In 1995, there were political discussions about building tunnels for trains under the city centre in Stockholm. An investigation was therefore conducted to investigate passenger preferences when it came to travelling by train in tunnels.

Name of study and main purpose	Travelling by train in tunnels To investigate passengers' valuations of travelling partly in tunnels
Places and dates	Stockholm-Södertälje-Gnesta and Stockholm-Nyköping, November 18-20, 1995
Type(s) of train/bus	InterCity trains, commuter trains (SL pendeltåg)
Methodology	Stated preference interviews on small portable PCs
Number and type of respondents	139 interviews in IC trains 107 interviews in SL trains
Studied attributes and attribute levels (Experiment 1)	The whole of the journey is above ground Five minutes of the journey is in tunnels A long bridge over water instead of a tunnel Ticket price: SEK 2 more, as now, SEK 3 less Travelling time: two minutes longer, as now, three minutes shorter
Methodological results	SP experiment 2 produced (seemingly) unrealistic results: About 6% of the travelling time in tunnels is as negative as 3% of the fare or as 6-9% extra travelling time. This would suggest that it is often not worth saving time by using tunnels.
Other SP results and comments	The estimated time values were normal, about SEK40/h for commuters with monthly season tickets and SEK 45/h for InterCity-passengers. In this respect, experiment 1 worked well.

It was decided to use two different SP experiments with different verbal and numerical formulations. Number one was designed for an absolute estimation model (with SEK and minutes), while number two was designed to produce relative valuations.

Different models were estimated for different types of passenger, but only the main results are presented below.

Table 7.12 Main valuation results for the two experiments.

Attribute description	Parameter	Stand.dev.	Value
SP EXPERIMENT 1 (1,062 observations)			
Price is increased by SEK 2	-0.647	0.123	–
Price is reduced by SEK 3	0.253	0.123	–
Travelling time is two minutes longer	-0.258	0.115	SEK 0.68/min
Travelling time is three minutes shorter	0.258	0.118	SEK 0.45/min
Five minutes of your journey is spent in tunnels, instead of "The whole of the journey is above ground"	-0.869	0.106	SEK -5
You travel over a long bridge over water instead of in a tunnel	-0.740	0.107	SEK -4
SP EXPERIMENT 2 (1,289 observations)			
Price parameter (relative, % of actual fare)	-0.227	0.019	–
Travelling time (relative, % of actual travelling time)	0.092	-0.010	0.4%fare/ %time
X min (≈6% calculated) of your journey is spent in tunnels	-0.759	0.087	3% of the fare 8% of the time

Five minutes in tunnels was valued as negatively as SEK 5 for InterCity travellers, SEK 2 for monthly season-ticket holders and SEK 4 for ticket holders in commuter trains. Daily commuters' valuations were only SEK -1.50 compared with SEK -5 for business and recreational travellers. Travelling on a bridge instead of through a tunnel was estimated SEK 1 less negatively (than in tunnels).

A multiple-choice question revealed that about 70% of the respondents thought "it was OK" to travel in tunnels. About 15% thought it was slightly unpleasant and less than 5% thought it is very unpleasant to travel through tunnels.

If the negative valuation results are correct, tunnels for passenger railways should be used restrictively.

7.8 Study of package effects for train concepts

An extensive SP interview study about package effects was conducted in 1995/1996 by a student (Lotta Schmidt) under my supervision. The nature of and reasons for package effects are discussed in Section 6.4 of this thesis. In this section, a particular study of package effects is summarised.

Name of study and main purpose	Value reduction when evaluating train concepts – a study of comfort, service and timetable factors using the stated preference method
Places and dates	To study the reasons for and size of package effects Part 1: Stockholm-Nynäshamn, 3 weekdays Oct. 1995 Parts 2 and 3: Stockholm-Malmö, 3+3 weekdays Nov.-Dec.1995
Type(s) of train/bus	Part 1: Commuter trains (X10/X12) Parts 2 and 3: Loco-hauled InterCity trains
Methodology	Stated preference interviews on small portable PCs
Number and type of respondents	Part 1: 341 regional travellers Part 2: 361 mostly inter-regional travellers Part 3: 558 mostly inter-regional travellers
Studied attributes and main valuation results, without taking account of package effects (In this table, the purpose is to show comparable attribute valuations, not the package effects investigated)	Seats with high and reclining seatbacks (commuter): +7% Air conditioning (commuter train): +6% Toilet on board (commuter train): +5% Free coffee and tea in each coach: 7-9% Trolley with sandwiches, drinks and magazines: 8-9% Restaurant car with hot and cold food: 8-14% More space for luggage (IC): 1% 10 cm extra legroom (IC): 5% 5 cm wider seat (IC): 4% Radio outlet for headphones (IC): 4% Smoking only in the rearmost coach (IC): 3% Higher frequency; 1 train/hour (IC): 4% 15% shorter travelling time (IC): 12%
Methodological results	There are significant reductions in attribute values when they are evaluated in packages. Comfort attributes showed the biggest value reductions.
Other comments	Package effects in general are analysed in Section 6.4

Summary of part one – comfort factors on board commuter trains

This study, part one, concentrated on the value of individually estimated attributes, which were then compared with combined factors where the corresponding attributes were given. The parameter values for a number of individually estimated attributes were obtained from experiment 1 and the values of corresponding attributes when they were part of the combined factors were obtained from experiments 2–4. The improvements in comfort included the following:

- high, reclining seats
- air conditioning
- toilets on board

The results of part one are based on four experiments, "SP games". Each of them is segmented for the purpose of analysing dispersed and consolidated presentations on the screen. So 12 different models were estimated and, for those interested in parameter value standard deviations, these can be found in Schmidt's report²²⁷.

In these experiments, an evaluation of reduced travelling time was also made. A reduction of 20% in travelling time was estimated to have a value of 11-13% of the fare level (which is low for these commuter trains in the Stockholm region).

The results for individually estimated factors and factors combined, "packages", are illustrated below.

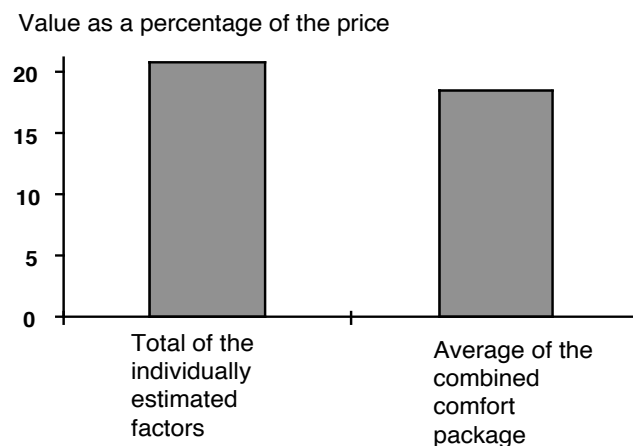


Figure 7.11. The results of Interview No. 1. The value of the comfort factors when estimated individually and when included in packages.

The study indicates that the value of the comfort attributes cannot be added up. In experiments 2–4, the value of the combined factors was less in every case than the total value of the attributes when estimated individually. In other words, three separate groups of individuals considered combined factors to be of less importance than the total value of

²²⁷ Schmidt, L., *Värdeinsknning vid värdering av Tågkoncept – Studie av komfort, service och tidtabellspaket med Stated Preferences-metoden (Value reduction when evaluating train concepts – A study on comfort, service and timetable factors using the stated preference method)*, (pages 111-112), KTH Traffic Planning, TRITA-IP AR 96-44, 1996

the individual attributes. Reductions of 4–20 per cent had been made. These results have led to the conclusion that the value of comfort attributes cannot be added up.

A question was asked about whether the value was affected by the way in which combined factors were presented. The aim of the question was to determine whether the results would be different if combined factors were presented in a more lucid way to the interviewee. Figure 7.12 illustrates the fact that the ratings were higher in cases where the attributes were clearly displayed on the screen.

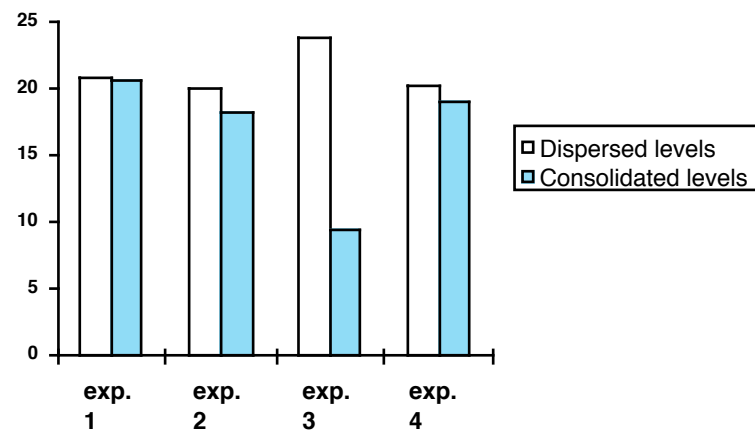


Figure 7.12 The value of all the improved comfort factors. The results are divided up in relation to the way the levels are displayed on the screen (dispersed, consolidated) and with respect to the experiment in which the result was obtained.

There is a tendency for dispersed combined factor levels to be rated more highly than the consolidated levels. One reason for this may be the fact that the client found the task easier under these conditions.

Summary of part two – service on board inter-regional trains

In this interview, the value of individually estimated attributes was compared with combined factors. The ratings for the individually estimated factors were obtained in experiment number 1 and the ratings for the corresponding factors when included in a package were obtained in experiments 2–4. The following factors were observed:

- restaurant car
- food trolley
- free coffee and tea in all coaches

In these experiments on combined factors, the value of a reduction in travelling time was also estimated²²⁸. A reduction of 25–41 per cent of the value was seen. Significance testing indicates that the rating of combined factors differs significantly from the total of the attributes when evaluated individually.

²²⁸ The estimation results for 28 different models are published in the original report (Schmidt).

These results are hardly unexpected. There is no clear-cut opportunity or benefit to be derived from being able to utilise all the catering methods during a trip and this leads to an “overlap” in the values of restaurant car, food trolley and free coffee. However, the value of each type of catering method is interesting if nothing else is available.

The value of each catering attribute is affected by the presence of other catering attributes. Interactive effects are thus present between the catering attributes in the study. Decreasing marginal use in terms of time and budget restrictions is likely to cause a reduction in the value.

Summary of part three – gradually increasing packages

This is the third and most extensive interview. In the first three experiments, the individually estimated values of comfort attributes, service attributes and timetable attributes were obtained.

Comfort attributes studied:

- Luggage compartments double the current size at the ends of coaches
- Increasing legroom by 10 cm
- Seat width extended by 5 cm
- Individually regulated ventilation

Service attributes studied:

- Restaurant car in combination with food trolley
- Radio with headphones at each seat
- Smoking section only in the last coach

Timetable attributes studied:

- Double the frequency of trains
- Travelling time reduced by 15 per cent

In the three initial experiments, individual attribute values were obtained. In experiment 4, the ratings for comfort, service and timetable combined factors were obtained. The same factors in the first three experiments were also included in these packages. Experiment 5 consisted of a single unit of combined factors, containing all the comfort, service and timetable attributes. In this experiment, the free distribution of tickets booked by phone, as well as station guides, was also included. The next figure (7.13) illustrates the results of Interview 3.

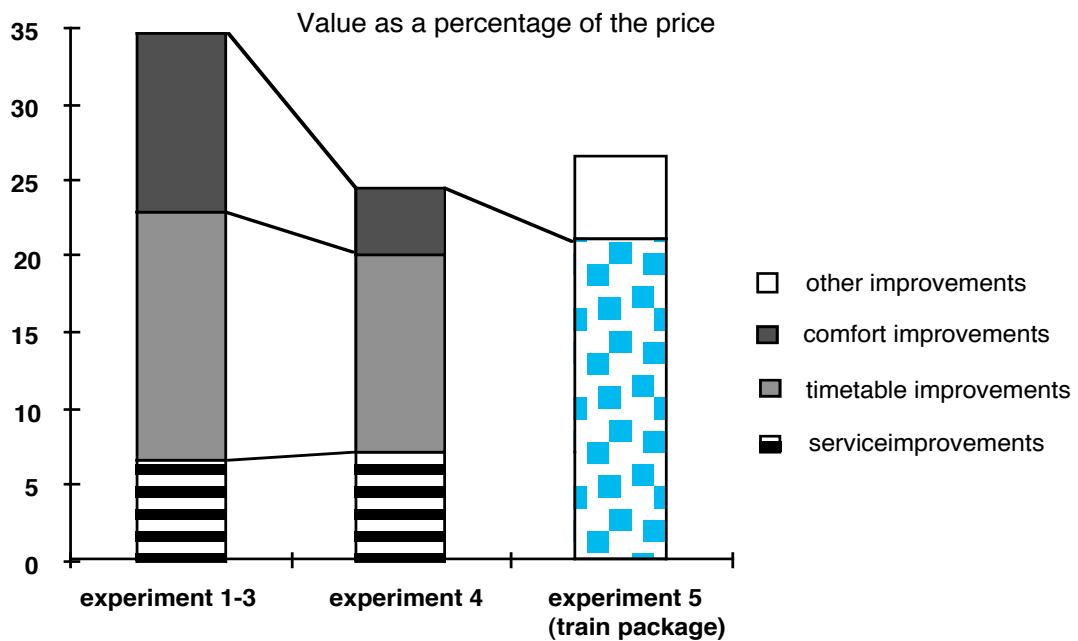


Figure 7.13 The results of Interview No. 3. The value of comfort, service and timetable attributes when estimated individually and when included in a package.

There is a 30 per cent reduction from experiments 1-2-3 to experiment 4. The difference between experiments 1-2-3 and experiment 5 is approximately 40 per cent. This reduction can be mainly attributed to the values of the comfort attributes, which were reduced by 64% of the price. The values of the timetable attributes were reduced by 20%. However, the value of the service attributes was not reduced in this study.

7.9 The value of night and day train services

This study was commissioned by SIKa, the Swedish Institute for Communications Analysis, in 1996. The aim was to obtain valuations for travelling by night and day trains and the summarised value of having both night and day train services.

Name of study and main purpose	Valuation of day and night train services
Places and dates	To investigate whether there is an extra (negative) value for travelling at night and to see whether the combination of day and night services has any extra value. Night trains Stockholm-Umeå/Luleå X2000 train Stockholm-Malmö March 10-15, 1996
Type(s) of train/bus	Night cars, mostly 1/2-berth and couchettes, 6-berth
Methodology	Stated preference interviews on small portable PCs
Number and type of respondents	Night train: 62 recreational + 51 business travellers X2000: 60 recreational + 102 business travellers Total: 122 + 153 = 275
Studied attributes and attribute levels	One price and two timetable attributes (night and day) 1. Price (see text) 2.1 No night train service 2.2 Night service as today, dep.8 pm arr.7.30 am(Umeå) 2.3 Later night service, dep. 11 pm arr. 7.30 am (Umeå) 3.1 No day service by train 3.2 Bus 4 h + train 4.5 h (9h with interchange) 3.3 X2000 service (6h), dep. 6, 9, 12, 15, 17 3.4 Faster X2000 (4h), dep. 6, 9, 12, 15, 18 Luleå interviews had longer travelling times. Malmö interviews had X2000 every second hour with 7 h and 5 h travelling times.
Main valuation results	Night train only SEK 520 (leisure) and SEK 815 (busin.) Night train + day trains SEK 1,055 (recre) and SEK 1,980
Methodological results	Bus (coach) + train with interchange received negative utility in relation to no service, which is questionable.
Other SP results and comments	This SP interview has been analysed using the think-aloud protocol method in a parallel degree project ²²⁹ .

²²⁹ Nyström, T., *Tänka högt-metoden. Kan tänka högt-metoden öka Stated Preference förklaringsvärde?* (The think aloud protocol-method. Can the think aloud-method increase the explanatory power of SP?), degree thesis no.96-27, KTH Traffic & Transport Planning, 1996

Background

In socio-economic cost-benefit analyses, the benefit of service changes customarily uses travellers' evaluations of time and frequency. The current service is then used as a reference. In calculations of the benefit of the Bothnia line, an attempt was made to use this method. The transport service to be evaluated is fast day trains Stockholm-Umeå (-Luleå). The night trains have been used as a reference. How should the time at night versus the time during the day be valued? How can the benefit of travelling on a night train in one direction and a day train in the other direction be included?

Due to these difficulties, the Department of Traffic and Transport Planning was commissioned by SIKÅ, in consultation with the National Rail Administration, to carry out a stated preference study. The study was performed in one week in March 1996.

The study and its results

Travellers on night trains destined for Umeå and Luleå were interviewed to obtain evaluations from current Stockholm-Norrlund train passengers. It could be assumed that night passengers would have a preference, displayed as a higher willingness to pay for a night train than the average Swede. In order to create a better balance, travellers on the X2000 between Stockholm and Skåne were also interviewed. They would be assumed to have a higher preference for day trains than night trains. They might also be assumed to represent the after-the-fact situation when the Bothnia line is built and serviced by the X2000.

Passengers were interviewed using pocket computers and were asked to make pairwise choices of timetables with and without day and/or night trains. The day and the night train service attributes also had different levels corresponding to old railways with slow services and new lines with faster services.

The results of linear logit models, segmented between leisure/work and Norrlund/Malmö, are presented below. The parameter weights of the different levels of day and night services are shown.

Tables 7.13 a/b Main valuation results.

Malmö, leisure	Parameter	t-value	Value (SEK)
Attribute description			
Price (SEK 1,000)	-4.20	9.2	—
Night train service	0.59	3.4	141
Faster night train service	0.60	3.2	143
InterCity 7 hours (Stockholm-Malmö)	1.44	7.1	343
X2000 5 hours (Stockholm-Malmö)	2.60	10.3	619
X2000 3 hours (Stockholm-Malmö)	3.06	10.2	728
Malmö, business			
Price (SEK 1,000)	-1.67	5.7	—
Night train service	0.60	4.7	361
Faster night train service	0.51	3.5	308
InterCity 7 hours (Stockholm-Malmö)	1.08	7.2	651
X2000 5 hours (Stockholm-Malmö)	2.15	11.8	1,290
X2000 3 hours (Stockholm-Malmö)	3.00	13.5	1,798

Norrland, leisure	Parameter	t-value	Value (SEK)
Attribute description			
Price (SEK 1,000)	-1.48	5.3	–
Night train service	1.32	7.9	895
Faster night train service	1.37	7.2	922
Intercity+bus 9/14hours (Stockholm-Umeå/Luleå)	-0.66	3.8	-446
X2000 6/10 hours (Stockholm-Umeå/Luleå)	0.67	3.6	454
X2000 4/8 hours (Stockholm-Umeå/Luleå)	1.06	5.4	717
Norrland, business			
Price (SEK 1,000)	-1.21	3.6	–
Night train service	1.55	8.3	1,274
Faster night train service	1.44	6.8	1,188
Intercity+bus 9/14hours (Stockholm-Umeå/Luleå)	-0.24	1.2	-194
X2000 6/10 hours (Stockholm-Umeå/Luleå)	1.27	5.7	1,044
X2000 4/8 hours (Stockholm-Umeå/Luleå)	1.50	6.1	1,233

The weight of the price attribute was found to be different, non-linear, for different levels of ticket prices. In the models shown above, the weights for the SEK 1,000 price levels have been used. The weight of money has been assumed to be linear from 0-1,000.

The valuation figures below show the value of having a certain service in relation to not having that service.

Table 7.14 Valuations in SEK of having certain services, in relation to not having them.

Malmö	Private	Business	Norrland	Private	Business
Night train	140	360	20.00 - 7.00	900	1,270
Faster night train	140	310	23.00 - 7.00	920	1,190
InterCity (7h)	340	650	Bus + train, incl. one c hange (9h / 14 h)	-450	-190
X2000 (5h)	620	1,290	X2000 (6h / 10h)	450	1,040
Faster X2000 (3h)	730	1,800	Faster X2000 (4h / 8h)	720	1,230

As a control, the time values can be calculated by comparing the values for the X2000 and (a two-hour) faster X2000.

Table 7.15 Implicit time values for marginal day and night travelling times (evening/morning).

Malmö	Private	Business	Norrland	Private	Business
Time value, evening night train	≈0	SEK -15/h	Time value, evening 20.00 - 23.00	≈0	SEK -25/h
Time value day; X2000	SEK 55/h	SEK255/h	Time value, day X2000	SEK135/h	SEK 95/h

The time value of having a faster night train is close to zero. It appears not to be worthwhile to delay the departures of night trains. (It is not apparent from this estimation whether it would be advantageous to delay the 5 pm departure for Luleå.)

The time values for Malmö travellers are close to the anticipated values. For night-train travellers, the time values deviate from the anticipated levels. This may result in part from the fact that a daytime connection *exists* and is highly appreciated and in part from the fact that *the difference between two large numbers* mathematically tends to be unreliable.

The above results can be presented as values for different timetables as shown below:

Stockholm - No rrland		
	Night tra in	Night tra in
Departure	5 pm	8 pm
Arrival Umeå		7.30 am
Arrival Luleå	7.30 am	11 am

Value private: SEK 900 versus no trains at all

Value business: SEK 1,270 versus no trains at all

Stockholm - No rrland								
	Night tra in	Night tra in	X2000	X2000	X2000	X2000	X2000	X2000
Departure	5 pm	8 pm	6 am	9 am	12 pm	2 pm	3 pm	5 pm
Arrival Umeå		7.30 am	12 pm	3 pm	6 pm		9 pm	11 pm
Arrival Luleå	7.30 am	11 am	4 pm	7 pm	10 pm	12 am		

Value private: SEK 1,350 versus no trains at all (SEK 450 versus night train)

Value business: SEK 2,310 versus no trains at all (SEK 1,040 versus night train)

Stockholm-Mal mö or vice vers a	
	Night tra in
Departure	9 pm
Arrival	8 am

Value private: SEK 140 versus no trains at all

Value business: SEK 360 versus no trains at all

Stockholm- Malmö or vice versa	Night train	X2000	X2000	X2000	X2000	X2000	X2000	X2000
Departure	9 pm	6 am	8 am	10 am	12 pm	2 pm	4 pm	6 pm
Arrival	8 am	11 am	1 pm	3 pm	5 pm	7 pm	9 pm	11 pm

Value private: SEK 760 versus no trains at all (SEK 620 versus night train)

Value business: SEK 1,650 versus no trains at all (SEK 1,290 versus night train)

Conclusion and discussion

Usually, when the ticket price is used in an SP experiment to investigate cost sensitivity, evaluations that represent *value added* (or consumer surplus) are obtained, over and above the ticket price that has been paid. In this special case, the reference levels are no trains and this has no value. The value should therefore represent *the entire willingness to pay*. In this case, the current ticket price should be deducted to obtain the consumer surplus, as I understand it. Whether or not this is correct is (not as yet) self-evident, but, if we choose a careful approach, the ticket price should be deducted.

By taking the average of the day-train travellers' (Malmö) and the night-train travellers' (Norrländ) individual willingness to pay, we obtain the following values:

Table 7.16 Valuation results, ticket price and consumer surplus

Value of service	Private travellers	Business travellers
Value of night train	$(900+140)/2 = \text{SEK } 520$	$(1270+360)/2 = \text{SEK } 815$
Value of night and day trains	$(1,350+760)/2 = \text{SEK } 1,055$	$(2310+1,650)/2 = \text{SEK } 1,980$
Extra value of day services	$1055-520 \approx \text{SEK } 500$	$1980-815 \approx \text{SEK } 1150$
Average ticket price	SEK 580	SEK 740
Consumer surplus per traveller – just night trains	$520-580 \approx 0$	$815-740 \approx \text{SEK } 75$
– night and day trains	$1,055-580 \approx \text{SEK } 475$	$1,980-740 \approx \text{SEK } 1,240$

The estimated result appears to be that the consumer surplus of having both day and night train services might be somewhere in the region of SEK 500 per private (leisure) traveller and about SEK 1,200 per business traveller. If we instead take the extra values of day services into account, these are of the same magnitude, for both private and business travellers.

The values achieved in this study have been questioned; they seem to be too high. If this is a result of focusing effects, that use to influence SP studies, or if there are some other methodological problems has not yet been solved. In case the achieved valuations are true they impose a high value of building the Botniabanan and to run both night and fast day services.

7.10 Evaluation of 2+3 seating (degree thesis)

This project was initiated to further investigate whether it is profitable to use wide-bodied trains with 3+2 seating on Swedish railways. The study was conducted using four different choice methods; SP pairwise on small PCs, best/worst conjoint, paper interviews about preferred seats and by studying which seats were chosen (RP, revealed preferences). So another reason for this study was to compare the results produced by various methods.

The work was conducted as a degree thesis by Pär Båge²³⁰.

Name of study and main purpose	Are wide-body trains profitable? To evaluate wide trains with 3+2 seating arrangement
Places and dates	Interviews on regional trains in Östergötland and Jönköping (Vättertåg).
Type(s) of train/bus	X14; regional two-car EMUs with some 3+2 seating
Methodology	Four value-elicitation methods were used: 1. SP interviews (CASI) with pairwise choices (SP1) 2. Best/worst interviews (CASI) 3. Paper interviews about preferred seats (SP2) 4. RP observations about chosen seats A calculation of the value and cost of wide-bodied coaches with 3+2 seating was also made.
Number and type of respondents	1.+ 2.: 160 passengers on local/regional EMUs About 70% were daily commuters
Studied attributes and attribute levels	Sitting where there are 2/3 seats side by side Sitting next to the window/aisle Sitting back/forwards Sitting face-to-face/back
Valuation results	See text
Methodological results	The four methods produced similar results for common attributes. The B/W study revealed a high level of importance for some factors (face-to-face/back).
Other SP results and comments	It should be possible to estimate the SP and RP results together, but this has not been done.

The data was collected on X14 trains which are about 3.1m wide on the outside. It is then possible to use a 3+2 seating arrangement using bus seats ($\approx 48\text{cm}$) but not using the standard train seat width ($\approx 53\text{cm}$).

²³⁰ Båge, P., *Är breda tåg lönsamma? En värdering av olika sittplatsarrangemang med fyra intervjuetoder (Are wide trains profitable? Evaluation of different seat arrangements with four interviewing methods)*, degree thesis 97-53, KTH Traffic and Transport Planning, 1997



Figure 7.14 Interior of the X14 EMU where interviews and observations were made.

The study started with an observation of the way people choose seats from main stations where the train was empty, or almost empty. Figure 7.15 shows an example of the seats that were taken during one observation. This revealed passenger preferences.

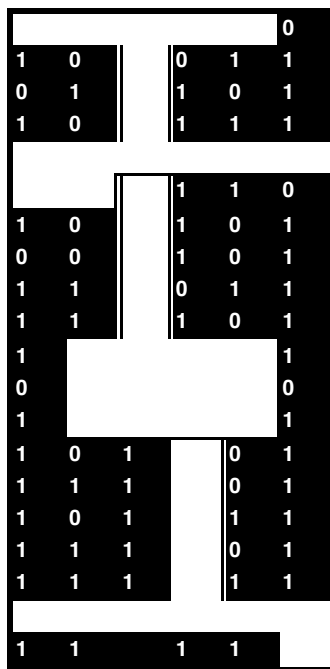


Figure 7.15 An example of an RP observation in an X14 car. Black represent seats, 1 = occupied, 0 = free seat.

To make discrete choice analysis feasible, there should always be at least one seat of each seat type free.

Passengers on the same trains were then interviewed using three SP methods. A computer interview contained a standard pairwise choice experiment (SP1) and a best/ worst experiment about similar attributes. Finally, a second SP experiment (SP2) was conducted in which people had to choose seats on drawings with seat arrangements, where only two seats were still free.

The estimates from the four different methods are similar, but there are a few differences. One is that passengers do not show a negative preference about choosing a seat in a group of three, while they state negative preferences in both B/W and SP2 interviews.

The best/worst interview revealed that the choice of seating arrangement matters. Sitting by the window and having the seat beside you free are the requests with the highest values on a common utility scale. Although face-to-face or face-to-back had an average value close to zero, it ranked fairly high in terms of importance. Clearly passengers have strong views about the way they sit in this context, but their preferences differ.

Table 7.17 Estimated parameters for the four different methods for passengers' seat preferences. One method, the RP study, was estimated using logit and probit models.

Attribute	RP		SP		
	logit (by hand)	probit (Limdep)	SP1	B/W	SP2
Price +7%			-0.58 (5.7)		
Price -10%			0.98 (8.8)		
Price diff. 17%				1.92	
Window seat	0.81	0.97 (14.0)	0.98 (8.8)	1.06	1.28 (5.5)
Centre seat	-0.75	-0.96 8.0	-0.58 (5.7)		0.37 (1.1)
Group of three seats	-0.03	0.42 (5.4)		-0.80	-0.68 (4.1)
Face-to-back seating	0.09	0.21 (3.2)	-0.05 (≈1.0)	0.10	
Free seat next to passenger			0.86 (5.3)	1.04	2.85 (6.6)

In the following figure (7.16), a common scale is used to present all the attributes and levels. The distances between two levels of an attribute can be compared to the distance between "today's price level" and "10% lower price". The attribute importance in relation to other attributes can be assessed by the height on the common utility scale.

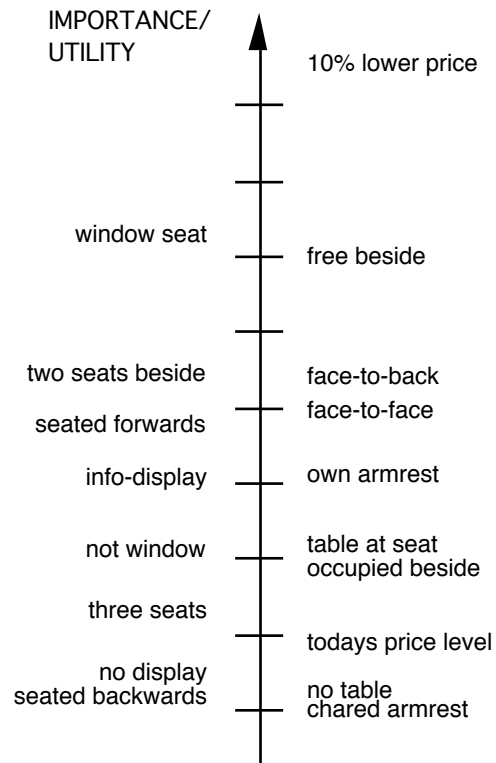


Figure 7.16 Results of the best/worst experiment, presented on a common scale.

The paper interview, SP2, contained 18 choices between different seats, also including the choice of standing up instead. This was an attempt to determine the value of the space for standing passengers. The results mainly reveal the same valuations as the other methods, but they also indicate that passengers do not like squeezing past other passengers who are already sitting down to reach an empty seat.

This degree thesis also calculated the cost-benefit for wide trains with 2+3 seating in comparison to standard trains with 2+2 seating. These calculations show that costs would decrease by about 8%, while the negative valuation is between 0 and 4%. This subject will be further elaborated on in Section 10.5.

7.11 Evaluation of BrainTrain

As part of a project about information technology and mobile working, a railway coach was converted to make it suitable for work and studying. The idea was to link the various campus cities of "Mitthögskolan" University; Östersund, Sundsvall and Härnösand more effectively. The travelling time between Östersund and Sundsvall is about two hours, while it is about one hour between Sundsvall and Härnösand.

Name of study and main purpose	BrainTrain passengers' valuations, spring 97 To evaluate passenger appreciation of the BrainTrain concept.
Places and dates	Railway stretch Östersund-Sundsvall-Härnösand. April 11, 1997 (a few interviews other days)
Type(s) of train/bus	BrainTrain coach, a special-purpose railway coach – a coach equipped for university studies and work.
Methodology	Paper questionnaires and computerised SP interviews. On paper: 1) Allocation of SEK 100 to a number of attributes 2) Best/worst experiments. On computer: Pairwise choices and best/worst (???)
Number and type of respondents	About 50 students and staff at Mitthögskolan University
Studied attributes and attribute levels	About 20 attributes related to the design and use of the "BrainTrain" coach - a railway coach specially converted for work and studies.
Valuation results	See text.
Methodological results	Individual estimates from B/W interviews showed distributions of values that are far from normal. Many respondents appear to allocate zero values to some attributes.
Other SP results and comments	This study used alternative SP methods. One reason was the specific goal of evaluating the design of a specialised coach.

The coach was planned to have a good office-like environment for work and studies, including information technology such as 220V outlets for PCs, Internet connections, printer, fax machine and so on.

The request to design and evaluate the BrainTrain interior was made to KTH and the work was done by the author of this thesis.

To increase the usefulness of this special coach, we proposed an interior design that could also be used for ordinary travellers, at weekends and during summer periods, for example. Another reason for this was the negative experience SJ had with their office coaches some years earlier.

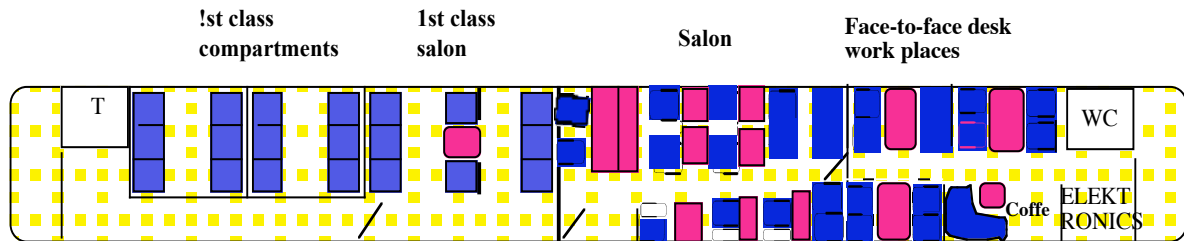


Figure 7.17 Approximate drawing of the BrainTrain coach.



Figure 7.18 Interior of the BrainTrain salon – "classroom".

Distribution of money

Two methods for evaluating the BrainTrain were used. The first method consists of asking the traveller to distribute money on various attributes.

The method has its shortcomings, but it was still worth a try. One shortcoming is that the respondents use different "scales". One person may have a very wide scope when it comes to what he/she finds important or less important, while others may have a carefully "balanced" scale of evaluation. Despite this and other unclear factors, the average of the travellers' evaluations is presented below.

The first distribution consisted of 11 factors classified by "compartment". The second distribution consisted of seven factors classified by "seat". The third distribution consisted of four factors classified under "traffic service".

Table 7.18 results from distribution of money experiment

Factor (compartment)	How many SEK? (part of SEK 100)
There should be a "work station" with a desk and movable chairs	0.15
There should be a "lecture saloon" with seats facing a whiteboard and an OH screen	0.07
There should be a "conference section" with a large conference table	0.04
There should be a separate coffee table	0.06
Mobile telephones in the compartment should work without any disturbance over the entire distance	0.07
There should be connections to external data networks (Internet)	0.15
There should be printers for printouts from PC and Mac	0.09
There should be fax machine in the coach	0.02
There should be a copier in the coach	0.07
There should be considerably less noise	0.09
The train should shake far less	0.19
Total	SEK 100 = 1.00
Factor (seat)	
The folding tables should be adjustable vertically and horizontally	0.26
You will always have access to the seat next to you (no-one unknown to you may sit there)	0.04
There should be a curtain for the work stations	0.07
The work stations should be furnished with adjustable office chairs	0.14
There should be electrical power (230V outlets) at the seats	0.16
Lighting should be adjustable for every seat	0.17
Ventilation should be adjustable for every seat	0.16
Total	SEK 100 = 1.00
Factor (traffic service)	
Departure/arrival times should be moved up 15 minutes	0.11
Travelling time should be reduced by 15 minutes	0.22
There should be five departures a day (compared with three at present)	0.43
There should be transfer buses between the station and the university for each train	0.24
Total	SEK 100 = 1.00

The results have been presented as parts of SEK 100, but they should not be interpreted in this way. The respondents were told the same thing.

Best/worst interview

An example of a best/worst alternative with two choices is shown below. There is one best and one worst response for each alternative BrainTrain type.

<u>Best</u>	<u>BrainTrain type 1</u>	<u>Worst</u>
	No Internet, printer, fax machine or copier on the train	X
	Your mobile telephone works as well as it does at present	
	Vibration and noise levels as today	
	No 230V outlet	
	Cost SEK 75	
	Three trains a day, as today	
X	Travelling time as today (about two hours)	

Figure 7.19 Example of questionnaire layout for best/worst question

The number of answers were distributed as shown below:

Table 7.19 Number of best and worst marks

Best no.	Factor	Level	Attribute (factor + level 0/1)	Worst no.
0	Data	0	No Internet, printer, fax machine or copier on the train	89
52		1	Internet, printer, fax machine and copier on the train	4
12	Phone	0	Your mobile telephone works as well as it does at present	10
10		1	Your mobile telephone works without interruption	3
0	Shaking	0	Vibration and noise levels as today	71
33		1	Much lower vibration and noise levels than today	6
2	Outlet	0	No 230V outlet	36
5		1	There is a 230V outlet	5
9	Price	0	Ticket price is SEK 75	116
145		1	The journey is free	0
25	Freq.	0	Three trains a day, as today	42
88		1	Five trains a day (instead of three as at present)	0
16	Tr.time	0	Travelling time as today (about two hours)	32
40		1	Travelling time is 15 min shorter than today	2

In the next diagram, the relative utility for the high levels (1) in comparison to the low levels (0) is shown. It has been calculated from the above statistics.

Table 7.20 Utilities and valuations for attributes in the best/worst experiment

Attribute	Utility	In SEK
DATA: Internet, printer, fax machine or copier on the train	8.7	41
PHONE: Your mobile telephone works as well as it does at present	0.3	1
VIBR+NOISE: Vibration and noise levels as today	6.2	29
COMPUTER CURRENT: 230V outlet	2.1	10
TICKET PRICE SEK 75/free	15.9	75
FREQUENCY: Five/three trains a day	6.8	32
TRAVELLING TIME: As today (about two hours)/15 min shorter	3.3	14

7.12 SP interviews for pre-study of the value of the Svealand Line

This was a degree thesis conducted under my supervision. An interview study was conducted on the buses between Eskilstuna and Stockholm, the same stretch as the new Svealand Line (opened in the summer of 1997), and in the city of Eskilstuna. The work was done as a degree project by Lars Segerman²³¹.

Name of study and main purpose	Travelling habits in the Svealand Line area of influence – people's knowledge and valuations
	To conduct a pre-study of knowledge and preferences prior to the opening of the new railway line
Places and dates	A. On board buses Stockholm-Eskilstuna B. In Eskilstuna; offices and shopping mall
Type(s) of train/bus	Medium-standard coaches (buses) replaced trains when the Svealand Line was being built (1994-1997).
Methodology	SP pairwise on small portable PCs
Respondents	280 persons, bus passengers and inhabitants of Eskilstuna
Studied attributes and attribute levels	<u>Price</u> (for Eskilstuna): SEK 55, 110, 130, 175 Price (in bus interviews): 50%, 100%, 120%, 160% (presented on screen in kronor (=SEK)) <u>Mode</u> : 1. The future train (type X2000), travel time 1 hour 2. The future train (type X2000), travel time 1 h 37 min 3. Standard SJ train, loco+coaches, travel time 1 h 37 min 4. Today's bus service, travel time 2 h 14 min 5. Your car (presented only to some respondents) <u>Frequency</u> : 1. Every half hour (rush hour more frequent) 2. Every hour (rush hour more frequent) 3. Every two hours (rush hour more frequent) 4. Every three hours (rush hour more frequent)
Other SP results and comments	Each mode had its own travelling time, apart from future trains, which had long and short time levels. From the difference in valuation of these two time levels, a time weight could be estimated. The ticket price and travelling time that were presented depended on the passenger's destination in the case of the bus interviews.

²³¹ Segerman, L., *Resvanor i den nya Svealandsbanans sträckning. Allmänhetens kunskaper om och värderingar av olika trafikutbud.*, degree thesis 97-51, KTH Traffic and Transport Planning, 1997

An example of estimation results, including parameter values, now follows. The rest of the results are presented in the text.

Table 7.21 Main valuation results.

Attribute description	Parameter	Stand.dev.	Value (%)
Price parameter	-0.0297	0.0024	–
SJ train including its travelling time level	1.165	0.200	+39%
New train with moderate speed	1.497	0.212	+50%
New high-speed regional train	2.903	0.254	+98%
Half-hour to one-hour frequency	-0.1939	0.188	-7%
Half-hour to two-hour frequency	-0.346	0.209	-12%
Half-hour to three-hour frequency	1.122	0.205	-38%

The reference level for the mode attribute is *bus* and its travelling time. The valuations are:

- SJ train: 39-52% of the price (including value of time)
- Future train (1, long time): 50-64% (incl. long time)
- Future train (2, short time): 98-108% (incl. short time)
- Car alternative: -87% of the price for bus/train journey

The value differed a little for various estimation models.

Value of time: SEK 65/h (average value)

Frequency: The reference level is *two trains* an hour.

- One train every hour: SEK -3
- Every two hours: SEK -15
- Every three hours: SEK -38

A few of the 17 conclusions in the study are as follows. Most of the people who were travelling by bus would probably have chosen the (faster) train if they had the opportunity. People in general had a good knowledge of the travelling time of the bus, but they underestimated the frequency of the bus service and overestimated the ticket price level. The increase in travelling that took place when the old and infrequent train service was replaced by a frequent bus service must depend on the addition of new travellers and not the fact that old travellers did more travelling.

The private car alternative had a negative parameter in comparison to train and bus alternatives, but this can be explained by the fact that people had to imagine and include a cost and travelling time for the car. This appears to produce no extra value for the private car; it may even be the case that the calculated negative value of -20% in comparison to the bus is correct. That would mean that with equal prices, travelling times and high frequency on public alternatives, fewer than 50% of travellers would chose the car for journeys to Stockholm.

7.13 SP-interviews for research project about the impact of the Svealand-railway

In 1994, the train service was closed on the previously inferior track between Stockholm and Eskilstuna. A new fast railway, the Svealand Line, was completed in the summer of 1997. During the construction period, buses were run at a high departure frequency, once an hour. The new railway is thought to be having an impact on the region's development. Oskar Fröidh at the Department for Traffic and Transport Planning, KTH, is analysing the railway's impact on housing, industry and regional planning.



Figure 7.20 A short version of the "X2000" is used on the Svealand-railway.

The main reason for including stated preference investigations is to evaluate travelling from a national economy point of view.

Within the scope of Fröidh's project, the residents' and travellers' evaluation of transportation is being studied before and after the new rail service opened. SP interviews were conducted in 1997 among bus passengers and residents and among train passengers and residents in 1998. For reasons of compatibility, paper questionnaires were used on board trains as well as in the postal survey.

To make it possible to compare the results with those of the Segerman thesis (see 7.12), similar SP interviews were conducted in 1998 on computers as were conducted in Segerman's work. The train passengers' evaluations can therefore be compared with the earlier bus passengers' evaluations in yet another way.

Name of study and main purpose	Establishment of the new Svealandsbanan rail link – impact on travel market and regional development²³². To conduct SP interviews within this research project about the impact of the new Svealand rail link.
Places and dates	A. On board buses Stockholm-Eskilstuna, Stockholm-Nyköping (spring 1997) B. On board trains Stockholm-Eskilstuna, Stockholm-Nyköping (spring 1998) C. Mail interviews in Svealandsbanan and Nyköping area (1997 and 1998)
Type(s) of train/bus	Medium standard coaches (buses) replaced trains when Svealandsbanan was being built (1994-1997). New train service with X2000-like trains started summer 1997.
Methodology	SP ratings of travel alternatives on paper questionnaires (1997 and 1998) SP interviews on small portable PCs (only 1998)
Number and type of respondents	Bus passengers Stockholm-Eskilstuna Bus passengers Stockholm-Nyköping (reference) Inhabitants in the Svealandsbanan area Inhabitants in the Nyköping area (reference)
Studied attributes and attribute levels	Price: Two levels for single fares (depending on dest.) Mode: Bus, former train, X2000 train Travelling time: Levels depending on destination Frequency: 2h/1h or 1h/half hour (depending on dest.)
Valuation results	See text.
Methodological results	Difficult to combine realistic alternatives with an uncorrelated orthogonal design. Average ratings of alternatives clearly showed the ranking. The car alternative received a low ranking compared with train alternatives.

This research project analyses the introduction and impact of a new rail service. The research is being led by Oskar Fröidh and I have been helping to design and conduct SP interviews on the value of the new high-speed regional train services.

²³² Research project by Oskar Fröidh, Traffic & Transport Planning, KTH, ongoing 1996-2001

Two rating assessment experiments have been completed in each paper questionnaire. The first experiment comprised buses, regular trains and high-speed trains (X2000). A travelling time was linked to each means of transport; it was then adapted to the individual destination. The price varied on two levels. The second experiment comprised alternatives with high-speed trains with varying prices, travelling times and departure frequencies, two levels for each attribute. In addition, drivers/car owners were asked to rate their "own car".

Since the main purpose is to establish the value of the new transportation, this can be presented without being divided into the sub-values of improved travelling time, departure frequency and means of travel. In the next phase, these sub-values may also be presented. However, it has been difficult to obtain reliable values in the grading questions, as the presented travelling times were connected to means of travel in order to be perceived as realistic by the respondents.

The value of three of the alternatives, for Svealandsbanan respondents (the mail survey), are presented below:

	Rating on a scale of 1-10, at high/low price levels	Approximate value (for Stockholm-Eskilstuna)
Standard SJ train, 1.5h	≈ 3.7/7.3	≈ SEK 20 more than bus
Bus service, 2h	≈ 2.5/5.4	Reference level (= 0)
New high-speed service, 1h (X2000-like)	≈ 5.4/9.4	≈ SEK 40 more than bus

If the mode itself has no extra value, the entire value would depend on time savings. In that case, the value of time is SEK 40/hour. Linear regression estimates based on the interviews on buses revealed SEK 40-45/hour and, for the inhabitants (postal survey), the value was estimated at SEK 45/hour. The extra value for travelling by train, especially the X2000, instead of by bus has been difficult to estimate, but it appears that SEK 10 is an approximate value for the X2000 in relation to the bus, when travelling time and frequency are equal. This should correspond to about 10% of the fare.

The individual ratings have also been converted to rankings and estimated using a discrete choice model in Limdep. The results of this estimation are of the same order.

In table 7.22, the estimation results for all Eskilstuna travellers are shown (1,758 observations).

Table 7.22 Main valuation results for Eskilstuna-Stockholm travellers.

Pairwise choice computer interview (1998)			
Attributes	Parameter	t-value	Value (%)
SJ train service including rel. low speed ref. is slow bus service)	(1.35	8.9	+72
New train with moderate speed	2.24	13.9	+120
New high-speed regional train service	2.97	17.4	+158
1h frequency (reference is 2 trains/hour)	0.01	0.1	0
2h frequency	-0.28	2.1	-15
3h frequency	-1.09	7.6	-58
Price -50%	0.89	6.7	–
Price +20%	-0.29	2.2	–
Price +60%	-1.44	9.9	–
Car alternative	0.73	4.5	+39

In the bus and train service alternatives, driving times were included. They were adjusted by the computer with relation to answers about origin and destination. The driving times were then randomised slightly around the average values. The randomisation was done using a rectangular frequency distribution function. Example of approximate average times for Stockholm-Eskilstuna: bus 120 minutes, SJ train 90 minutes, new train 90 minutes and 60 minutes.

The following results from the pairwise choice interviews in 1998 on board the new Svealandsbanan trains are compared with the on-board bus interviews in 1996. The results for 1996 relate to all destinations along Svealandsbanan, while the value for 1998 is for Eskilstuna.

Table 7.23 Comparison of valuation results from on-board pairwise choice interviews in 1996 and 1998.

Attribute	Autumn 1996 on board the buses	Spring 1998 on board the new Svealandsbanan trains
(Old)SJ train	SEK 17 more than bus	15% ≈ SEK 15 more than bus
New train (X2000)	SEK 31 more than bus	36% ≈ SEK 36 more than bus
Time value	SEK49/hour	48%/hour ≈ SEK 5/h
Frequency 1h → 30min	SEK 0 (0 - 3)	≈ SEK 3
Frequency 2h → 1h	SEK 10 (10-17)	≈ SEK 12
Frequency 3h → 2h	SEK 35 (14-35)	≈ SEK 37

The valuation results are about the same on board trains in 1998 as they were in 1996 on board buses.

7.14 Interviews about train travel, via the Internet

This was a degree project conducted by Karin Törnström under my supervision.

Name of study and main purpose	Interviews about train travel, via the Internet The aims of this project were to learn how to use Internet to conduct surveys, to test and evaluate several different ways of interviewing on the Internet, to make a simple assessment of the usefulness and general application of the answers that are received from the Internet and to investigate perceptions of train travel among the general public.
Places and dates	Sept.1997-April 1998
Methodology	Interviews on the Internet with SP experiments and other questions
Number and type of respondents	Various numbers of respondents for different parts of Internet interview (25-about 160) The majority of the respondents belonged to the Swedish Railway Club.
Studied attributes and attribute levels	Packages of 1) timetable attributes and 2) comfort & service attributes Separate attributes; timetable, comfort and on-board service
Methodological results	Difficult to get people to answer specific train (design) questions on the Internet. Too few answers. With open questions, people seldom mention any specific comfort and service factors. They mention the ticket price as an important factor for the choice of train.
Other SP results and comments	The study used SP designs that were too simple to work well. Rating method appears to have worked the best.

This project included three surveys. Two preliminary studies and one main study were uploaded onto the Internet, one at a time. The questionnaire was answered and returned by Internet users. The respondents' answers were sent to a database with a cgi script. All the information needed to upload your own survey onto the Internet was developed in this project.

The first interview: open questions about important factors

The first study was a preliminary study to identify the attributes which influence the public to choose to go by train or by any other form of transportation. The purpose was to find a few attributes to be used in the main study. The result of the first study was that the method of questioning is good if your questions are specific or if you want general answers.

The second interview: listings of attributes and their importance

In the second preliminary study, the fact that the survey related to train travel was mentioned. The survey consisted of a long list of attributes and the respondents were supposed to say whether each attribute was important or less important for them. The result was governed by the 45 attributes that were listed. The three attributes that most respondents thought were important were “delays reduced by half“, “no smoking areas on the train“ and “5% reduction in fares“. The three most important comfort- and service-related attributes were “air conditioning“, “adjustable seats“ and “modern, spacious lavatories“.

The second preliminary interview performed its purpose, i.e. it gave us an insight into the factors that are most highly valued. The data from the second study, the long list, was also used to conduct factor analysis. This was conducted at a later stage (by me) and is not included in the degree thesis.

Factor analysis results

A factor analysis with eight factors revealed the following. Attributes with factor score weights of more than 0.2 are shown below:

Factor 1: Want fax machine and copier. Must be business people.

Factor 2: Dislike travelling in tunnels and over bridges. People who are anxious about one are also anxious about the other.

Factor 3: Want well-cleaned stations, well-cleaned trains, WCs in stations and reclining seatbacks. To a lesser extent, smoke-free, wider chairs and more legroom also belong to factor 3. It seems that people like both cleanliness and space.

Factor 4: Prioritise higher frequency (twice as many trains), trains at the same time every hour (fixed timetable), ten minutes shorter travelling time and less than 20 minutes to the railway station. Checking-in of luggage also correlates to a lower degree. This factor could perhaps be called flexibility or ease of travelling(?).

Factor 5: Want face-to-back seating, two seats side by side, air conditioning, bistro in train and more shops at stations. Lower price is less important than for other factors. These factors could perhaps be called comfort and luxury.

Factor 6: Reading saloon and reading lamps are included, but catering at seat has a strong negative score for this factor. This factor is probably associated with reading or working.

Factor 7: Face-to-face seating, children's play area, pram area, music outlets at seat. To some extent also information signs and lower price. Could this be families with children?

Factor 8: This factor includes modern coaches, no interchange and 5% reduction in ticket price and fewer (half as many) delays.

The third interview: three SP experiments on package valuations

The third study, the main study, was an attempt to define the public's willingness to pay for different attribute packages and it is also a comparison between three different methods. The same questions were asked using three different methods to make it possible to compare the newer best/worst method with two well-established methods. The three methods were: paired choices, best/worst and rating responses.

The timetable package consisted of two attributes with two levels each; change of train and travelling time. The comfort and service package consisted of eleven attributes with high or low levels. The attributes were air conditioning, adjustable seats, bistro with some food, information display on board, wall socket by the seat, play areas, music outlet by the seat, lighting, small/large lavatory and 10 cm more legroom.

The three experiments, all of which included packages with the same attributes, resulted in different willingness-to-pay levels, as shown in the table below:

Table 7.24 Valuation estimates of packages using three methods in Internet study.

Valuations as % of price level	Timetable package	Comfort and service
Pairwise choices	18%	21%
Best/worst	12%	16%
Rating	12%	33%

The survey performed with rating responses appears to be the one that worked best. The estimates are probable and the t-values are good, but one problem is that this survey had few responses, only 25.

The fourth interview: best/worst for separate attributes

In the fourth survey, the best/worst method was used in a slightly different way. This time, the purpose was to estimate sub-values for the attributes included in the packages. If a 33% price increase were to be allocated, as all the comfort and on-board service factors were valued together, then it would look like this :

Table 7.25 Valuation of attributes from Internet study (see text)

Attribute	Valuation of the attribute as % of the fare
More legroom	7.2
Air conditioning	6.8
Catering on board	6.4
Adjustable seatbacks	5.1
Table at your seat	2.9
Dimmed lighting and reading lamps	1.5
Music outlets	1.2
Play area	1.0
Information signs on board	0.4
AC outlet (for PC etc.)	0.3
Large lavatory	-1.1

The values from this study are slightly lower than the values from previous studies.

Comments

The response frequency for the main study was low. It is likely that the subject was not of sufficient public interest to make people make the effort to answer the surveys. The survey that was considered the easiest was the one conducted using the rating responses method.

One way to judge the usefulness of the answers is to compare their valuations with valuations from previous studies. If the prominent attributes in the main study are taken into account, it can be seen that the valuations for air conditioning, adjustable seats and bistro are almost as high as in previous studies. The valuation of 10 cm more legroom is as high as or slightly higher than in previous studies. The valuations that are low in the main study are remarkably low.

When it comes to the degree of representativeness, women and senior citizens were under-represented and people who usually use the train were over-represented. In the specific case of this study, many members of the Swedish Rail Club answered because there was an advertisement on their home page. To have a more representative selection to answer surveys on the Internet, it is firstly necessary to send requests to complete a questionnaire to a statistically correct selection and above all wait until more people above 50 have access to and use the Internet.

7.15 Evaluation of a large number of timetable, comfort and on-board service attributes.

After fifteen studies of various attributes, many of them relating to comfort and on-board service, I wanted to validate or check the estimated attribute values using a method which took account of the package effect. The aim was to obtain lower and more realistic values. It was also important to include many attributes in the same study.

Name of study and main purpose	Investigation of a large number of timetable, comfort and on-board service attributes
Places and dates	Trains Stockholm-Malmö, March-April 1998
Type(s) of train/bus	X2000
Methodology	Two level: Packages at level 1 with pairwise choice, CASI and level 2 with best/worst and listing methods for estimation of separate sub-values
Number and type of respondents	535 respondents, about 60% men Business trips 45%, leisure about 35% and less than 10% work+school travellers.
Studied attributes and attribute levels	Level 1: Timetable package with seven attributes, comfort package with seven attributes and on-board service package with five attributes. Level 2: All the separate attributes ($7+7+5 = 19$ attributes) See text.
Methodological results	Best/worst and listings were used and produced reasonable results (at the second level in this study).
Other SP results and comments	Ordinary pairwise choice SP probably works better with packages than when it is used for direct estimates of secondary "soft" attributes.

All the interview versions contained two levels of questions, not counting the variable background questions. At the upper level, the value of three attribute packages was investigated; a timetable package, a comfort package and an on-board service package. At the lower level, trade-offs between the attributes in different packages were investigated. The role of this lower level is to divide up the packages in order to be able to distribute the package values into distinct attributes. Price was only included as an attribute at the upper level.

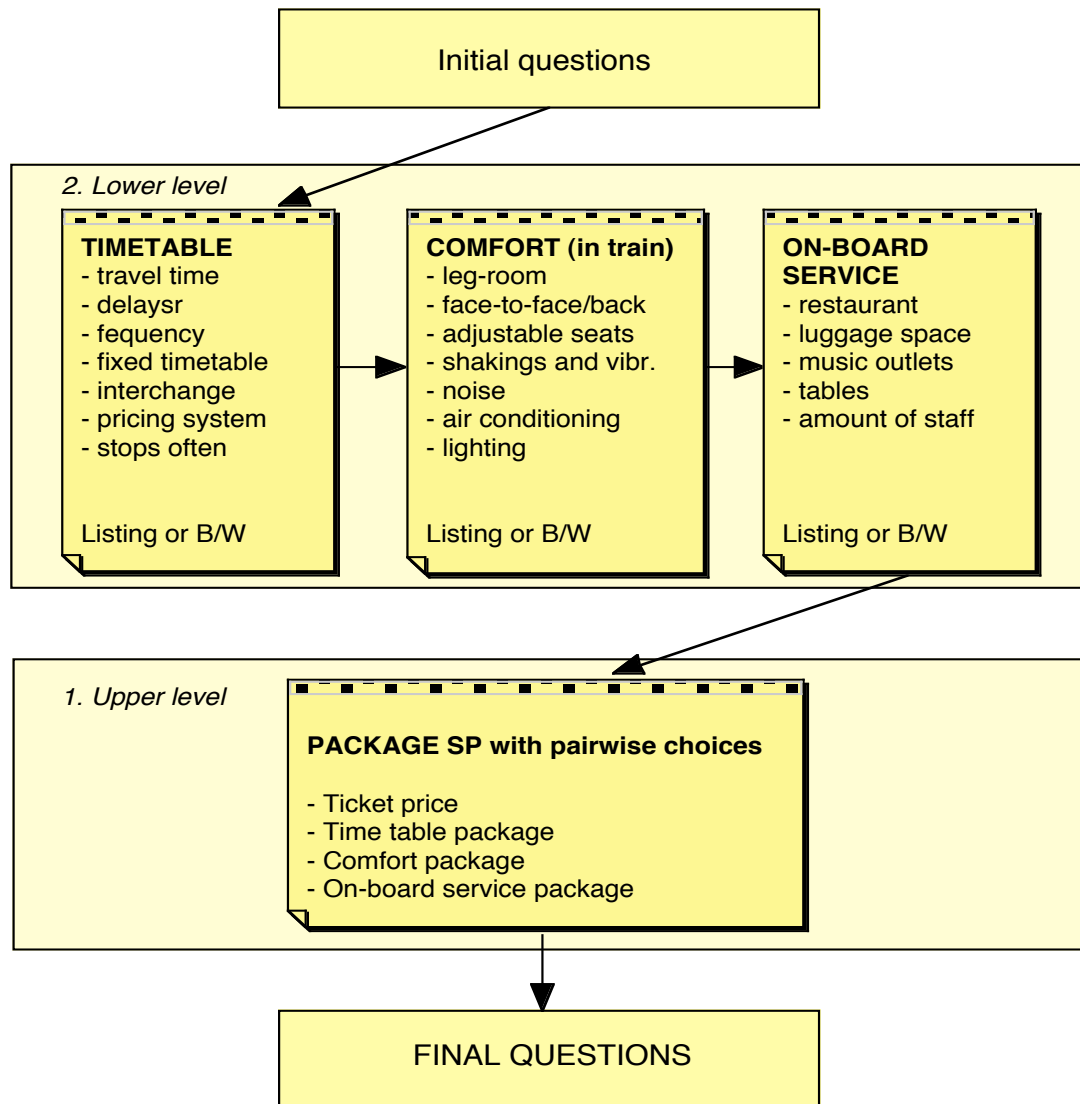


Figure 7.21 Illustration of the interview levels and the order in which the questions were put.

To make the respondents familiar with the various timetable, comfort and service attributes, the lower level was conducted first. When conducting the package SP, the respondents were familiar with the content of the packages.

One objective was to test the so-called best/worst conjoint method for the lower level. As with ordinary pairwise conjoint (pairwise SP), this requires the respondents to make a fair number of choices, if a large number of attributes are going to be evaluated. For this reason, only one package per interview type was used as a B/W experiment.

The other two were used as "listings". The way listings were used in this study was as follows; respondents were asked to pick the best and second best from a list of five or seven attributes. To supplement this, they were also asked to pick the worst and second worst from the inverse level of the attributes.

Values for timetable, comfort and service attributes

The valuations for the timetable, comfort and service packages were all higher than expected. Previous findings have shown that the "package effect" reduces the value quite substantially. For example, the valuation of a separate comfort attribute can decrease by 50% or more when it is included in a package. The parameters, t-values and number of observations are shown in table 7.26.

Table 7.26 Estimation results from the pairwise choice experiment for various segments.

	All respondents	Business trips	Leisure trips	Work+school
Price (%)	-0.045 (23.4)	-0.041 (15.8)	-0.043 (16.5)	-0.038 (9.3)
Timetable	1.65 (16.9)	1.71 (15.2)	1.44 (12.9)	1.53 (8.8)
Comfort	1.91 (22.1)	1.93 (16.3)	1.64 (14.4)	1.49 (8.8)
Service	0.96 (13.6)	0.88 (9.5)	0.88 (8.7)	0.70 (4.8)
r ²	0.362	0.321	0.315	0.203
No. of observ.	3,040	1,606	1,447	608

The differences in parameters for the segments used here, business, leisure trips and work+school, is fairly small. The parameter for money, for 1% of the ticket price, is very much the same. The difference is no greater than 0.007, which it must be if the null hypothesis that the parameters are the same is to be rejected. (The t-values above are used and normal distribution is assumed.) The other parameters were not tested.

At the lower level, the package values could be divided and the sub-values were allocated to the separate attributes. In this abbreviated text, the result for the comfort attributes is shown. Various estimation methods were tested and the results for two methods of best/worst and one for the listings are shown in the table below.

Table 7.27 Valuations of separate comfort attributes.

Comfort attribute	B/W count	B/W logit estimation	Listing	As percentage of fare (+42%)
Your legroom is 5 cm larger instead of 5 cm smaller	19	18	19	8%
Face-to-back instead of face-to-face seating	6	7	3	1% - 3%
Your seatback is adjustable instead of not adjustable	20	19	28	8% - 12%
More instead of somewhat less shaking and vibration than in this train	20	19	23	8% - 10%
Somewhat more instead of somewhat less noise than in this train	11	12	12	5%
Air conditioning with cool air in the summer time instead of no air conditioning, but windows that open	17	17	11	5% - 7%
Dimmed lighting and reading lamps instead of full fluorescent lighting	9	10	4	2% - 4%

It can be seen from table 7.27 that these methods produced similar results, at least for the comfort package attributes.

The values for the other attributes are only shown below, in table 7.28. Most of the values are also compared with values from other KTH (mostly my) studies:

Table 7.28 Valuation results from this study with comparisons with other studies.

Attribute	This study	Other studies	Comments
<u>Timetable</u>			
10%+10 min travelling time	2-7%	6-10%	Usually measured as SEK/h
No change of train instead of one change	8-10%	9-13%	Depending on difficulty
Double train frequency	3-4%	4%	Schmidt, see 7.8
Delays are rare instead of one 15-min delay every fifth journey	10-11%	16%	Difference in description
Regular departure times (There is one train every hour at the same time instead of an irregular service)	2-4%	1-3%	Lindh (somewhat different attr.)
Simpler fare but fewer discount prices instead of today's fare	0-3%		No other investigation known
The train stops at few stations instead of many stations	3-7%		No other investigation known
<u>Comfort</u>			
10 cm legroom	8%	6%	Average of 10 cm more and less
More/less vibration	8-10%	11%	Norwegian ICE train
More/less noise	5%	8%	Norwegian ICE train
Air conditioning	5-7%	≈10%	Norwegian ICE train
Adjustable seatbacks	8-12%	6-11%	Various KTH studies
Dimmed lighting + reading lamps	2-4%	4/ 11%	Local train/regional train
<u>On-board services</u>			
Catering	8%	5-11%	Depending on type of catering
Music/radio outlets	1%	2- 5%	Various KTH studies
More/less luggage space	3%	1%	Schmidt, see 7.8
Table at your seat	5-7%	2%	Båge, see 7.10

It is important to know the exact formulation of the attributes, but in table 7.28 only brief descriptions are given.

Some of the differences in valuation levels may be caused by different attribute descriptions. For example, the noise and vibration attributes described by both "less" and "more", the difference between them, while in the other studies the comparisons have been between "more" and "as today".

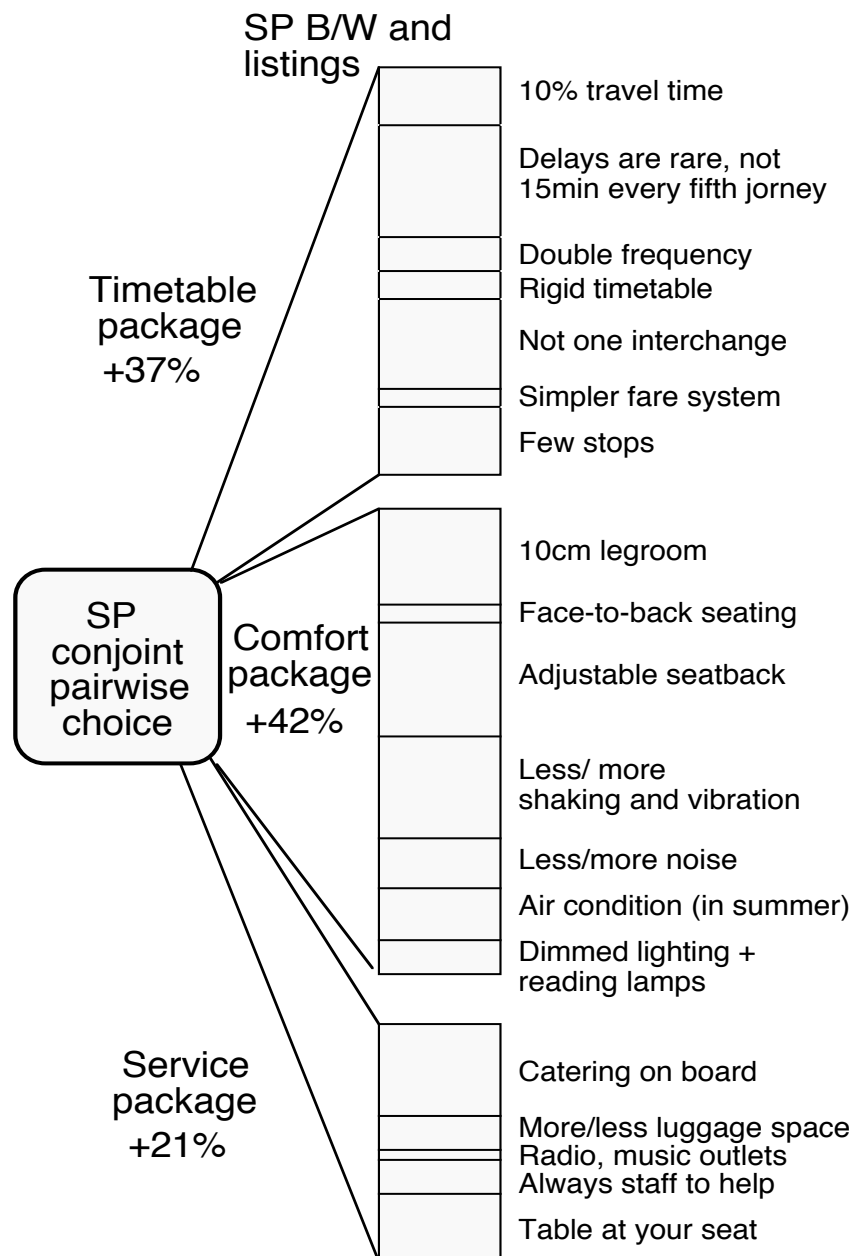


Figure 7.22 Diagram showing the main valuation results: package values as well as distributed attribute valuations. The values shown are percentages of the fare level. (The values for the three packages happen to add up to 100%, but this is just a coincidence.)

Distribution of attribute valuations among respondents

People's preferences differ; different individuals have different preferences. So the valuations of attributes for a number of individuals have some sort of statistical distribution. The forms of these distributions have been investigated by calculating individual valuations for attributes and then making histograms. The valuations are calculated from individual B/W sub-values.

The resulting distributions can be close to or far from the normal distribution. The assumption is that hard attributes like cost and travelling time are more close to normal distribution than many of the softer comfort and service attributes.

The distribution shape looks very much the same for a number of attributes. Only a few examples will therefore be presented below. The first example is an attribute with a somewhat skewed "normal" distribution. It is the distribution of the weights of one interchange.

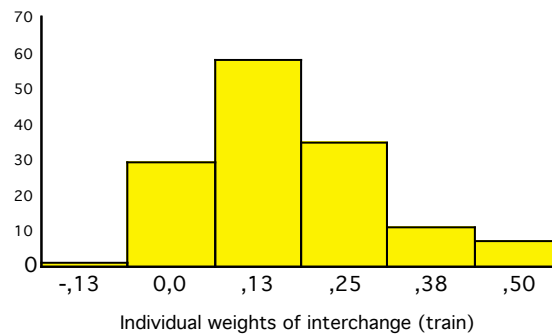


Figure 7.23 Histogram of interchange weights

The second example is an attribute with a very skewed distribution, far from normal. It is the distribution of the weights of travelling time.

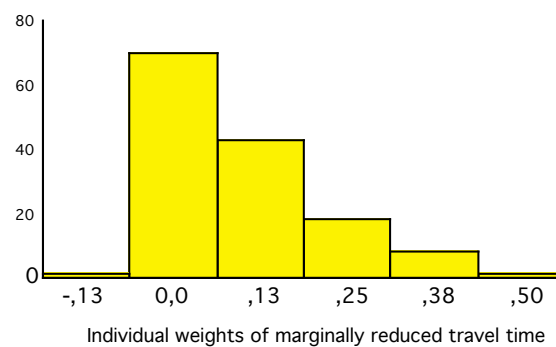


Figure 7.24 Histogram of travelling time weights

Factor analysis

Factor analyses have been conducted on the listing data. Four factors have been used for the seven timetable attributes and for the seven comfort attributes. Three factors have been used for the service attributes. A summary of the findings:

There appears to be a factor behind the wish for *high frequency and few stops* during the journey. It appears to me to be some kind of ease of travelling.

Another factor reveals that *shaking and vibration and noise* belong together. They could preferably be aggregated to create one factor/attribute in future SP experiments. The

second comfort factor influences the individual to like plenty of legroom but at the same time to be less interested in air conditioning. This seems odd to me.

Conclusions

On the whole, the methodology has worked sufficiently well and provided interesting support for two things:

- The fairly high valuation that was previously obtained for comfort and service attributes is largely supported.
- It should be possible to use simplified methods similar to this one when estimating the value or sub-values of a number of secondary attributes.

7.16 Evaluation of InterRegioMax, a high-capacity test coach with more seats

Partly as a result of my work, a ten-year-old passenger coach was converted in 1998 by SJ to accommodate more seats than normal SJ coaches. The test coach had 90 seats in comparison to 70-80 in normal SJ coaches of the same generation. Three methods were used:

- 2+3 seating with increased legroom in half of the coach
- 2+2 seating with reduced legroom in the other half of the coach
- reduced number of WCs; one instead of two

KTH was commissioned to evaluate the new interior.



Figure 7.25 Colleagues testing the seats in the "InterRegioMax" test coach. From left to right: my supervisor professor Bo--Lennart Nelldal, Karin Törnström, KTH (nowadays at SJ) and Jan G. Forslund, SJ Passenger Division.

The test coach was given a neutral colour scheme with blue seats and grey walls. The idea was that the colouring should not affect the passengers positively. (However, the evaluation revealed that it did.)

Name of study and main purpose	Evaluation of InterRegioMax (B20) To evaluate interior solutions, especially 3+2 seating, for the possible further conversion of coaches.
Places and dates	Stockholm-Uppsala shuttle train, ..May 98 Mälarbanan; Stockholm-Västerås(-Örebro), .. May 98 Väst kustbanan; Göteborg-Malmö, ..June 98
Type(s) of train/bus	B20; a 26 m former B2 coach, built by Kalmar Verkstad in about 1985?, converted with new interior in 1998 by TGOJ. It has some 3+2 seating areas. See drawing. <u>Reference – other coaches on test train:</u> Uppsala route: train with InterCity coaches from about 1980 (mostly B7) Mälarbanan; mixture of InterCity coaches, renamed InterRegio Väst kustbanan; special InterRegio furnished coaches
Methodology	Paper questionnaires and CASI (computer assisted self interviews) SP interviews on small portable computers. "Listing SP" were tested on the questionnaires.
Number and type of respondents	450 computer (CASI) interviews and 565 paper questionnaires
Studied attributes and attribute levels	<u>SP on computer:</u> – ticket price – type of coach – occupancy – number of WCs in the coach. <u>Listings on paper:</u> See result table (7.32).
Valuation results	The valuation of the experimental coach was high ($\approx 10\%$ of the fare) and this may be mainly due to its freshness. 2+3 seating can be accepted, especially if the seats have the standard width.
Methodological results	Listings produced usable results, but the estimation method has not been fully developed and it is ambiguous. It is unclear which assumptions should be made.

Interviews were made on three potential routes. The first, the Uppsala route, has capacity problems with crowded trains. The second, the Mälar Line, needs new vehicles and the third, the west coast line from Gothenburg to Malmö, is competing with parallel bus services with low prices.

All passengers valued the test coach positively in spite of the 2+3 seating. Open questions revealed that passengers appreciated the freshness and modernity of the converted interiors. The Uppsala travellers were particularly positive. This can be explained partly by the fact that the standard (InterCity) coaches on this route are fairly worn. The reference coaches on the other routes have already been converted or refurbished.

Table 7.29 Valuation results for the Uppsala route (1,126 observations).

Attribute description	Parameter	t-value	Value (%)
Price parameter (relative, % of fare)	-0.0852	15.5	–
IRmax coach but with only 2+2 seating	0.9525	6.5	+11
IRmax coach but with only 2+3 seating	0.5335	3.6	+6
Wide IRmax coach but with wide 2+3 seats	0.8383	5.7	+10
Two WCs (instead of one)	-0.1143	0.8	-1
There are many free seats (instead of full train)	0.4370	3.1	+5
Two WCs and free seats (package)	0.7031	5.0	+8

Table 7.30 Valuation results for the Mälar line (1,002 observations).

Attribute description	Parameter	t-value	Value (%)
Price parameter (relative, % of fare)	-0.1443	14.8	–
IRmax coach but with only 2+2 seating	1.3150	7.7	+9
IRmax coach but with only 2+3 seating	0.5914	3.6	+4
Wide IRmax coach but with wide 2+3 seats	0.8553	5.0	+6
Two WCs (instead of one)	0.3331	2.1	+2
There are many free seats (instead of full train)	1.2050	7.2	+8
Two WCs and free seats (package)	1.3090	7.5	+9

Table 7.31 Valuation results for the west coast line (1,056 observations).

Attribute description	Parameter	t-value	Value (%)
Price parameter (relative, % of fare)	-0.1034	12.8	–
IRmax coach but with only 2+2 seating	0.7515	5.3	+7
IRmax coach but with only 2+3 seating	0.3263	2.3	+3
Wide IRmax coach but with wide 2+3 seats	0.4908	3.6	+5
Two WCs (instead of one)	0.2442	1.8	+2
There are many free seats (instead of full train)	1.0070	7.0	+10
Two WCs and free seats (package)	1.0800	7.3	+11

A "listings" method was used to elicit importance estimates for a number of attributes. Travelling time and cost were included in the listing. They were specified as marginal changes of 5 min and SEK 5 less per journey.

Table 7.32 Results as a percentage of the respondents for the included listings experiment.

"Please mark the factors/things that are important for you on a journey like this one. You can mark as many you want, but remember that, if you mark none or all of them, SJ will have difficulty making priorities."	Important	Less important
My travelling time is reduced by 5 min	33%	49%
The ticket price is 5 SEK less per journey	72%	19%
I don't have to sit where there are three seats side by side	25%	57%
I don't have to sit in a narrow seat	47%	35%
The coach has two WCs (instead of one)	29%	52%
The aisle is made 10 cm wider	19%	61%
I have 10 cm more legroom	39%	43%
My seat has a reclining seatback	63%	24%
There is a table at my seat	61%	25%
I can sit face-to-back	17%	60%
I can sit face-to-face	17%	61%
There are reading lamps	54%	28%
The noise level is the same as in this coach or lower	74%	12%
There is more room for luggage than in this coach	20%	57%
Other (please write):	65 times	243 times

The percentages important/less important could be transformed to a utility scale if one makes and accepts some presumptions. An outline has been made, but this is not presented here.

7.17 Evaluation of double-decker cars on trial in Sweden

SJ has capacity problems on the Uppsala Line and the new Svealandsbanan. This was one of the reasons why SJ loaned a double-decker trainset from DWA/Bombardier for four weeks in November-December 1998. One of the reasons why I agreed to evaluate passenger reactions to this double-decker train was the strategic importance double-decker trains could have when it comes to reducing the cost of passenger train services.



Figure 7.26 Bombardier/DWA double-decker trainset (photo: Bombardier, not exactly the configuration that was tested.)

Name of study and main purpose	Evaluation of double-decker trainset DWA/Bombardier "Competence" To evaluate passenger reactions to the actual train design and their valuation of trains with two levels.
Places and dates	Svealandsbanan; Stockholm-Eskilstuna-Hallsberg, 20-27 Nov. 98 Mälarbanan; Stockholm-Västerås-Hallsberg, 30 Nov.-4 Dec.98 Stockholm-Uppsala shuttle train, 7-11 Dec.98
Type(s) of train/bus	DWA/Bombardier double-decker coaches: one driving trailer + one intermediate coach 2nd class and one intermediate coach 1st+2nd class. Low floor entrances in all coaches. <u>Reference – other coaches in test train:</u> Uppsala route: train with InterCity coaches from about 1980 (mostly B7) Svealands- and Mälarbanan: no other coaches in train

Methodology	CASI (computer assisted self interviews) SP interviews on small portable computers. "Listings SP" were tested on supplementary questionnaires.
Number and type of respondents	≈650 computer (CASI) interviews and ≈200 paper questionnaires
Studied attributes and attribute levels	<u>SP on computer:</u> – ticket price – type of coach – occupancy rate <u>Listings in computer and on paper:</u> – 5% or 5 min shorter travelling time – 5% or SEK 3/6 lower ticket price – travelling on double-decker – not travelling on double-decker – not a narrow seat – 10 cm extra legroom – adjustable seatback – table at the seat – sitting face-to-back – sitting face-to-face – there are reading lamps – noise level the same as in this coach or lower – more room for luggage than in this coach
Methodological results	Two simplified SP methods were tested and compared. An attribute (attribute level difference) importance listing method revealed similar results to those produced by a method in which the same attribute descriptions were ranked.
Other SP results and comments	The valuations varied considerably for the three railway lines on which the double-decker were tested.

The main estimation/valuation results are shown by table 7.33. The table shows a model with a common price parameter but where the parameters for the coach types are separated with respect to the three railway lines on which the coaches were tested. The rolling stock in ordinary service, the passengers' references, are different on the three different lines: On the Uppsala line older InterCity coaches, on the Mälärbanan slightly refurbished InterCity coaches and on the Svealandsbanan X2000-trainsets are in service.

Table 7.33 Main valuation results.

Attribute description	Parameter	Stand.dev.	Value (%)
Ticket price (% of fare)	-0.462	0.037	–
<u>Type of coach</u>			
This coach (double-decker), Svealands Line	-0.233	0.16	-5%
This coach (double-decker), Mälars Line	-0.601	0.22	-13%
This coach (double-decker), Uppsala Line	0.339	0.23	+7%
This coach but with standard modern SJ interiors, S	0.392	0,15	+8%
This coach but with standard modern SJ interiors, M	0.206	0.24	+4%
This coach but with standard modern SJ interiors, U	0.270	0.17	+6%
X2000 train, Svealands Line	0.494	0.16	+11%
X2000 train, Mälars Line	0.266	0.23	+6%
X2000 train, Uppsala Line	0.170	0.17	+4%
<u>Occupancy rate (crowdedness)</u>			
There are many free seats, but not by the windows	-0.081	0.09	-2%
There are a few free seats	-0.212	0.11	-5%
There are no free seats – you have to stand up	-2.046	0.13	-44%

The valuation of the double-decker car with its actual interiors was as negative as 5-20% of the fare, but the value for double-deckers given the same interior was as positive as 5-10% of the fare.

A similar study conducted by Lindh²³³ in 1991 in which a similar type of double-decker car were tested by SJ also revealed positive valuations for the double-decker concept. On that occasion as well, the Swedish passengers gave a negative value to a simpler interior, but the bi-level concept itself appeared to be valued positively (at about 4-5 % of the fare).



Figure 7.27 Passengers on board the German double-decker answering the computer interview.

²³³ Lindh, C., *Resenärernas krav på regionaltåg*, KTH Traffic Planning, Bulletin 76, TPL 91-09-75, 1991

Valuations of various attributes using listing methods

A test of two versions of "listing" methods was conducted. The same attributes and levels were generally used in computer and paper interviews. In the computer interview, the respondents were asked to rank the first eight of 11 attributes²³⁴. The method in the paper interview instead involved marking each attribute as "important" or "not important". The results are similar to those shown in the diagram:

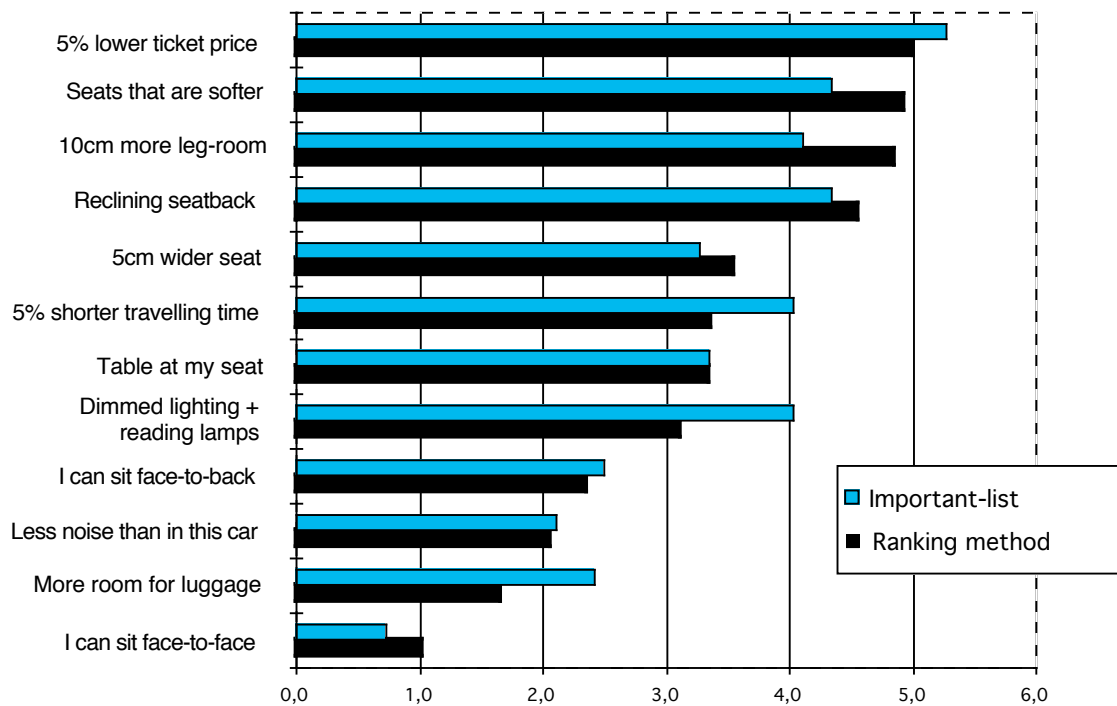


Figure 7.28 Valuation results for Uppsala travellers from two methods: an important/less important listing in paper interviews and an attribute ranking method used in the computer interviews.

The main conclusion of this study is that trains with two levels could have a positive value that goes beyond the value of the charm of novelty, even though this probably explains a large part of the positive appreciation. My view is that the value could be somewhere in the region of 0-5% of the fare.

²³⁴ The rankings in this method can be converted to pairwise choices between (almost) all attributes and then counted in accordance with Thurstone's proposals (see Thurstone references)

8. Passengers' evaluation of ticket prices and travel attributes

This chapter begins with the importance of ticket price for existing and potential passengers.

There is a note on qualitative evaluations. Evaluations of this kind have been made to a lesser degree by me. Section 8.3 summarises these results and includes some results from other research.

SP valuations can be presented in many ways, for example as absolute or relative monetary values (SEK or % of the ticket price). The complexity of these problems has led to an extra analysis of the way passengers' valuations depend on travelling time and cost. The last two sections in Chapter 6 deal with non-users' valuations of travelling by train and the effects on demand.

8.1 The importance of competitive ticket prices

The following data come from an SJ investigation of the market in 1987²³⁵. Travellers stated that the comfort primarily made them choose to go by train. When asked about improvements, in order to travel even *more* by train, the following answers were obtained.

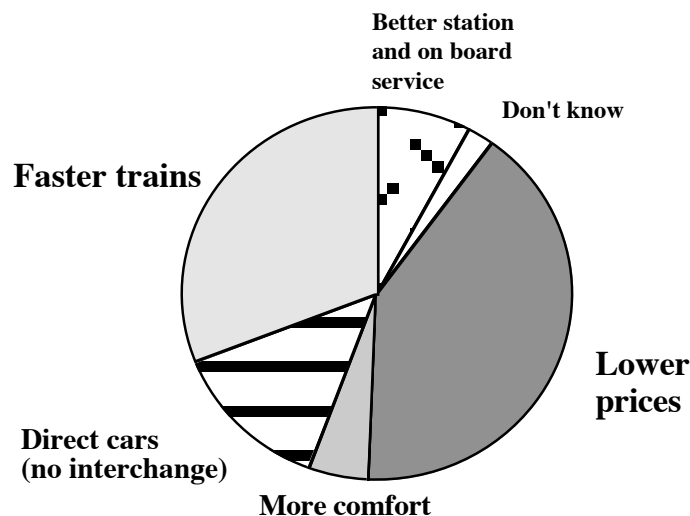


Figure 8.1 Travellers' wishes regarding improvements. Source: SJ 1987.

It can be established that (private) travellers' order of priority is:

1. LOWER FARES
2. FASTER TRAINS
3. DIRECT CARS (no interchanges)

Number 1 relates to the train ticket prices. At medium distance, 100-600 km, trips by train cost more than by bus but less than by plane.

²³⁵ SJ Structural Investigation, internal company report, 1987

However, it is difficult to interpret the answer to questions like this one and like this:

- "What is the most important factor for you when you consider going by train?"

People will probably say that it is the ticket price. One example of this comes from Rosenlind²³⁶ who presented a list of 27 vaguely described attributes related to trains and (interregional) train travel. "Low price" received the highest average score; 91.7 of a possible 100. However, does this mean that it is more important to reduce the prices by 10 %, for example, than to cut travelling times by 50%? A distinction of this kind should be made.

In 1992, "Järnvägsfrämjandet" conducted a questionnaire among ordinary people at work, at school and in the city. A total of 370 persons were interviewed. Seven of ten (70%) claimed that they would travel more by train if ticket prices were lower, while shorter travelling times and more train services would encourage only 30% to travel more. Also in this case, the answers must be interpreted with care, because we do not know what scale of improvement people imagined.

One observation that shows the importance of ticket price is that people often sort lexicographically on ticket price when conducting stated preference experiments. That means that every (small) variation in ticket price is for some persons more important than all the other attributes.

The importance of relatively low ticket prices for market share is greater when people have alternatives. The introduction of a large number of parallel bus services has increased the importance of competitive prices. A report from SIKÅ²³⁷ showed that 88% of the people who had chosen a long-distance bus that runs in parallel with the train mentioned the lower price level as a reason for choosing the bus.

Price elasticity shows how the travelling rate is affected by the price. This elasticity is naturally different for different markets, but a long-term (say 5-10 years) figure that has been mentioned by the Swedish economist J-O Jansson²³⁸ is around -1.0. This figure corresponds to an equal relative change of train ridership as in relative price.

Jansson has proposed a large scale differentiation in ticket prices and (1999) SJ's prices are currently so differentiated that the fare system might be hard to understand.

My conclusion is that the price level is a number one concern when working with the competitiveness of passenger rail. Long-distance buses charge about 0:50 SEK/km, which could be a target for, budget travellers' price levels, at the very least. It is also the price level that will meet the cost people think of when people travel two by car.

²³⁶ Rosenlind, S.; *Tågresenärers värderingar av trafikering, vagntyper och service*, (Passengers' valuations of traffic services, coach types and on-board service, in Swedish), KTH Traffic Planning, Master thesis/ examensarbete 94-1, 1994

²³⁷ SIKÅ (The Swedish Institute for Communications Analysis), *Utvärdering av en ändrad reglering beträffande prövning av tillstånd till busslinjetrafik* (Evaluation of a changed regulation regarding licences for long distance bus services), Report 1997:2

²³⁸ Jansson, J.O.et.al., Optimal fares and financing of railway passenger transport, (in Swedish with a summary in English), *TFB & VTI forskning/research*, No.5, ISSN 1101-2986, July 1992

8.2 Some qualitative evaluations

The terms quality and qualitative are used in this thesis with two different meanings. The more general meaning of quality is "a distinctive element" and qualitative is used as the opposite of quantitative. The other meaning is the one used in the expression "lack of quality" – when a product does not fulfil reasonable requirements consumers impose on the features or performance of products.

Definitions of quality in recent years have the customer rating or experience of quality²³⁹: as their starting point in one way or another: *Quality is a summary of product or service characteristics, which indicates its capacity to satisfy spoken or unspoken needs.*

In Sweden, a great deal of qualitative research on the design of public transport hardware has been conducted in recent years under the leadership of Lisa Warsén at TFK. In 1997, KFB published a number of reports from this closely connected work. Nordgren, Sjöström & Warsén²⁴⁰ describe a number of (qualitative) design methods for developing public transport in a report with the translated name: "Products that work". In another report from this joint work Monö et.al.²⁴¹ describe our perceptions and their effects on behaviour in the spatial public transport environment. This is important work which is necessary alongside the predominantly quantitative methods used in my work.

An interesting British study by Killey²⁴² was conducted in 1998 using mailed questions on the Internet. Its name, "The customer focused railway. What does theory suggest it might be, and what do passengers think?", describes the content quite well with one exception: The author mainly interviewed railway industry people like rail service planners and not the passengers themselves, as I have done. Killey's report shows explicitly how differently the expression "customer-focused" is interpreted by different people.

A well-planned stated preference study can start with a qualitative interview study to find out the attributes respondents find relevant and important. It is also meaningful to find the expressions/ words people in general use about these attributes. This has, for example, been made in a study about rolling stock quality improvements by Wardman and Whelan²⁴³. They conducted a combined RP/SP study which started with an extensive qualitative section: Almost 1000 rail passengers were interviewed. The aim was to assist in the design of the quantitative surveys but also to illuminate any complexities involved in perceptions of rolling stock. A few results from this study will be quoted later on.

One example of qualitative assessments collected in one of my studies can be seen from figure 8.2. It shows a representative selection of spontaneous associations with "SJ trains". The qualitative opinions in the figure show that SJ trains give rise to both negative

²³⁹ ISO 8402 and ISO 9004/2 (Swedish and international standard)

²⁴⁰ Nordgren, P, Sjöström, S, Warsén, L, *Produkter som fungerar*, KFB report 1997:42.

²⁴¹ Ljunggren, S, Monö, R, Nordström, M, Svedmyr, Å, *Trevlig Resa - Våra sinnens perceptioner och deras effekter på beteende i kollektivtrafikens rumsliga miljö*, KFB Report 1997:43

²⁴² Killey, R., *The "customer focussed railway". What does theory suggest it might be, and what do passengers think?*, Publisher not mentioned (the report was sent by the Internet), December 1998

²⁴³ Wardman, M., Whelan, G., *Rolling stock quality improvements and user willingness to pay*, ITS working paper 523, Leeds, March 1998

and positive associations. The negative associations reveal a lack of quality and wishes for improvement.

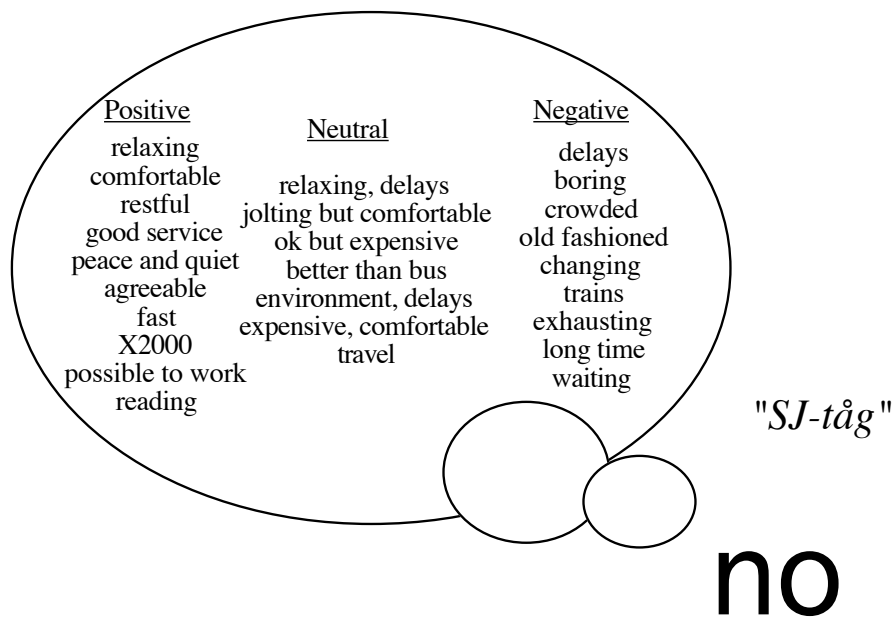


Figure 8.2 A representative selection and the most frequent answers to the question about what spontaneously comes to mind in association with SJ trains

In a study conducted in Blekinge County, the relationship between positive and negative associations was about 20/80 for "SJ trains", less than 10/90 for "railbus" but as much as 93/7 for the innovative train service "Kustpilen". Many of the positive associations about "Kustpilen" related to speed. People associated the Kustpilen with being a fast train, even though the speed differed very little from that of the old trains.

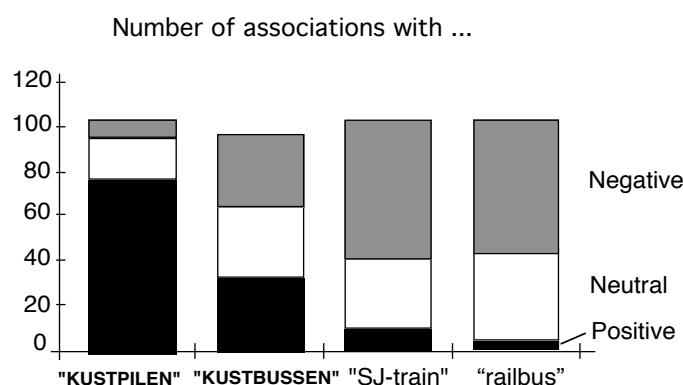


Figure 8.3 Number of qualitative associations to various train passenger transport products. (Data from Blekinge)

The data for the above diagram comes from Blekinge, where people were found to associate more negatively with "SJ-train" than in a reference study, where "SJ-train" triggered more neutral associations. One interesting finding here is that different types of

train product can trigger both better and worse associations than a high-quality bus service product (Kustbussen).

Sometimes it is possible to pick up qualitative comments about travelling by train. These word-of-mouth comments may give some idea of what people think. Here are a few examples:

- "We have tried the X2000 to get here and the journey did not feel like a train ride. It was like sitting at home instead."

- "It's strange that we didn't get seats (in the X2000) opposite one another when I asked for them. Even in the airlines can arrange that." (??)

Compared with quantitative studies, qualitative studies of train service have the advantage that they elicit answers the interviewer did not expect from the beginning. Qualitative studies can be used to provide a rough estimate of the attractiveness of different "train products" and as a follow-up of improvement measures. On the other hand, qualitative studies do not handle conflicts or trade-offs or show how many resources need to be invested in the realisation of customer demands.

The study of InterRegioMax, a test coach with more seats than standard passenger coaches included four open questions, such as: "What was your first thought when you entered this coach?" It was possible to use only 25 characters and many respondents wanted to write more than that. Most associations related to freshness. It seems that the fact that the coach was new, modern and clean meant a lot. Perhaps this can be compared with buying new clothes, even when the old ones are not worn out.

The answers to the *open questions* have revealed attitudes and preferences that would hardly have been apparent with only multiple-choice alternatives.

A well planned quantitative study, read SP study, should start with a qualitative part. A good way is to start with focus group discussions. They aim to identify the attributes people care about and what they call them.

8.3 Summary of quantitative valuations of train attributes

The quantitative valuations presented in this chapter mostly stem from SP experiments with train passengers on board Swedish InterCity trains. The valuations are generally presented as a percentage of the ticket price (or fare level). The reasons for this are given in section 6.5.

The valuation figures presented here are not downscaled with respect to the anticipated existence of package effects. Where results stem from studies in which the effect of packaging was considered, these results are, of course, presented. This way of arranging results does indeed have the drawback that for some attributes or measures we know the "real" values better than for others, and comparisons may be somewhat insecure. On the other hand this unreliability also exists when aggregating and using results that stem from different studies. (In section 10.7, "Summary of values and costs of various measures", conservative values with indications of unreliability have, however been used in the ball park diagram.)

8.3.1 Timetable factors

Timetable factors are usually included in the traffic models that are also used in Sweden to forecast future travel. Earlier models were always created using travelling habit research and the Revealed Preference method.

Travelling time

When interviewing leisure train travellers "shorter travelling times" often appear to be the second most essential area for improvement - for business travellers, it is the most crucial factor. The incidence of demand for shorter travelling times can be expressed in relation to travel costs. For the average (leisure) traveller, (marginal) travelling time is almost as great a sacrifice as the (marginal) ticket price. This implies that it is almost as necessary to reduce travelling time by 10% as it is to lower the ticket price by 10%.

Ratings of travelling time changes in business travel depend partly on the rating by the traveller and partly on the employer's rating. The employer's rating is estimated as being lower depends on the fact that more than half the travellers work while they are on the train (Algers et.al., 1995²⁴⁴).

²⁴⁴ Algers, S., Hogusson, B., Lindqvist, J., *Tidsvärdesprojektet - resultatredovisning* (The Swedish VoT project - results), Transek AB, May 1995

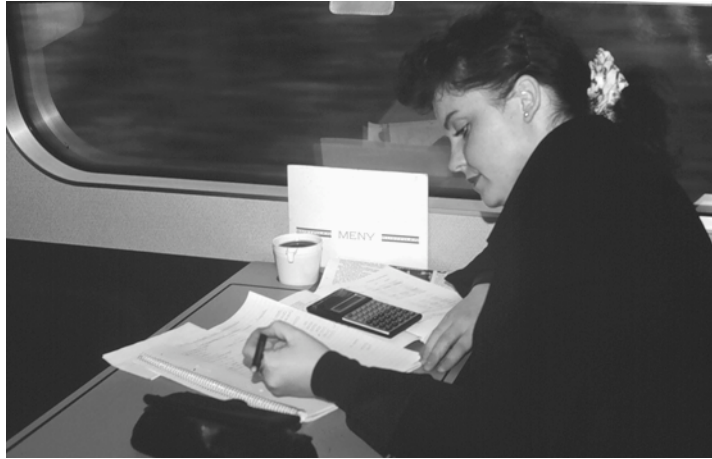


Figure 8.4 The potential to work on board a train can "reduce" the time offering but also the value of time savings.

The time values used in Swedish socio-economic analyses of traffic investment are SEK 70/h for leisure travellers. The value-of-time (VOT) for business travellers is two to four times higher.

In some of my SP studies, travelling time has been included. In these cases, the value-of-time has been calculated, as is often done to check whether a study has produced reasonable and comparable results in relation to other studies.

Example: While I usually estimate the weight of money related to relative cost (as a percentage of the fare), I also usually compare the weight of the relative travelling time. This is then often in the range of 0.5-1.0% fare/% time for leisure travellers. The fare for one hour of travelling by train is about SEK 100/h for long-distance 2nd class. If we then change the travelling time by, say, 10%, this change has the value of 5-10% cost, which is SEK 5-10 per hour. However a 10% change in travelling time corresponds to about six minutes per hour, so 6 minutes is valued at SEK 5-10 and 60 minutes (=1h) is valued at SEK 50-100. This corresponds well to the VOT obtained by others.

In the two studies of the Svealand Line (sections 7.12 and 7.13), time values have been estimated at SEK 50-65/h. This line has a mixture of regional and interregional travellers.

Number of stops

I have long suspected that the number of stops one experiences during a train ride influences the feeling of patience and thereby the perception of time. In the large SP study in the spring of 1998 the attribute "number of stops" was included in the listings part of the study. The level "train stops at few stations" was valued 3-7% more highly than "train stops at many stations". This indicates that my hypothesis may be true.

Departure frequency

The value of higher departure frequency is often expressed, for want of anything simpler, in terms of money per minute interval at varying departure intervals.

On the other hand, passengers are not likely to prefer trains departing at 50 minute instead of 60 minute intervals, which means every hour on the dot. According to the above rating of departure frequency, such a change would be positive.

From the Svealand Line study (section 7.12) we can see that, with a reference level of two trains per hour, other levels of departure frequency were valued:

Every hour: SEK -3

Every second hour: SEK -15

Every third hour: SEK -38

If the train frequency is doubled from every second to every hour, this would result in a gain of SEK 12, which corresponds to 12% with an anticipated fare level of SEK100/h. Doubling once more, from every hour to every half hour, is then valued at about 3%.

"Double train frequency" was valued at 3-4% of the fare by train travellers in my compound study (section 7.15). This appears to be a fairly low value, compared with the value of many other attribute improvements, but it may be partly explained by the bias there is when interviewing train travellers – who have already accepted the train on the existing conditions.

Business travellers who fly set great store by departure frequency, so it would be wise to use the above departure frequency values cautiously. This is demonstrated in a recent study by Engström et al. (1997)²⁴⁵.

Changing trains

Transfers between trains are rated as negative in many ways, depending on their ease and the time they take. In some situations and for some people, changing trains is extremely disagreeable; for instance, when it takes a long time, when it is uncomfortable or much luggage is being carried. For old people and the disabled, it can be experienced as particularly troublesome.

²⁴⁵ Engström, M. et.al., *Flyg och snabbtåg i trafiksystem*, (Air and high speed trains in the transport system, in Swedish), KFB Report 1997:10



Figure 8.5 Older people may need help to be able to make a transfer.

It is therefore probable that transfers are rated differently and that the average values presented should not be taken too literally. KTH studies indicate that willingness to pay for the ticket decreases by 9-13 % if changing trains is necessary. Other studies²⁴⁶ show that unwillingness to change trains consists of a fixed and a variable part. The fixed part can, for example, be expressed as extra travelling time and is situated in the interval 30-60 min. The incidence of changing trains is summarised below:

Table 8.1 Various estimates of the negative value of a transfer

CHANGING TRAINS (TRANSFERS)	
SP studies at KTH ²⁴⁷	9-13% of the ticket price, fixed part plus time value ≈ 1.5 times travelling time value The fixed part is also $\approx 30-60$ min travelling time
Reduction in ridership according to regression analysis	- 25-30 %

I assume that the influence of interchanges is greater than the valuations by train passengers indicate. An earlier regression model created at KTH²⁴⁸ shows that each transfer reduces travelling with the corresponding service by about 25-30%.

²⁴⁶ Lindh, C, (and Kottenhoff, K), The value and effects of introducing high standard train and bus concepts in Blekinge, Sweden, *Transport Policy*, 1995 Volume 2 Number 4, and

Wilmart, C., (SNCF) Les effets des ruptures de charge sur la concurrence entre l'avion et le train, *Les actes du congress WCRR'94 (World Congress On Railway Research)*, pp.307-314, (1994) and

Ongoing study (Feb.99) for valuation of journeys Stockholm-Jämtland (Lindh, A., KTH Traffic Planning)

²⁴⁷ Lindh, C, (and Kottenhoff, K), The value and effects of introducing high standard train and bus concepts in Blekinge, Sweden, *Transport Policy*, 1995 Volume 2 Number 4, and

Rosenlind/Kottenhoff, *The negative value of changing trains*, not published, presented in section 7.6, and

Ongoing study (Feb.99) for valuation of journeys Stockholm-Jämtland (Anders Lindahl, KTH Traffic Planning)



Figure 8.6 Changing trains may require some effort, even if the other train is waiting at the same platform.

8.3.2 Comfort factors

The term comfort factor is used here to signify the experience of on-board comfort and it is related to the type of vehicle and interior fittings. The most "traditional" comfort factor is sometimes called ride comfort and is related to jolts and vibrations. Below, noise is presented together with vibrations, because they are closely related.

Ride qualities, vibrations and noise

Good ride quality with little jolting, vibration and noise is rated highly in spite of the fact that the levels in modern trains on the present high quality tracks are appreciably lower than in the past. This confirms that travellers are prepared to "pay" for avoiding deterioration. "Somewhat less jolting and vibration" is valued at 10% of the fare. Less noise has been rated about as highly as less vibration in my InterRegio study (see section 7.3).

Studies at KTH have, however, shown that the value of a number of comfort factors can not be added in the usual way. There are several reasons, such as diminishing marginal utility, overlapping and other method-related weaknesses. So, the value of less noise and vibration is not the sum of the values we have obtained for each factor. In this example, the "sum" of 10% and 10% is much lower than 20%.

Table 8.2 Valuations of vibration and noise

VIBRATION AND NOISE	
"A little less vibration and shaking than in this train"	+11 % (from InterRegio study)
"A little lower noise level than in this train"	+10% (from InterRegio study)

²⁴⁸ Björkman, B., Möller, *Järnvägens potentiella utvecklingsmöjligheter – Servicefaktorers inverkan på järnvägens persontrafikmarknad*, (The potential for development of the railway, in Swedish), KTH Traffic Planning, meddelande 58, TRITA-TPL-86-09-40, ISSN 0349-4373, 1986

"More instead of somewhat less shaking and vibration than in this train"	- 8-10% (SP study spring 98)
"Somewhat more instead of somewhat less noise than in this train"	-5% (SP study spring 98)
"The noise level is the same as in this coach or lower"	+8% (SJ experimental coach B20, May 98)
"The noise level is the same (as in this coach or) lower"	+2% (Double-decker evaluation, Dec. 98)

In my "final" SP study from the spring of 1998, the value of a lower vibration level was estimated at 8-10% while a lower noise level reached 5% willingness-to-pay. These figures are somewhat lower than the figures from the earlier SP study and noise especially appears to be less important.

One comment on the differing valuation levels for noise in the experimental B20 coach and the double-decker is that the first one was probably experienced as a surprisingly quiet and thereby comfortable coach, while the other one had a noise level that was experienced as desirable.

Temperature and air quality

Improved ventilation and air conditioning may have a high value (about 10% of the ticket price) if the actual trains are experienced as unsatisfactory. Otherwise, the value is lower (about 5%).

Air conditioning is a term for something else. What people want primarily is good air quality and a pleasant temperature, which may not be provided in reality in a train with air conditioning. This may produce too much cold, draught or noise. "A little more noise" is valued about as negatively as "air conditioning" is valued positively! The conclusion is that acceptable temperatures and good air quality are basic demands which must be met, otherwise the travellers react.

Table 8.3 Valuations of temperature and air quality

TEMPERATURE AND AIR QUALITY	
Air conditioning which gives cool air in the summer	11-12% (IR study)
Individual ventilation at each seat	10% (IR study)
Air conditioning with cool air in the summer instead of no air conditioning, but windows can be opened	5-7% (SP study, spring 98)

There is also a trade-off between, for example, air quality and noise (but this has not been explicitly investigated in any of the SP experiments conducted.) If, for example, very noisy AC equipment is running, the cooled air may be preferred by some, but others may find the noise too disturbing in relation to the improved climate. (Well-designed AC equipment does not generate much noise, but in some cases the above trade-off should be considered.)

Seat comfort

The seating arrangements, seat configuration and seat standard are of paramount importance. When travelling in a group people generally like to sit facing each other and talk (face-to-face seating). When travelling alone you often want to read, use headphones or rest. Seats placed behind one another (face-to-back) are preferred in comparison to face-to-face. Of those travelling alone, 50% prefer face-to-back seating (see results in section 7.1). Many do not care whether they sit face-to-face or face-to-back, but those who do care have very strong preferences. Those who want face-to-back regard it as negative up to 10% of the price to have to take a face-to-face seat if the opposite seat is occupied. By the same token, the smaller group of "face-to-face sitters" are willing to pay about 7% of the price to be able to sit in this way. The conclusion is that trains that offer only one seating formula do not comply with the different customer preferences.

Some travellers prefer to ride facing forward. A previous hypothesis that this way of riding causes less train travel sickness has been rejected, since the opposite appears to be the case²⁴⁹. One argument in favour of reversible seats has disappeared.

Sitting where there are three seats in a row has been rated negatively in an earlier study. In 1996/97, a deeper analysis with both interviews and observations of passenger preferences through their actual choice of seat was carried out. The preliminary results indicate that the aisle seat in a row of three seats is more preferable than the corresponding seat in a two-seat row. When trains are not full, at least up to a occupancy rate of 80%, a seat arrangement of "3 + 2" is an interesting solution even from the traveller's point of view.

Reclining seatbacks are highly appreciated in the SP interviews (about 6-10%).

The ratings of some factors can be seen in Table 2.6

Table 8.4 Valuations of seat comfort

SEAT COMFORT	
Face-to-face; one traveller sitting opposite (somebody)	- 9%
Face-to-face; those preferring this solution	+ 7%
Compartment for four or six persons	- 6%
Reclining seatbacks	6-10%
10 cm more or less legroom	4 - 7%
5 cm wider seat	4%
"Comfortable" seats	6- 10%

Table 8.7 Value of some seat factors

The seating offered in trains is more spacious than in competing modes of transport, but the appreciation of space in buses is as high as in trains. This is explained by the fact that expectations of space in buses are lower and there may be self segmentation. The main reason for the lower train-space utilisation is not the seat area but the train areas for aisles, entrances, luggage, hand and registered luggage, appliances, machinery, toilets, catering,

²⁴⁹ Förstberg, J., *Motion related comfort levels in trains*, KTH Railway Technology 1996, TRITA-FKT report 1996:41

staff and so on (see Section 2.1.1). Only some of these areas are supposed to be experienced by the traveller as enhancing comfort.

One interesting question is whether space utilisation should be increased by reducing the distance between seats. That is why the traveller ratings have been closely studied²⁵⁰. In trains, a difference of 1dm in legroom is rated at 4-7% of the fare and reductions are more strongly felt than additions:

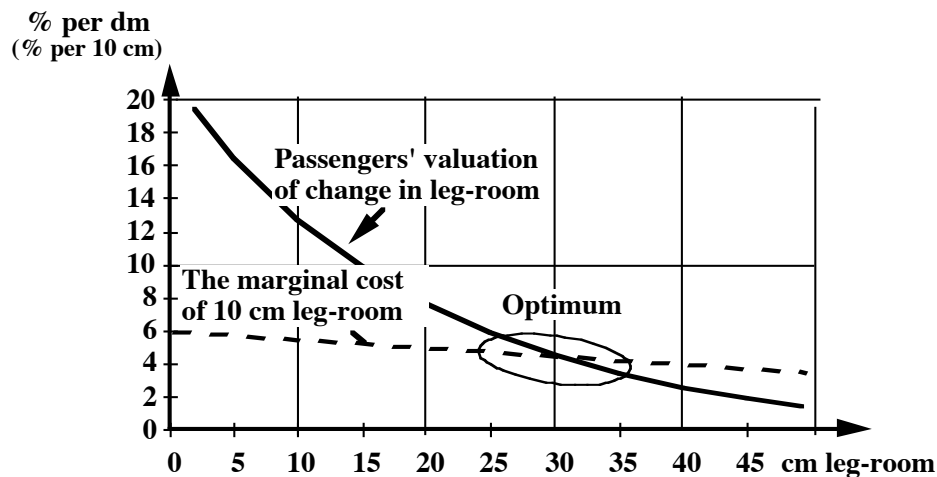


Figure 8.7 Rating and cost of change in legroom on Swedish long-distance trains (see text)

In her study of seat configuration, Hansson (1996) comes to the conclusion that seat distance can be reduced from the present 95 cm to 80 - 85 cm. This can be achieved by making seatbacks 5 cm thinner and improving their design (allowing passengers to stretch their lower legs) coupled with a reclining mechanism which does not intrude on the space of the passenger behind. Approximately the same conclusion has been drawn (1989) by Johansson who stated that the seat in a long-distance bus/coach received as high marks from its passengers as the long-distance train space was given by train travellers. As can be seen from Section 2.5, it is doubtful whether a reduction in the *experienced* space should be realised.

Travellers generally prefer to have a seat, but there are cases when standing is preferred. The evaluation of 2+3 seating, summarised in Section 7.10, (also) revealed that a number of the interviewed regional travellers preferred to stand rather than taking an inner seat between two seated persons or a seat by the window, when the other seats were already occupied. Perhaps they did not want to ask the passengers who were already seated to get up from their seats to allow them to reach the free seat.

²⁵⁰ Kottenhoff, K., *Train Interiors and the Value of Space*, KTH 1994, TRITA-IP AR 94-14

Table at your seat

To have a table at your seat makes it possible to use the riding time for work, hobbies, games or eating. We should therefore expect a fairly high valuation for having a table.

Table 8.6 Valuations of tables at the seat

TABLES	
Table...	2% (in regional commuter trains, Båge 96)
"There is a table at my seat"	≈ 6% (SJ experimental coach B20, may 98)
Table at your seat	5-7% (SP study, spring 98)

The preference for tables was fairly high, according to my "final" SP study from the spring of 1998 and the interviews in the B20 experimental coach. A lower value appear from Båge's degree thesis. I suspect the latter valuation level is too low.

Some confusion in terms appears to exist between my definition of *table* and SJ's:

SJ use to print information about tables on tickets. But; "Reserved seat with table" can be a seat at the aisle where there is a small table by the window. The fold out tables included in the seat backs in front of you in face-to-back seats are not mentioned on the tickets.

SJ appears to use "table" as an indicator of face-to-face seating.

Lighting/illumination

Subdued general lighting supplemented by reading spot-lights has a relatively high rating.

Table 8.7 Valuations of lighting

LIGHTING/ILLUMINATION	
Subdued lighting + individual reading lamps	8% (in X10 train, IR study 93)
Subdued lighting + individual reading lamps	2-4% (SP study, spring 98)
"There are reading lamps"	≈ 6% (SJ experimental coach B20, may 98)
"There are reading lamps"	≈ 3% (Double-deck study, Dec. 98)

The reference level for the illumination attribute is direct striplight (light tubes) in the SP experiments. In reality Swedish passengers should have their own experience of subdued lighting because some versions of Swedish InterCity coaches have illumination of that type. There are indications that the preferences for what type of lighting is the best differs from person to person, the time of day and the type of journey. Therefore very light illumination by strip lights does not receive the highest value.

Passenger room division

Riding in a *compartment* is rated negatively by many Swedish travellers, 4% lower than riding in an open saloon. There is, however, a group of travellers with a slight preference for compartments. Smoke-free trains where smokers are directed to special smoking areas are rated at 6% of the ticket price.

Reading saloons and chat corners are rated at 5-8%. This indicates that there are many people who do not want to be disturbed. Play areas for children are rated, probably for the same reason, at 3-10%. The highest value is given to "family coach with large play area

and child keepers”, while the lower limit is when considering the package effect reported in the background study. The reported evaluation is an average of all the respondents' valuation – families with children are more appreciative, but even people without children were shown to value special family cars positively.



Figure 8.8 A play area was usually standard in Swedish IC trains during the 1990s.

Smoke-free trains are valued positively by (Swedish) travellers. Smokers and non-smokers were segmented to check the view of the smoking minority. The segmentation showed that smokers accept a smoke-free train with smokers' corners, giving it a value of about zero per cent.

Table 8.8 Valuations for passenger room division.

PASSENGER ROOM DIVISION	
Family coach with a large play area for children and a child keepers	10%, reduced to 3% in a service package (Rosenlind ²⁵¹)
Family coach with a small play area for children	8% (Rosenlind)
Reading salons for reading, rest and work plus "talk corners" for cheerful social life	5-8%
No smoking in train, except in smokers' corners where smokers must go to smoke	4-8%

The mobile telephone problem; co-travellers are disturbed by other passengers talking on their mobile phones, has been noted but not evaluated monetarily.

Luggage space

The value of increased storage space for luggage has been evaluated in a few studies.

Table 8.9 Valuations for luggage space

LUGGAGE SPACE	
More luggage space	+1%
More instead of less luggage space	+3%

²⁵¹ Rosenlind, S.; *Tågresenärers värderingar av trafikering, vagntyper och service*, (Passengers' valuations of traffic services, coach types and on-board service, in Swedish), KTH Traffic Planning, Master thesis/ examensarbete 94-1, 1994

The result can be as indicating that a few passengers have problems finding enough space for their luggage. The attribute of luggage service is presented in section 8.3.3.

Entrance arrangements

A study has examined the value of good entrance arrangements for the average traveller. Platform-height, level entrance was then rated at 4% of the fare. In connection with other traveller interviews on trains with wide entrance doors and roomy vestibules, like the Norwegian ICE train, the spontaneous comments have been positive.

In research on the need for the disabled to be able to travel and the potential of public transport, entrance conditions have been studied by Dr. Agneta Ståhl and Dr. Jan Petzäll. It turns out that the number of persons with some form of handicap is very large, while there are few seriously disabled persons in wheelchairs. About 250,000 Swedes have serious mobility impairments²⁵². In an evaluation of the Board of Transport regulations concerning public transport adapted to mobility-impaired people, Ståhl et al. write about measures relating to *embarking and disembarking problems* and state that:

- these measures have reduced the problems,
- this applies to a particularly large extent to the most mobility-impaired people,
- simplified embarking and disembarking is still the most common wish among the most disabled within the group concerned, and that it then above all is a question of perfectly level embarking facilities on all means of transport.

The organisations for the disabled regard platform-height, level entrances as the obvious solution. When asking questions, the disadvantages that may emerge in other places in the case of entrance arrangements are difficult to include; low-floor entrances can, for instance, cause steps to be placed in the centre aisle of vehicles. The total value of platform-height, level entrances can hardly be solely on this arrangement and on the average traveller's willingness to pay. This demand should instead be looked at from moral and political points of view, which should also take account of other solutions which might be pertinent.

8.3.3 On-board service factors

We regard arrangements and courtesies that are not available on all trains but which the transport operator can choose to give or sell to its customers as service.

Luggage service

Rosenlind²⁵³ found that having the opportunity to register (check) one's luggage was valued at 4% of the fare.

²⁵² Ståhl, A., *Providing transportation for elderly and handicapped in Sweden*, TFB (today KFB) report 1991:17

²⁵³ Rosenlind, S.; *Tågresenärers värderingar av trafikering, vagntyper och service*, (Passengers' valuations of traffic services, coach types and on-board service, in Swedish), KTH Traffic Planning, Master thesis/ examensarbete 94-1, 1994

Electronic information systems

Willingness to pay for the service given by electronic sign systems appears to be fairly low. (On the other hand, information about delays is an often heard request.)

Catering

The value of different levels of catering can be seen from table 8.10. These values should not be interpreted literally. What is interesting is that the ratings actually rise with the level or "quality". One intriguing possibility which has not been evaluated is to offer a free meal at the seat, also in the class the majority of travellers choose.

Table 8.10 Valuations for different types/levels of catering, taken from various studies.

CATERING	
Coffee vending-machine (related to no catering)	3-6%
Free coffee and tea in each coach	≈ 6%
Food trolley	≈ 11%
Buffet / Cafeteria	≈ 14%
Restaurant with hot meals	≈ 17%



Figure 8.9 Bistro in a German InterRegio train.

Music terminals and video

Headphone terminals for radio and music have a value of 1-4% of the ticket price. A minority of travellers probably rate this service fairly highly. A study has shown that about 25% of travellers want at-seat music. Slightly over 10% want to watch video. In a KTH study, the value of at-seat video display was estimated at 6% of the fare.

Other service factors

Other factors include an office service such as a telephone, fax and copier. This service receives low ratings from private travellers but is ranked more highly by business travellers. Possibility of contacting the driver, in trains without guard, is positively rated. This is useful to know in case of one-person operating. Existence and design of toilets are highly rated.

8.3.4 Quality fulfilment factors

Quality ratings are all about quality fulfilment, e. g. the traveller experiences imperfections in the travel product that is purchased. Shortcomings relating to punctuality, tidiness and modernity are accounted for here.

Punctuality

Delay time is rated as being twice as inconvenient as travelling time. For private travelling, SIKa recommends SEK 130/hour. Lindh²⁵⁴ has found that the risk of being delayed was experienced 6-7 times more negatively than the actual delay (SEK 14 and 2/min. respectively).

Table 8.11 Valuations of punctuality

PUNCTUALITY	
Being delayed	2 SEK/min (120 SEK/h)
The risk of being delayed	14 SEK/min
Better punctuality from 80% to 90% in time	16 % of fare, calculation by Lindh
"Delays are rare" versus "one 15-min delay every fifth journey"	10-11% (SP study, spring 98)

The calculation example by Lindh shown in the table gives a figure which with some caution can be used to compare the weight of punctuality with other attributes. My own study produced a figure of the same magnitude.

Occupancy rate (crowdedness)

The impact of the occupancy rate was investigated in both tests in 1998 with new types of passenger coaches in the Mälars region.

Table 8.12 Valuations of occupancy rate

OCCUPANCY RATE (CROWDEDNESS)	
There are many free seats, but not by the windows	-2%
There are a few free seats	-5%
The train is full (instead of many seats are free)	-5% to -10%
There are no free seats – you have to stand up	-50% (approximate), -100% in 1st class

The results show that the value of train travel diminishes slowly up to 100% occupancy and then, when you have to stand, it declines steeply. First-class passengers showed a negative valuation of 100% – they were not willing to travel under such conditions. In second class, the value of the journey decreased by almost 50%.

²⁵⁴ Lindh, C., Widlert, S., SJ-resenärers kvalitetsvärdering, KTH Traffic Planning, Meddelande 71, TRITA-TPL 89-10-62, 1989

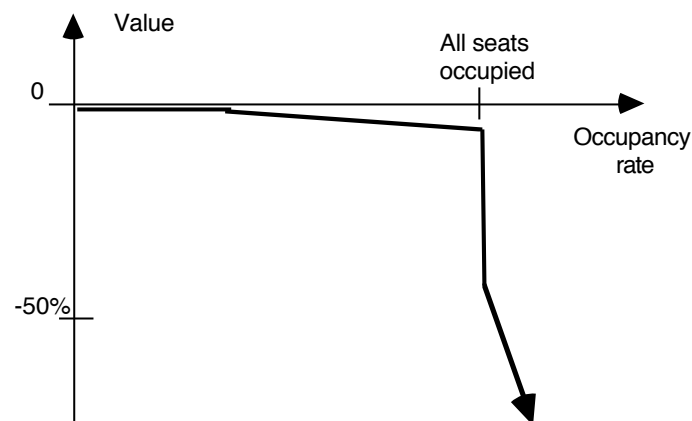


Figure 8.10 A sketch to visualise how passengers value occupancy

Tidiness, cleaning and modernity

If the train is tidy, cleaned and not old-fashioned and shabby, the traveller receives a feeling of freshness which is highly valued. The value of tidiness naturally depends on the alternative. A survey indicates 5% willingness to pay. Modernity is hard to isolate from certain comfort factors, but one assessment is the fact that the vehicle per se is "new and modern" is rated at 5-10% of the fare. A well-designed, refurbished interior in an old coach is enough to receive a high positive valuation.



Figure 8.11 The Swedish standard InterCity interior from 1980, reference coach in many SP studies. Coach class B7.

The following table shows ratings of vehicles from different epochs. Some of these ratings are probably due to actual comfort differences, but some depend on "modernity" differences. There are several other quality factors, such as the staff attitude towards travellers, the value of which is even more difficult to quantify.

Table 8.13 Valuations of modernity; new or refurbished vehicles.

NEW OR REFURBISHED VEHICLES – OLD VEHICLES	
Double-decker cars (Swiss 1991, German 1998) /different SJ-coaches (as reference)	+3% - +8%
German InterRegio coach (chartered) /coaches from the 1960's and 1980's	+8% and +4% respectively
Swedish InterRegio coach /coaches from the 1960's	+8%
Kustpilen (IC/3) /ordinary SJ train	+10% - +20%
X2000 /ordinary SJ-train	+5% - +10% (even higher for business travellers)
Experimental coach with 2+3 seating /ordinary SJ-coaches	+5% - +10%

An evaluation²⁵⁵ of Swiss double-decker cars that were chartered for the Uppsala shuttle for a few weeks in 1991 indicated that travellers preferred them to SJ's standard InterCity coaches. In this case the negative ratings for the simple interior fittings of the Swiss shuttle train were excluded. Similar conclusions can be drawn from the chartering of the German double-decker trainset in 1998 (See section 7.17).

The "Kustpilen", which is made up of trainsets (IC/3) designed in Denmark, receives high ratings compared with a "standard SJ train" but even higher ratings compared with railbuses which are not included in the table.

The figures for the X2000, in the table, are the ones calculated from the Svealand Line studies. The double decker study in 1998 revealed that the marginal value for the X2000 from business travellers is about two times higher than that from leisure travellers. On the other hand, business travellers also valued double deckers more highly.

Pre-studies conducted at KTH, in which respondents were able to evaluate pictures of the Kustpilen interior respectively the X2000 interior showed lower valuation levels than the ones "revealed" by travellers in these trains and estimated from SP experiments.

8.3.5 Summary of train attribute valuations

The first summary is a diagram of willingness-to-pay for comfort and on-board service attributes solely from KTH studies. These studies were presented in chapter 7. The SP methods differ and no account has been taken of the type of train. Nor are the valuations presented after being segmented into business and leisure travellers.

The interesting information in the diagram is to see the order of the valuations and the variation ("variance") between them.

²⁵⁵ Lindh, C., *Resenärernas krav på regionalståg*, KTH Traffic Planning, Meddelande 76, TPL 91-09-75, 1991

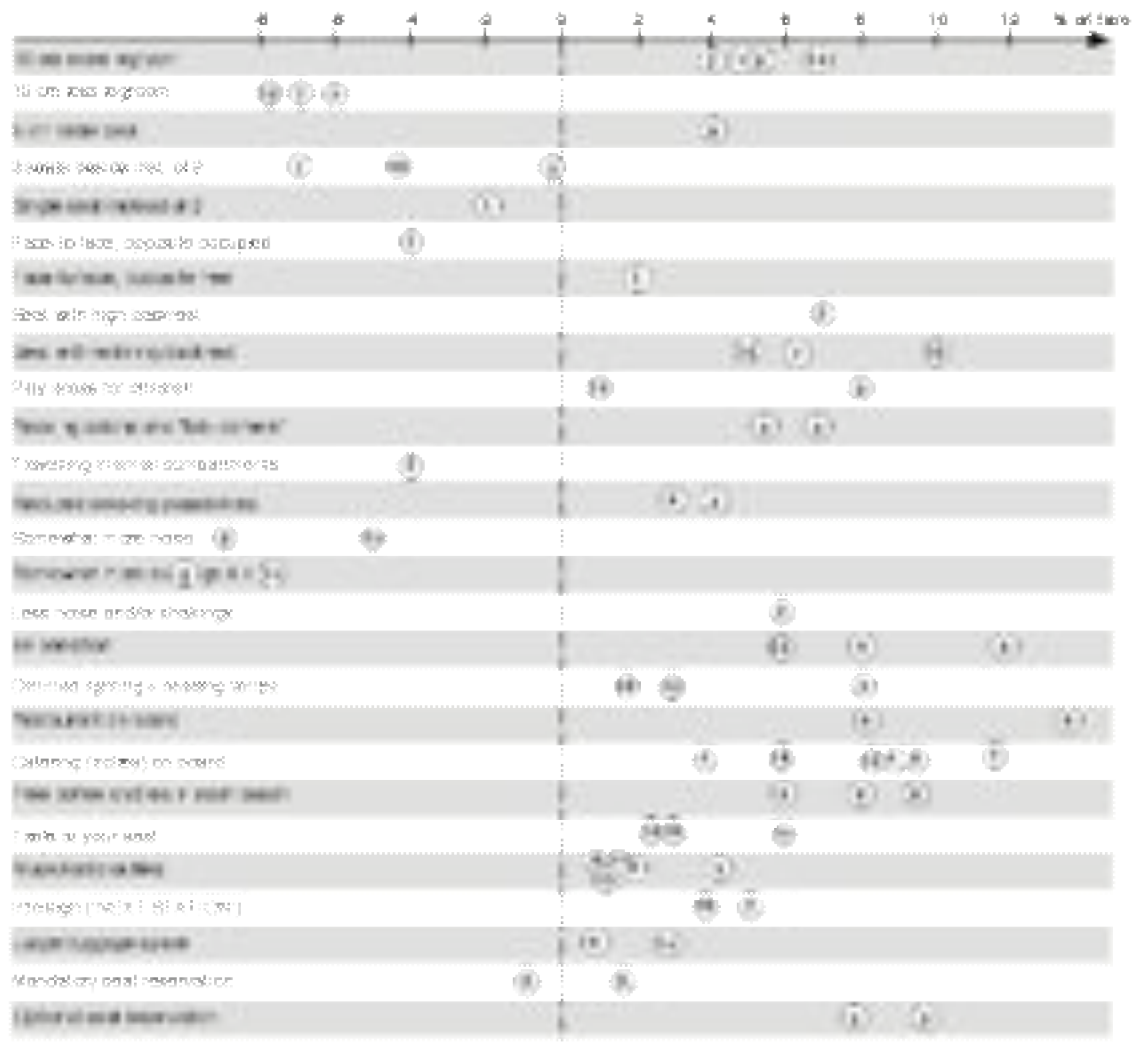


Figure 8.12 Willingness-to-pay results in % of ticket price (fare), from KTH-studies presented in chapter 7. The numbers of the studies are the same as the numbers of the studies in chapter 7

It can, for example, be seen that more or less legroom always receives relatively high valuations and the variation among different studies is not so great for this attribute. Another example which has large variations is play areas. It was valued highly in study (3) with train passengers, but much lower in the Internet study (14).

The following figure (8.13) presents the results of several KTH studies graphically (Kottenhoff, 1993, 1994a, Lindh 1989, 1991, Rosenlind 1994, Schmidt 1996, Widlert 1992). The bars represent willingness to pay as a percentage of the fare (ticket or season-ticket price). The values mainly relate to singular ratings - if more steps are taken simultaneously, their total value will be less than the sum of the singular ratings.

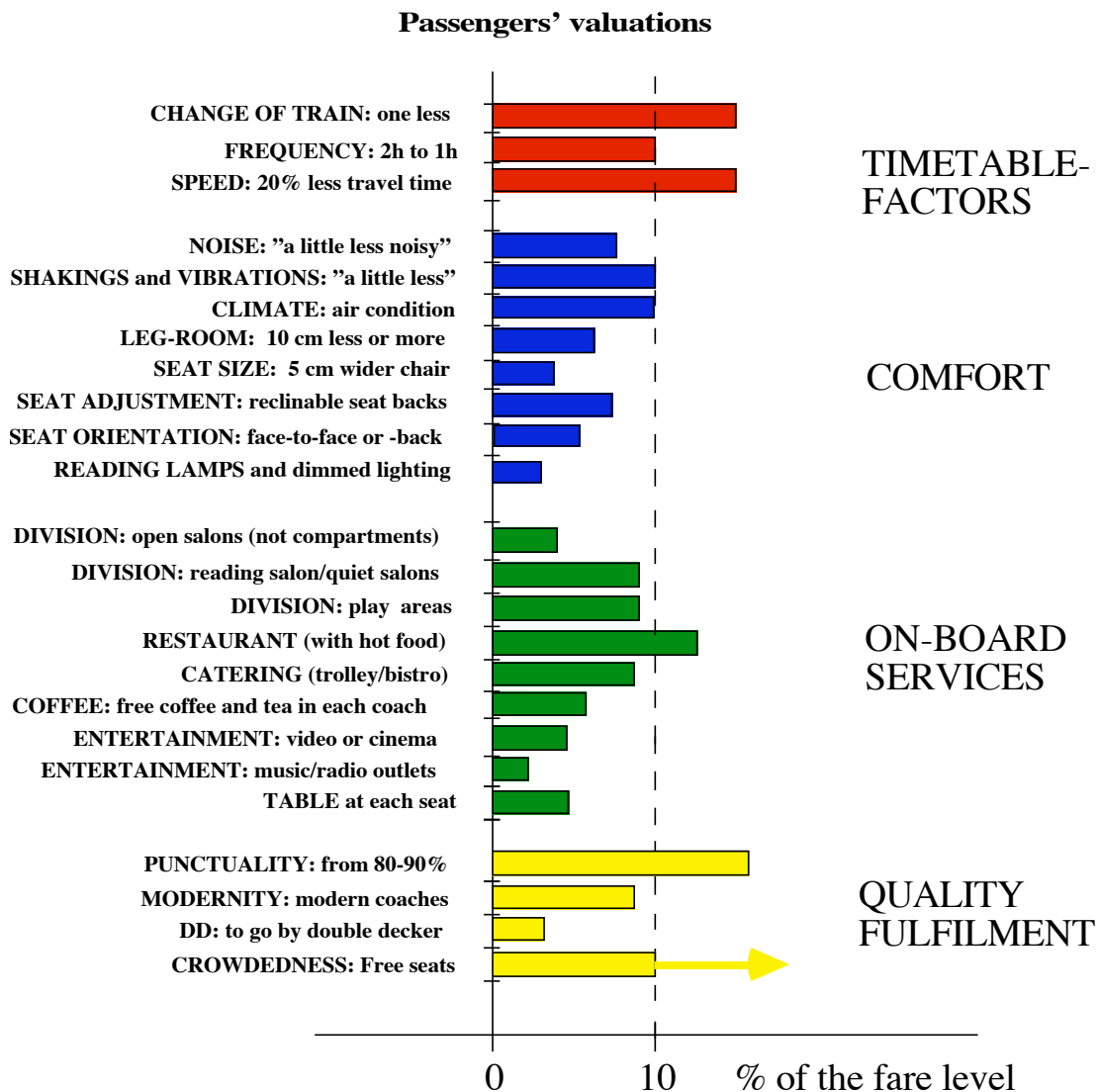


Figure 8.13 Examples of passengers' valuations of attributes classified according to timetable, comfort, on-board service and quality fulfilment. The evaluations stem from stated preference studies primarily conducted by Traffic and Transport Planning, KTH.

The bars representing valuations show that there are many comfort, service and quality improvements that are rated as highly or almost as highly as shorter travelling times. This is not to say that higher speeds can be disregarded. Shorter running times contribute per se to greater effectiveness and lower costs and many potential and moneyed person are pressed for time. Sometimes travelling time can be decisive if people want to go and come back on the same day (time-budget restrictions). Business travellers are very sensitive to travelling time when choosing means of transport.

The values presented must be interpreted and used with caution. One example is the relatively high value for air conditioning. The reason for this is probably that people require air quality and temperature to be good. However they probably forget that many AC units make a noise, which is negatively valued. From this example should be learnt that the valuation estimates for certain measures must be used with good sense.

8.3.6 Comparison with international valuation results

I have decided not to mix Swedish valuation results for the studied standard factors for several reasons. One is that it is then clearer what I or my colleagues at KTH have done. Another reason is that the circumstances, the transport system, in other countries may be very different and would be complicated to understand and describe.

On the other hand, I do not think human beings, in various European countries are so different, for example culturally, that this would create heavy bias. My impression is that people react similarly to the stated preference experiments we ask them to participate in. Having said this, a few valuations of trains in Denmark and Great Britain will be briefly presented.

The KTH results have been partly checked against the results of some foreign studies (DSB by Steer, Davies & Gleeve 1986 and 1987²⁵⁶, BR 1986). A few results from the Danish (DSB) studies of interregional and regional trains are summarised below. These studies each contained about 35 attributes, but about 10 which can be compared to our results have been chosen here.

Table 8.14 Comparison of valuation levels for a number of factors in KTH and DSB studies.

Factor (approximate attribute description)	KTH studies	DSB 1986 Interregional	DSB 1987 Regional
TIMETABLE			
One change of train	10-13%	16%	18%
Double/half train frequency	3-12%	≈7%	≈7%
20% less travelling time	≈15%	23%	7%
Fixed interval timetable	≈2%	21%	15%
COMFORT			
Reclining/adjustable (and comfortable) seats	7%	11%	13%
Seat orientation (face-to-face)	≈0%	–	2%
ON-BOARD SERVICE			
Open saloon coaches	4%	-5%	8%
Reading salons and family compartments	8+8%	13%	
Catering (trolley/ cold meals)	6-11%	14%	
QUALITY SATISFACTION			
Punctuality	≈15%	19%	14%
Crowdedness (all seats occupied)	-5 to -10%	-6%	≈ -10%
Modern interior	4-8%	5%	≈10%

The valuations in Sweden and Denmark look similar, with a few exceptions. The small differences for most attributes can be explained by "random" circumstances such as differences in SP design, attribute descriptions, population sampling, travel purposes,

²⁵⁶ Steer, Davies & Gleeve Ltd, *Research to evaluate passenger investment priorities*, (about Intercity services) prepared for DSB June 1986 and *Research to evaluate passenger investment priorities for regional services*, prepared for DSB 1987.

length of journeys and so on. The attribute that really differs is the fixed interval timetable. In Denmark, people are used to having this scheduling, when the train travellers in Sweden have been used to checking the timetable before travelling.

The order and weight of the five most valued attributes in the Danish InterCity study might be of interest:

1. Journey time (20% improvement)	1.79
2. Fixed interval timetable	1.64
3. Punctual trains (no delay equal to 10% of journey	1.52
4. Improved station WC (location and cleanliness)	1.40
5. Improved station waiting facilities	1.34
Price: Fares (no 10% increase)	0.79

One interesting observation is that two station-related attributes receive high weights (each corresponding to about 17% of the fare each). This shows that there are more important circumstances to consider than just the train attributes investigated in this thesis.

The impact of changing trains estimated in Sweden corresponds quite well with the following international experience. In France, travelling increased by about 30% when a transfer was eliminated in 1992 for a TGV service Paris - Lorient²⁵⁷. Wardman²⁵⁸ shows results from Great Britain which indicate that changing trains influences travelling almost twice as much (1.7-1.8 times transfer elasticity) on journeys of more than an hour as it does on one-hour journeys.

The British Passenger Demand Forecasting Handbook²⁵⁹ contains a lot of evaluation results. Values from the 1986 edition is not used for comparison here. Regrettably it has been difficult to achieve a copy of the present edition.

Wardman has conducted a number of studies of the passenger rail market. He has increasingly suspected that the valuations of secondary attributes produced by SP studies are too high. He and Whelan therefore designed and executed a study in England 1997/98²⁶⁰. It started with a qualitative part, an exploratory interview with train passengers to identify the attributes that interested them. Next, both revealed and stated preference methodology was used. In the RP study passengers who really had a chance to choose between train types were asked about the choices they really made. There were two SP experiments, one labelled and one unlabelled. In the labelled one, the same train types were used as in the RP study. The difference now was that the questions about choices were hypothetical. The other SP experiment was unlabelled. It described train alternatives in which only a few attributes differed.

²⁵⁷ Vilmar, C., Les effets des ruptures de charge sur la concurrence entre l'avion et le train, World Congress on Railway research, Paris 1994, vol. 1 p.307-319,

²⁵⁸ Wardman, M., *Inter urban rail demand, service quality and competition*, University of Leeds, World Congress on Railway Research (WCRR), Paris 1994, vol. 1 p.159-164,

²⁵⁹ British Railways Board, Policy Unit, *Passenger Demand Forecasting Handbook*, June 1986

²⁶⁰ Wardman, M., Whelan, G., *Rolling stock quality improvements and user willingness to pay*, ITS working paper 523, Leeds, March 1998

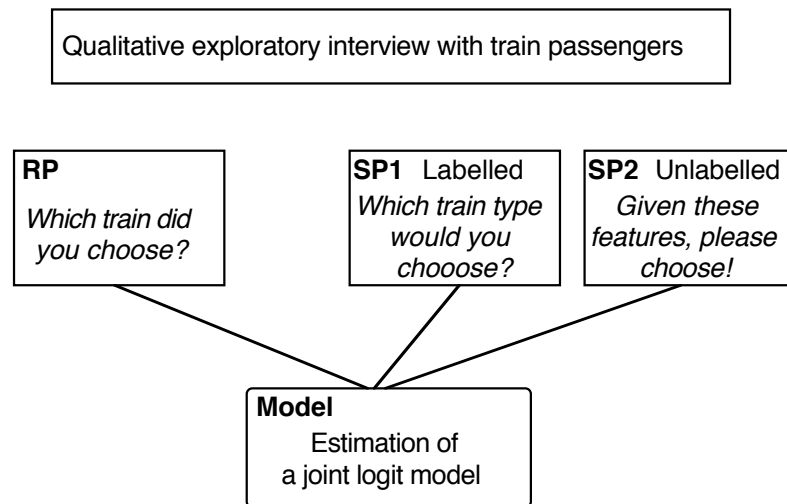


Figure 8.14 An overview of Wardman/Whealan's study (see preceding text).

The interesting thing about Wardman's study is not only the ambitious methodology but also and especially the low valuation levels that emerged. The highest difference in willingness-to-pay between the best and worst train type was about 2% of the fare. The combined effect of all attribute levels distinguishing these train types should then be included in this 2%.

The levels obtained by Wardman's (1997/98) study are then about up to a power of ten lower than the levels normally produced by SP studies, mine and others.

8.4 Valuations by various user segments

When segmenting the respondents in terms of various factors, socio-economic, travel purpose or other, the differences have been quite small compared with the general accuracy of the SP method. Comfort attributes in particular are therefore assumed to be common to all people to a certain extent. Having said this, some variations by user segments will nevertheless be presented.

8.4.1 Commuters and other passenger segments

A few studies have been used to see whether there are preference variations between people with various travel purposes. The most significant and striking difference discovered is that commuters pay more attention to space related comfort factors than other travellers.

The diagram below (figure 8.15) is taken from the "legroom study" (on Ostkustbanan, see section 7.1). It shows that commuters to and from work are less pleased with roominess at their seat. It must be emphasised that the interviews were conducted mostly in InterCity coaches, designed for long-distance passenger demands. The commuters may have been even less pleased with a traditional regional interior design.

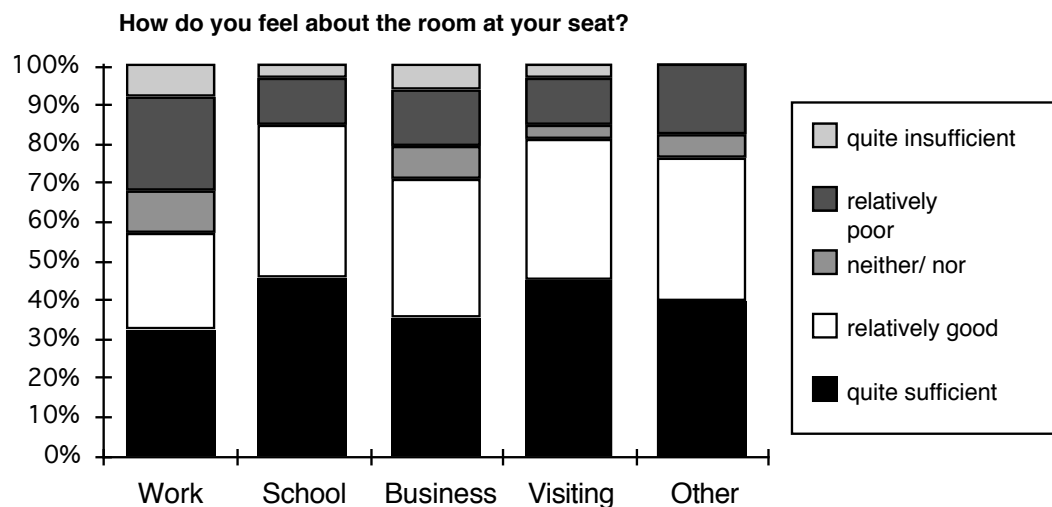


Figure 8.15 Passenger evaluation of roominess by travel purpose. (Ostkustbanan, see section 7.1.)

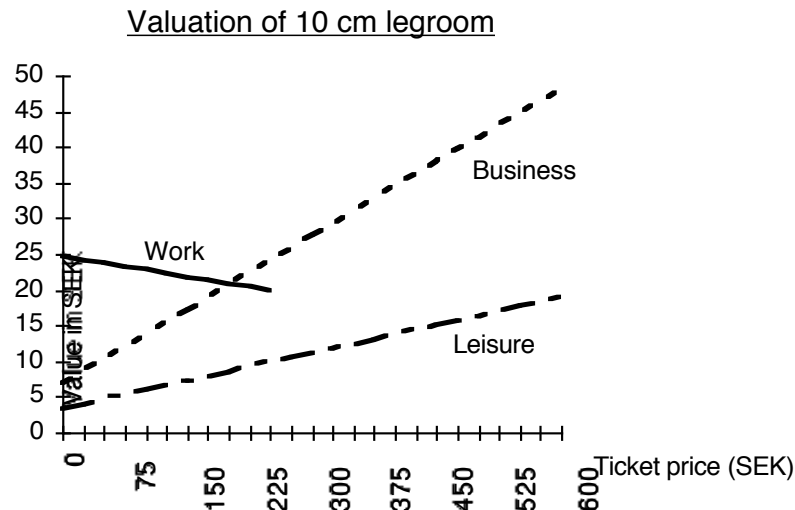


Figure 8.16 The valuation of legroom dependent on ticket price for different traveller segments.

Lindh's double decker study²⁶¹ from 1991 reveals similar results. The regional travellers on the Stockholm-Uppsala route, which is in general serviced by loco hauled InterCity coaches, were most willing to pay more for increased comfort.

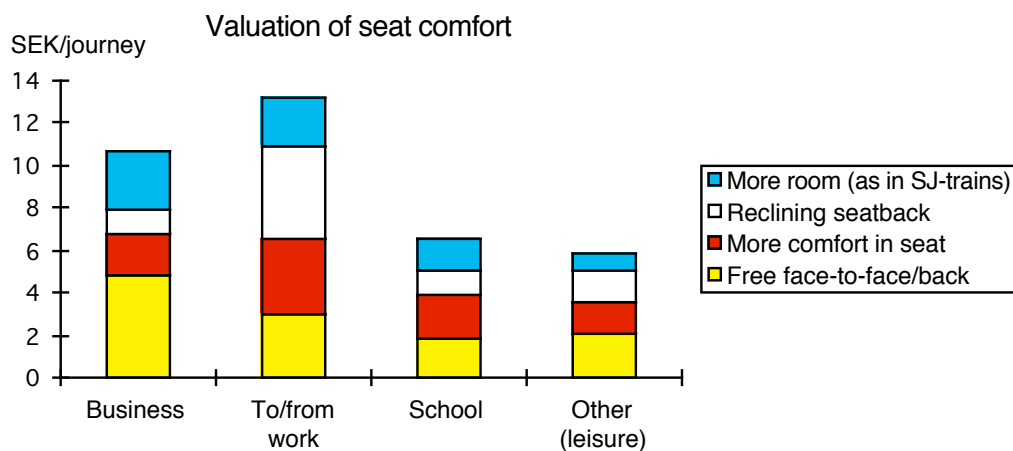


Figure 8.17 Valuations of seat comfort for various traveller segments. From Lindh (1991), Double decker evaluation.

The value of seat comfort, and especially reclining seatbacks, appears to be higher for travellers to and from work, even when valued in absolute money, in Lindh's study from 1991. Normally the relative value – % of the fare – is high(er) for this segment, but in this study even the absolute value was high.

²⁶¹ Lindh, C., *Resenärernas krav på regionalståg*, KTH Traffic Planning, Meddelande 76, TPL 91-09-75, 1991

Sometimes, regional travellers have revealed low absolute willingness-to-pay (Widlert²⁶²) for various improvements. In these cases, they have often travelled on low-cost monthly tickets. Their relative willingness-to-pay has been higher.

When regional travellers have lower valuations this can be an effect of self-selection. People with less willingness-to-pay are attracted by cheap tickets and they may impose fewer demands on comfort factors, manifested in the choice of a less comfortable train (with a traditional regional interior design). In Widlert's study, this was the case in both regions where interviews were made; Skåne and Östergötland.

8.4.2 Non-users valuations of travelling by train

Non-users' valuations of train travel are important, but only a few attempts to catch their preferences have been made in my work.

On the one hand, we note that non-users' valuations of train standard factors are sometimes higher than the users' valuations. This may perhaps be interpreted as meaning that non-users are not pleased enough with the standard level in trains. On the other hand, we can ask whether non users would react very much to changes to many of the train standard factors, such as seat comfort. Non-users probably have far less knowledge of the train system and the level of various timetable, comfort, service and quality factors.

In many studies I have asked the respondents about their car ownership and car use. The answers can be used for segmentation into different attribute weights. A few results from the InterRegio study will be presented here. At first figure 8.18 shows that about 10% of the train passengers mostly went by car "this route".

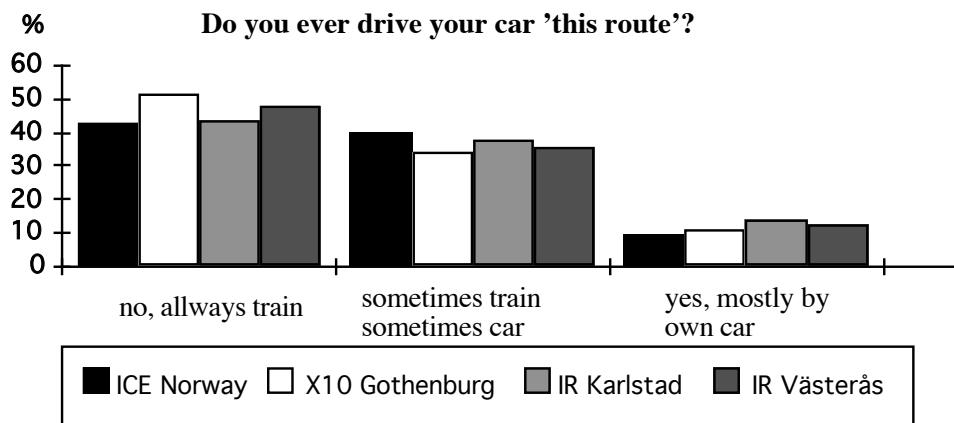
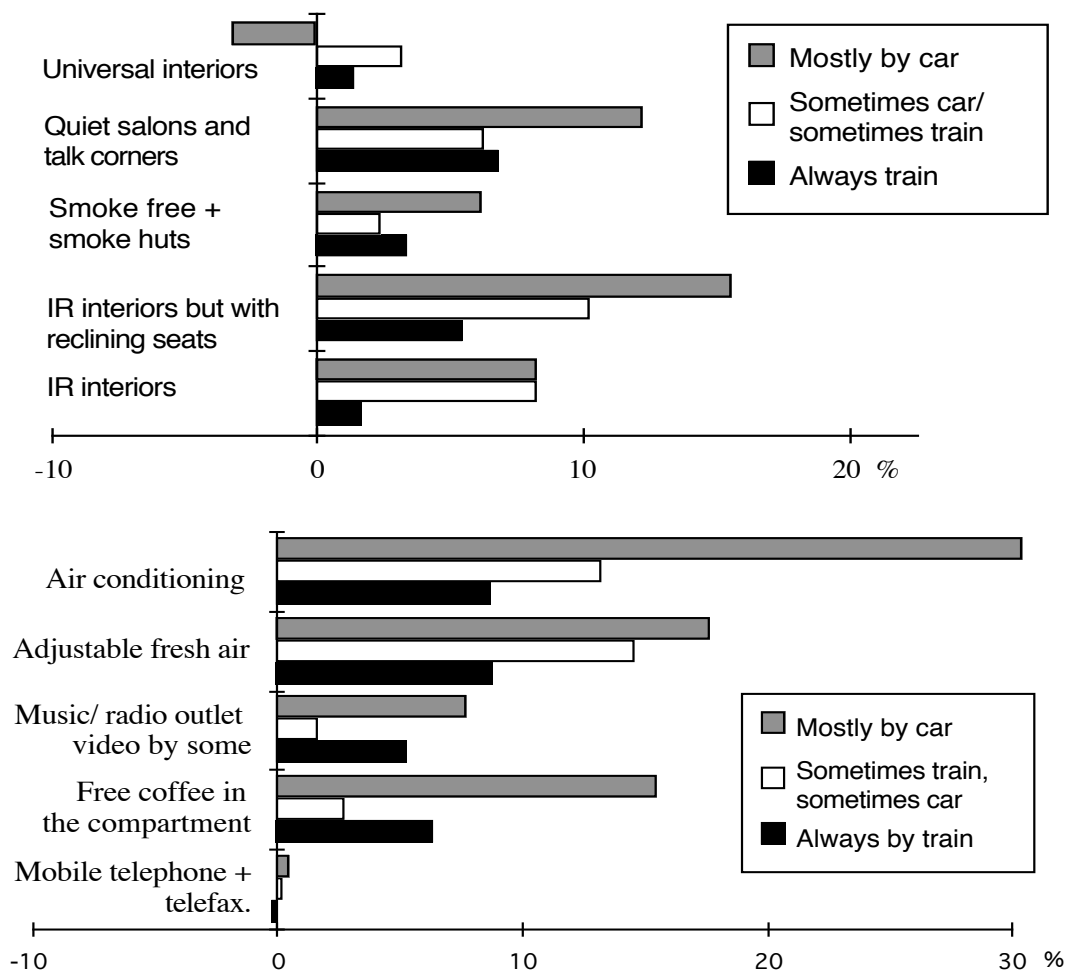


Figure 8.18 Proportion of the interviewed that drive or go by car "this route".

Those who mostly go by their own car are car drivers and they could represent a percentage of the motorists. We could assume that their valuations more in the direction of the average for car drivers.

²⁶² Widlert, S., *Trafikantvärderingar vid regional trafik, TFB report 1992:2*



Figures 8.19-8.20 The valuation of various interiors, comfort and service measures for segments with different car usage.

All (monetary) valuations are higher for those who mostly go by car. The reason could of course be that their preferences for high standard is higher than for the regular train users. But, the reason may as well be that their preference or valuation of money could be lower. In section 6.5.3, figure 6.36 showed that price sensitivity is lower for those who seldom travel by train. A lower sensitivity for price results in a relatively higher valuation of other attributes included in the same model.

The SP studies including travellers and inhabitants along the new Svealand Line (see section 7.13) reveal that the differences in valuation levels are not very large. Table 8.15 shows the ratings from train passengers to/from Eskilstuna and inhabitants of Eskilstuna city in 1998.

Inhabitants value *bus and private car* more highly than train passengers do. Train passengers value the *X2000* more highly. Those people who have already paid relatively expensive tickets, the train passengers, give a lower weight to the price level than inhabitants do. This may indicate that lower prices are more important to attract new passengers than prices are to keep existing customers.

Table 8.15 Ratings given by train users and inhabitants of Eskilstuna 1998 (Svealand study, see section 7.13)

	Alt.	Train riders	Inhabitants	Difference
Bus, low price level	A1	3.3	4.5	1.2
Bus, high price	B1	2.0	2.1	0.1
Train, low price	C1	5.9	6.9	1.0
Train, high price	D1	4.2	3.7	-0.5
X2000, low price	E1	8.8	9.5	0.7
X2000, high price	F1	6.4	5.7	-0.7
Car	E2	5,6	7.2	1.6

The Svealand study does not include separate comfort and on-board service attributes. So it is hard to judge from this study how inhabitants would value such factors.

Kroes et.al.²⁶³ concludes from a study in the Netherlands, the Zwolle-Almelo regional line, that "people that rarely or never ever use the train had similar preferences for train features as the regular users". They also appeared to have the same elasticity values. "The non train users, however, were considerably less sensitive to improvements in the train system, and it seemed very hard to persuade them to start using the train." The most effective measures for these people appeared to be fare decreases and travelling time improvements, according to Kroes' study.

Kroes also states that one-third of the target population in this study were completely insensitive to improvements in the train system and would under no circumstances use the train because of high car ownership, relatively low driving costs and good roads.

Reasons for not using the train

My experience is that one receives a variety of answers when asking why people do not use train instead of another mode of transport. My impression is that they defend their choice rather than explaining it in terms of trade-off factors between rail and other alternatives. This observation is in line with the differentiation and consolidation theory. The differentiation and consolidation effects indicate that people who make a choice tend to differentiate or overvalue the alternative they are inclined towards and afterwards defend the chosen alternative.

When an inhomogeneous group of people is observed their valuations are different. If it is a group of car drivers there are drivers who have real problems travelling by train, and even considering the train as an alternative, but there are probably also drivers who could use the train with ease and have frequently considered the train. For the second type, a small service improvement could be enough for them to make a new decision; to change the transport mode. This may be explained the way that only the consolidation effect has made them value the car alternative highly enough to choose it (the last few times).

The same reasoning can be applied to regular train users.

²⁶³ Kroes, Sheldon & Swanson, Developing choice models using stated preference research, Hague Consulting Group and Steer Davies & Gleeve

D. Evaluation of measures and conclusions

9. Trading off attractiveness against effectiveness

The need to evaluate the measures which be implemented and the performance and design that is the best arises because there is a conflict of some sort. On the one hand there are many things that would be appreciated by travellers, but, on the other hand these things cost money and ticket prices are then in danger. Another type of conflict arises when some passengers prefer one alternative and others prefer another. A quantitative trade off will provide guidance to resolve these conflicts.

In section 9.1, an account of the supply measures which have been studied in relation to passengers' standard attributes is presented. Section 9.2 describes the restricted type of cost/benefit analysis conducted in this thesis.

9.1 Supply measures and attractiveness attributes

The classification of the attractiveness/passengers and the effectiveness/supply aspects is an attempt to use different descriptions. When it came to attractiveness, the attributes were chosen which would be of importance to passengers, but they were still of a technical nature to some extent. When it came to effectiveness, on the other hand, standard technical measures were used. The difference between the two is illustrated below:

Table 9.1 Examples of supply measures and attractiveness attributes

<u>Effectiveness/ supply measures</u>	<u>Attractiveness/ passengers' attributes</u>
Top speed (km/h), average speed (km/h), acceleration (m/s^2)	Travelling time (h, min)
Seat spacing (mm)	Legroom (cm)
Noise level (dB(A), dB(L))	"Noise level as in this train", "Somewhat less noise than in this train"
Vibration level (Wz value, m/s^2 , dB)	"Vibrations as in this train", "Somewhat less vibration than in this train"

The structuring included grouping supply features into six categories and attractiveness attributes into four. The supply measures influence the attractiveness in a way that can be illustrated by a matrix. Timetable attributes, e.g. travelling time and frequency, are influenced by the performance of the train, e.g. top speed, but also to some extent by the exterior train configuration, e.g. train size.

Table 9.2 Relationships between classification groups of attractiveness attributes (on rows) and rolling stock supply classification (in columns).

	EXTERIOR CONFIG.	INTERIOR TRAIN DESIGN	PERFOR- MANCE	DESIGN	TECHNICAL QUALITY	AUXILIARY EQUIPMENT
TIMETABLE	(+)		+			
COMFORT		+	(-)	(+)	(+)	(+)
O.B. SERVICE						+
QUALITY FULFILMENT		(+)	(+)	+	(+)	(+)

The point is that one technical measure can relate to and affect more attractiveness attributes. So a higher speed level (a performance measure) can, for example, make shorter travelling times (timetable attribute) possible but also have a negative effect on ride quality (comfort attribute). The perception and experience of vibrations naturally depends on the vibration level, but it also depends on related noise. The perception of roominess or space comfort depends on the physical dimensions of the seating area but also on the colour, design, materials and shape.

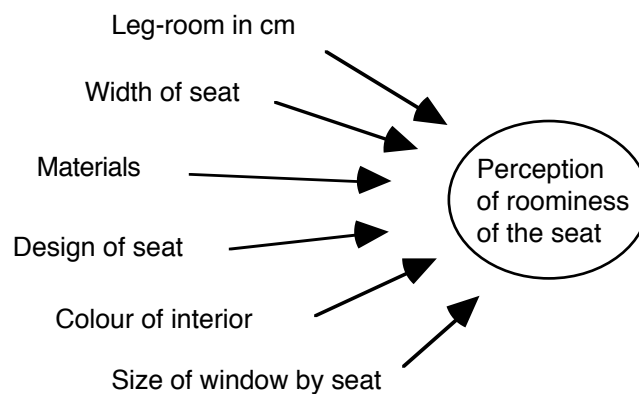


Figure 9.1 Many physical factors can influence the perception of one attribute. In this figure, this is exemplified by the perception of the roominess of a seat.

In a similar way, one of the passengers' attributes may be influenced by more than one technical measure.

9.2 Cost-benefit analysis

Comparisons of costs and benefits can be made at various levels. A socio-economic analysis attempts to quantify as many relevant aspects as possible. On the other hand, a business-economic analysis includes costs and revenues for a business company, in this case it would be the railway operator. There are possibilities in between. The term "traffic economy" in this thesis refers to costs and benefits that are directly related to the traffic, for example the value of shorter travelling times and enhanced comfort. Indirect costs – the cost of external effects like environmental effects – are not included.

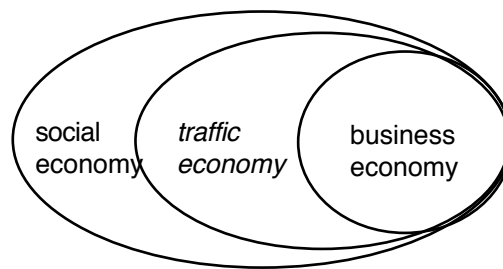


Figure 9.2 Correspondence between social, business and traffic economy. The latter includes business economy and is part of the economy.

A more complete business-economic cost/benefit analysis should include the dynamics to which various measures and changes in technology can lead. This naturally includes the direct cost of the measure and the passengers' valuation of it, but also the results of an increase in the number of passengers resulting in higher revenues and probably also increased costs.

A corresponding socio-economic analysis would add the external effects relating to the environment, traffic safety and so on. To calculate these, it is necessary to calculate the effects an improved train service may have on mode split – the reduction in car, bus and air traffic.

Figure 9.3 illustrates relations between a technical measure, its cost and the corresponding attribute(s) and passengers' valuation of this. The increased (or decreased) value may lead to an increased (or decreased) number of passengers, which in turn may call for a change in the produced supply and thereby increasing (or decreasing) costs. Another way is that the operator changes the ticket prices in direct relation to the changed value or willingness-to-pay. In this way the number of passengers should not be altered.

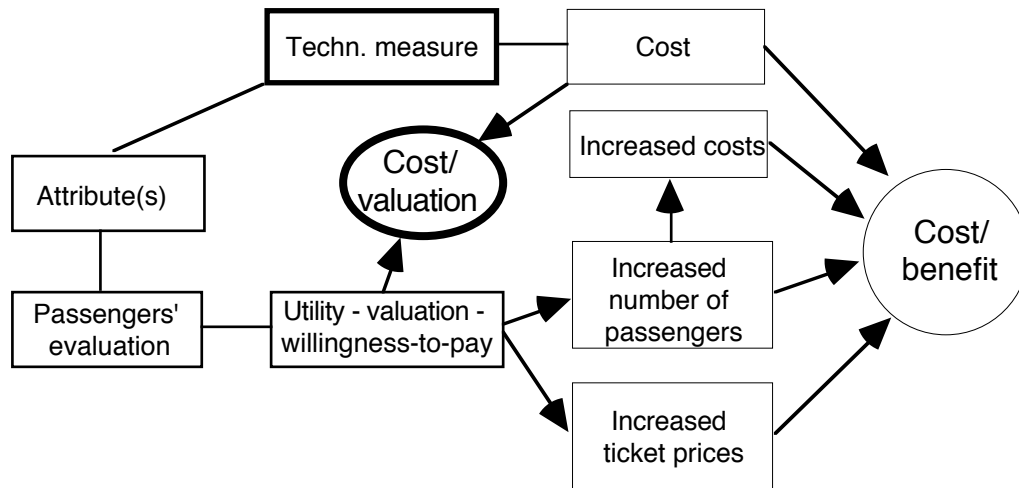


Figure 9.3 Relationships between measures, costs, willingness-to-pay, increased travelling and benefits. In this thesis a restricted wtp/cost comparison is made, not a full cost/benefit analysis.

A simpler "cost/benefit" comparison is made in this thesis. The passengers' *valuation* of a measure is compared with its cost. This is illustrated by cost/valuation in figure 9.3. The next figure (9.4) is a simplified version which better illustrates the method used.

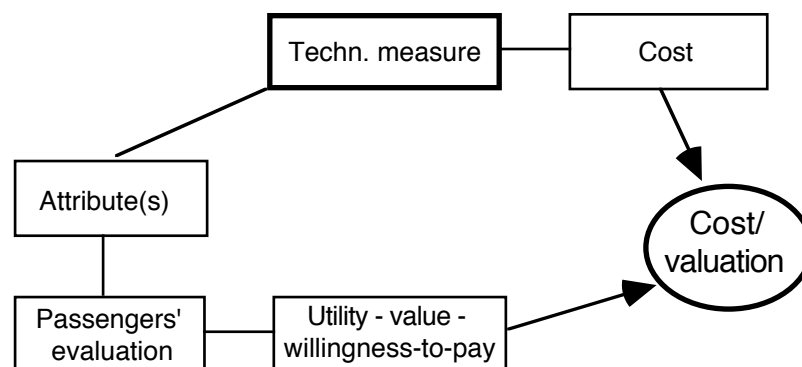


Figure 9.4 The part of the cost/benefit evaluation that is most often used in this thesis; comparison of passengers' wtp with the cost to the operator for the measure in question.

As shown by figure 9.4, measures are evaluated by comparing the cost of a measure with the passengers' monetary valuation of it.

The concepts of benefit, utility, value, valuation and willingness-to-pay do not have exactly the same meaning or implications. A full cost/benefit appraisal is replaced by a cost/valuation appraisal, where valuation stands for the passengers' valuations of various measures, estimated using stated preference methodology. The term valuation is chosen instead of willingness-to-pay because the latter may imply that there is an immediate opportunity to raise ticket prices and because willingness-to-accept is sometimes more relevant.

9.2.1 Method for comparing relative revenue and cost changes

Using an economic model, in this case "Tåganalys", it is possible to calculate *cost changes in per cent*. They can be compared with *revenue changes in per cent*. In a primary approximation, the latter may be assumed to equal the passengers' valuation of a certain change. The prerequisite for this comparison to be fair is that the traffic just about breaks even, that is to say costs are covered 100%.

From figure 9.5, it can be seen that there are many opportunities for cost and revenue changes that are of interest. They include combinations of increased and/or decreased cost and revenue. The most interesting measures are of course those which both decrease costs and increase revenues.

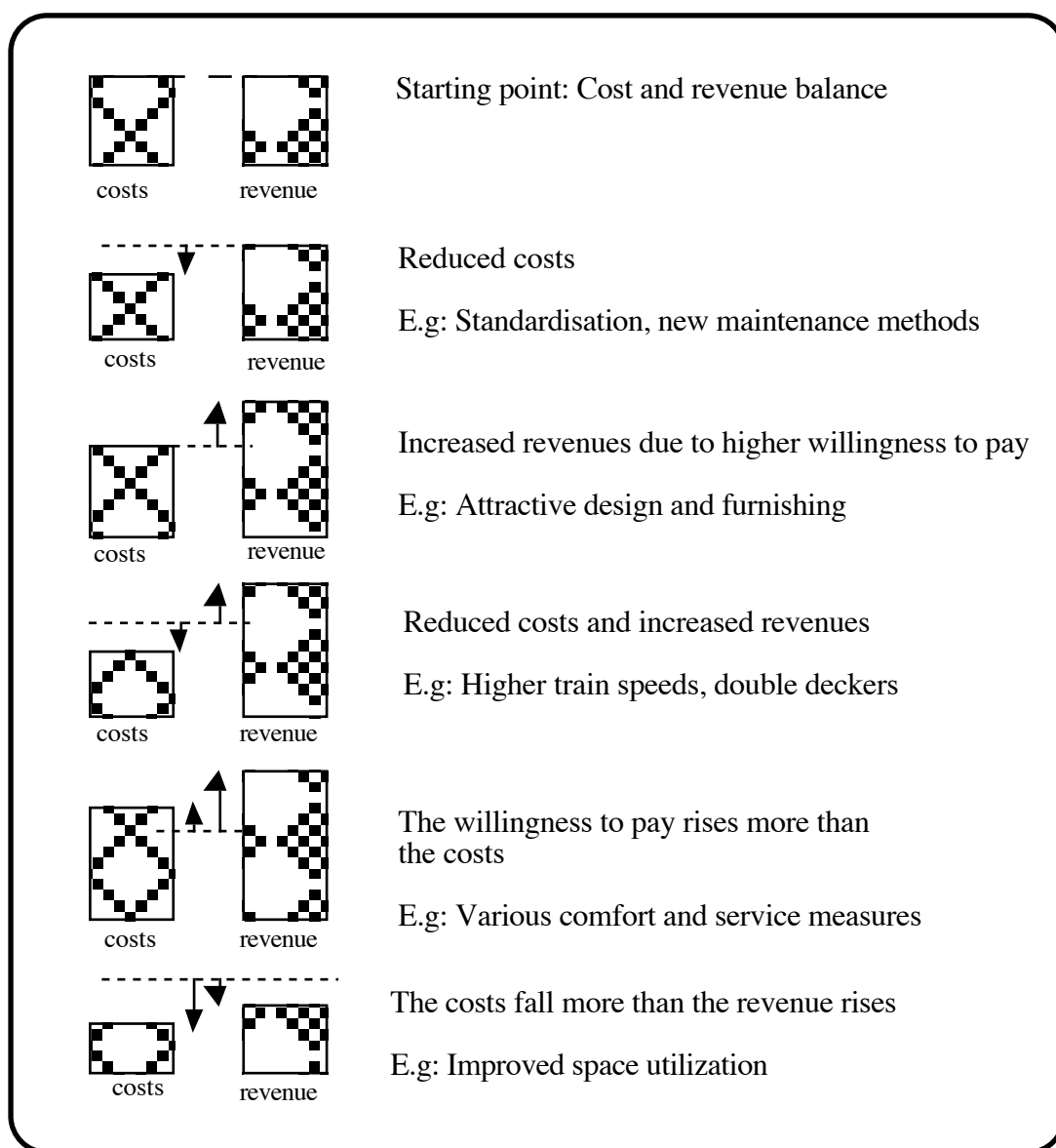


Figure 9.5 Lower costs and/or higher revenues

If costs and revenue do not more or less break even, say that revenue is lower than costs, the comparison of marginal costs and marginal revenues is more complicated. The thing to do would be to compare the absolute cost and revenue changes. Another possibility would be to multiply the relative valuation figures, measured as a percentage of the fare, by the cost coverage rate.

The attractiveness in terms of valuation and effectiveness resulting from cost changes can also be presented in an X/Y diagram.

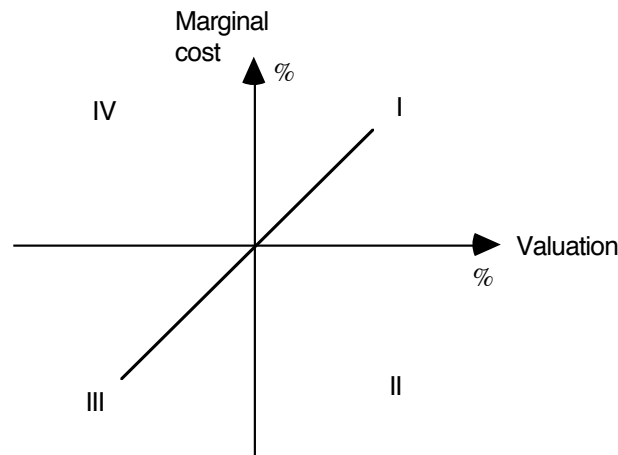


Figure 9.6 Valuations and marginal costs can be presented in an X/Y diagram.

The line between I and III divides the area into "profitable" measures to the lower right and "unprofitable" measures to the upper left. The profitability is marked because the valuations obtained by SP methods are, as already mentioned, not sufficient for the anticipated real revenue changes and the effect on costs of a change in the number of passengers

Some means of increasing effectiveness and/or attractiveness are highlighted in chapter 10.

10. Traffic economy for a sample of measures

In this chapter, some means of increasing efficiency and/or attractiveness are highlighted. The classification used for the division of this chapter is based on the classification of the supply (presented in Chapter 3).

As mentioned before, traffic economy includes

- costs and savings related to the measures
- passengers' valuations of the measures

In some cases, a measure only affects one of these; cost or valuation.

10.1 Evaluation of exterior train configuration

Exterior train configuration includes three main areas, train composition, train weight and exterior measurements. In this section, an example of train composition is given. Train weight has been analysed from an economic and technical point of view by the Railway Group²⁶⁴. In this work, I have not made any cost-benefit calculations about (for example) reducing weight.

The area of exterior measurements has been dealt with by analysing the costs and benefits of the two concepts, double-decker trains and extra wide-bodied trains. Both of these concepts have important implications for the coach interior and passengers' comfort valuations. So the cost benefits for high or wide-bodied trains are presented in Section 10.6, which deals with train concepts.

10.1.1 Locomotive and multiple unit trains

An example of the way locomotive or multiple-unit trains can affect costs is given here. The investment cost for a locomotive train is compared with that of an electric multiple-unit (EMU) train and an EMU-hauled trainset at different capacity levels.

²⁶⁴ Railway Group KTH, Andersson,E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik*. (Efficient Passenger Rail Services for the Future, in Swedish – English version is under way, 1999), KTH Railway Group report 9702, 1997

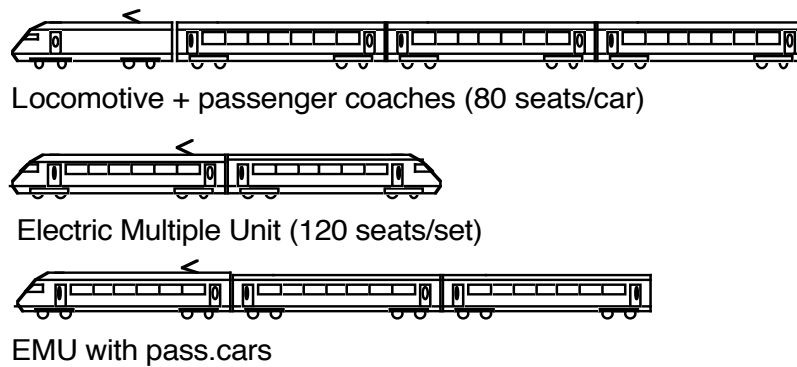


Figure 10.1 These three train types are used in the comparison. The third train “EMU with pass.cars” is a combination of an EMU (multiple-unit train) and standard passenger cars.

From the diagram in figure 10.2, it is apparent, as expected, that electric multiple-unit (EMU) trains are less expensive than loco trains in connection with small train sizes – lower capacity.

It can also be seen that, with a demand of about 120 to 240 seats, the hybrid form in which a powerful motor car unit hauls standard passenger cars is the least expensive type of train in this example. Among other things, this stems from the fact that the use of space is higher when the motor unit is used. It is assumed that all vehicles can be combined with all the others. The coupling of vehicles should be quick, something that must be handled easily by regular train staff. The Danish IC/3 front is the most intelligent device so far!

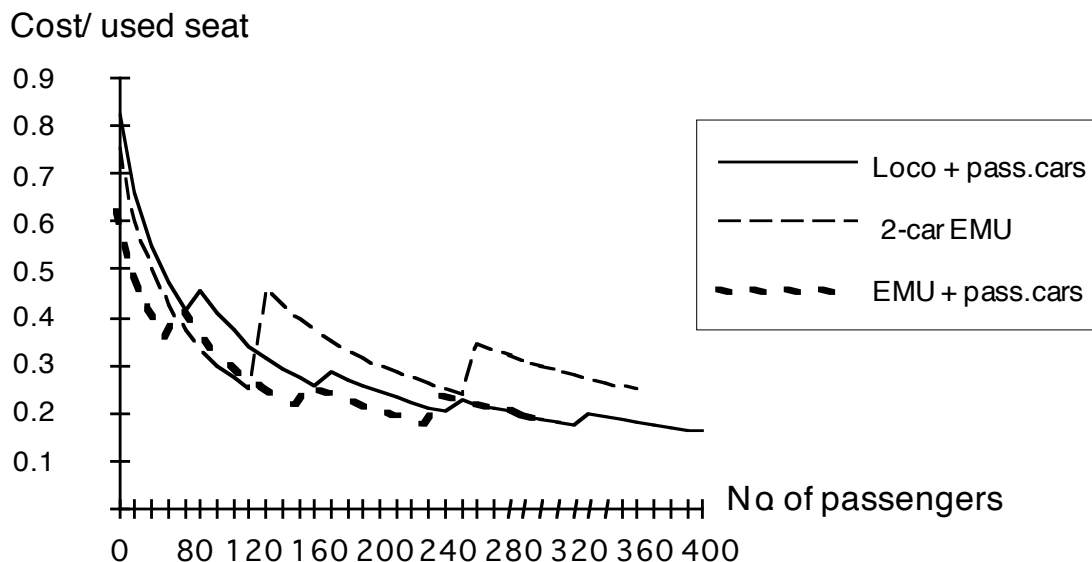


Figure 10.2 Investment cost per seat for various train types.

10.1.2 Gangways, train sharing and coupling

There are many interesting and supposedly important measures with regard to train size and train sharing and coupling that have not yet been closely analysed. The only attempt that have been made is a preliminary analysis of cost and optimal trainset size (see Section 4.4.2).

Train sharing and coupling has benefits and drawbacks. The benefits include the opportunity to increase the average occupancy and to create timetables with fewer interchanges for passengers. The problems to be considered include delays because of sensitivity to disturbances. This question is of importance to the train designer because it relates to the optimal size of the trains, the level of connectability and the design of the gangways between cars and trainsets.

Some experience and/or hypotheses are as follows:

- Smaller train units permit more frequent services, but the cost increase is often too large. Nelldal does, however, show (in *Efficient Passenger Rail Systems*²⁶⁵) that, given a certain demand, one-vehicle train units in differentiated 15-min service should be able to cover the extra costs.

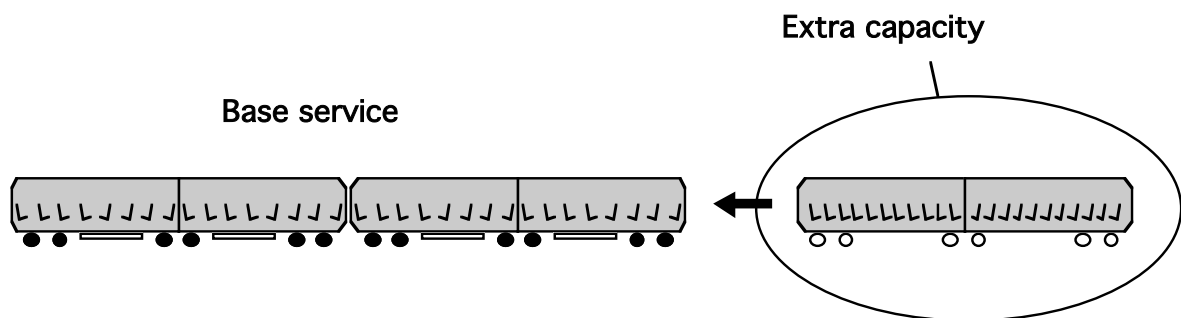
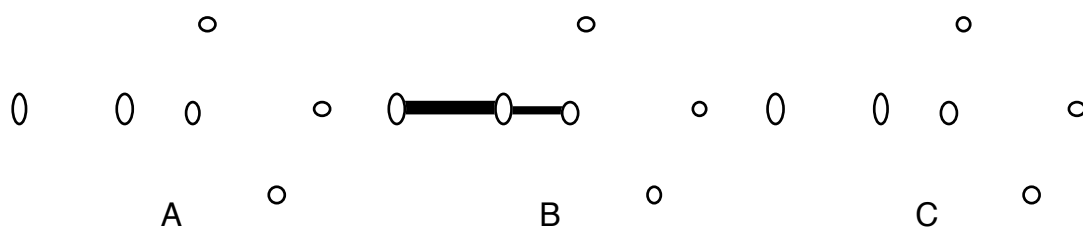


Figure 10.3 Illustration of a flexible size concept.

- Vehicle concepts which permit easy adaptation to variations in demand should be beneficial. It would be interesting to identify the situations in which the benefit is larger than the extra cost of these flexible size concepts.
- Train designs which permit rapid train coupling should be beneficial in certain circumstances (figure 10.4).
- Gangways, like the Flexliner gangway, between train sections should be beneficial in certain circumstances. The permissible train speed must not be reduced (too much), train staff can be better utilised and catering can be shared/minimised. It should also be possible to even out the passenger load in different parts of the train.
- The opportunity to run direct trains/cars in more relations increases the passenger value.

²⁶⁵ Railway Group KTH, Andersson, E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik*. (Efficient Passenger Rail Services for the Future, in Swedish – English version is under way, 1999), KTH Railway Group report 9702, 1997



A - Main line and branch lines with transfers.

B - TCS-system: Train Coupling and Sharing – few transfers necessary.

C - Direct services with separate trains and few transfers.

Figure 10.4 Three ways of running trains with a main line and branch lines.

As has already been mentioned, these aspects have not yet been fully analysed within the framework of this study. A preliminary analysis of potential cost reductions is made in section 4.4.3 (page 144). It shows cost reductions from 6 to 8 per cent by having trains with gangways. A deeper cost/benefit analysis of train coupling and sharing should be considered for further research.



Figure 10.5 Three Flexliner trains, in service as Kustpilen, meeting in Hässleholm.

The Danish InterCity traffic system is designed as a TCS system. Trains leaving Copenhagen westwards consist of up to five Flexliner/IC/3 trainsets. In Jylland the trains are shared and the shorter train(sets) are directed to different destinations.

10.2 Evaluation of internal use of space

One central theme in this thesis is that space must be used effectively. Several space-related aspects have therefore been studied. The costs and valuations for some of these aspects are shown below.

10.2.1 How passengers prefer to sit

Face-to-face and non-facing (face-to-back)

Sitting *non-facing* or sitting *face-to-face* has no significant value on average, but people are different! Up to 50% of travellers prefer to sit non-facing when travelling alone.

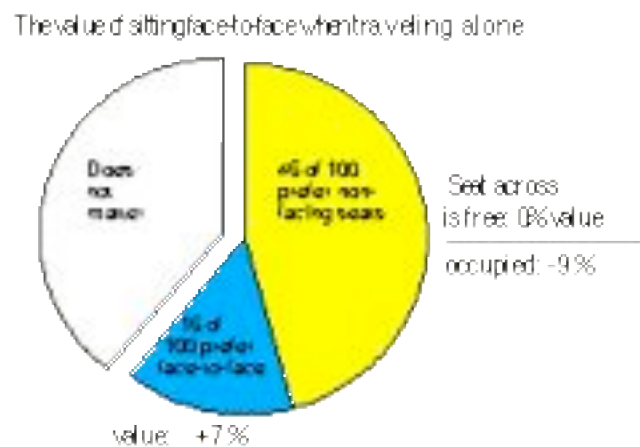


Figure 10.6 Almost 50% of train travellers prefer to sit non-facing (as in a bus) when travelling alone. The non-facing passengers place a negative value on sitting face-to-face when the seat across is taken.

Those who claim to prefer to sit in non-facing seats put the value of sitting face-to-face at minus 9% of the ticket price, when the seat across is taken. If the seat is free, they have no negative view of sitting face-to-face. Those who prefer sitting face-to-face, a minority when travelling alone, put the value of sitting in non-facing seats at minus 7% of the ticket price.

Building interiors with both face-to-face seating and non-facing seats costs virtually nothing extra. (It can be argued that one or the other type of seating requires more space, but no general evidence in support of this has been found in our research.)

Attractive and effective seats

High *seat comfort* may cost money in different ways: a) More room to the front and sides results in fewer chairs in a given area; b) A more comfortable chair could be more complicated and thereby more expensive to manufacture and maintain.

The thickness of the back of a modern bus seat is just under 5 cm, compared with about 10 cm for a train seat. This alone should correspond to $5/95 \approx 5\%$ improvement in the utilisation of space if thinner seatbacks were used. Even more space can be saved using an intelligent recliner mechanism.

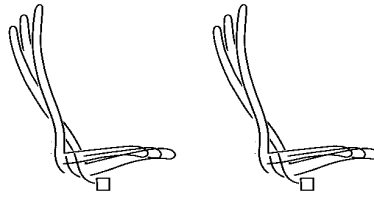


Figure 10.7 Seats with thin backs and a space-lean recliner function can save about 10 cm per seat, without reducing comfort.

Utilising cheaper chairs *per se* can reduce the total train service costs by just about 1%. A greater gain can be made by using space-lean chairs. A chair that requires 10 cm less space would save 10% space, thereby reducing train service costs by about 5%.

Table 10.1 Value and cost of space-lean seats

Space-lean seats	
Value	—
Cost - space	-5 %
Valuation minus cost	Minus 5 %

Seat width

Getting a train seat which is 5 cm wider is valued at up to 4%. If these seats cannot be placed 2+2 but 2+1, they will increase costs by at least 10%, so this is not recommended. Another way would be to use wider carbodies, allowing wider seats. A wider body would increase train service costs by about 3% and the cost/valuation ratio would be around 1.

Legroom

The value of legroom (the distance from the knees to the seatback or to the opposite passenger) is about 0.6% per cm on average – but the value of each cm diminishes when the actual legroom is larger.

So, is it profitable to change the seating space? The space elasticity (cost influence rate) is around 0.5. A 10% improvement in the utilisation of the space resource requires about 9 cm ($\approx 10\%$) less legroom (in the Swedish B7 coach). This results in a $(0.1 \times 0.5 =) 5\%$ lower cost and receives a negative appreciation of more than 6%. Reducing legroom may cause the loss of some percentage points. This can also be seen in figure 10.8.

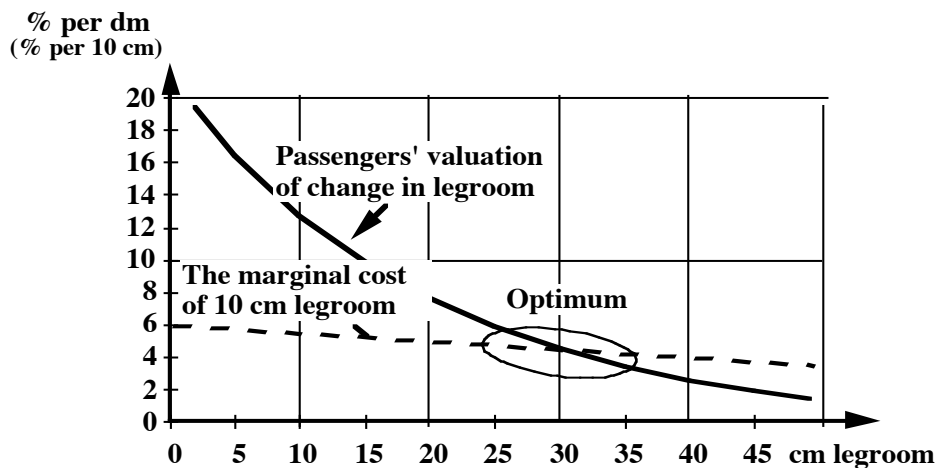


Figure 10.8 Evaluation and trade-off of change in legroom.

Table 10.2 Value and cost of legroom

Legroom (average)	
Marginal value of 10 cm, around legroom ≈ 25 cm	$\approx 6\%$
Cost of 10 cm marginal seating space	$\approx 5\%$
Valuation/cost ratio	≈ 1.0

Reclining seats (seatback supports)

The value of recliners in long-distance trains is estimated at 6-10% of the fare. (One survey, however, indicates a lower value; 3%). The cost of recliners is dependent upon the construction and available space). A conventional construction with a back support which folds backwards requires perhaps 7-15 cm more space than a non-reclining chair. The cost is calculated using the project economy model.

Table 10.3 Value and cost of reclining seatbacks

Reclining seatbacks	
Value	(3-) 6-10%
Cost – construction:	$\approx 1\%$
– space:	3-7% at space elasticity = 0.5
Valuation/cost ratio	Approx. 1.0-1.5

Provided that the cost of space is not too high, reclining chairs are profitable. The cut-off point should be located where about 15 per cent more space is needed.

Compartments

Sitting in a small *compartment* with 4-6 seats is awarded a negative value of 4% of the price by Swedish train passengers. People differ in this respect, however; some like it, as they do when it comes to face-to-face seating.

The cost of having compartments is fairly high, because compartments use space inefficiently. A passenger coach with nothing but compartments for six persons has at least 25% fewer seats than a well-furnished coach with open saloons. A 25% reduction in space utilisation raises the cost level by about 12%. The conclusion is that compartments are negative for the average traveller, even from a cost point of view (if ticket prices rise when costs increase).

Table 10.4 Value and cost of compartments

Compartments	
Value	-4%
Cost - space	12% at space elasticity = 0.5
Valuation minus cost	Minus 16%

Play areas (or children's corners).

In current Swedish InterCity trains, there is often a family coach with a play area that takes up about a third of the furnished area in the coach. This should equal 20-25 seats. With a capacity of 400 seats, the play area "costs" about 3%. A small play area corresponding to four seats in every second-class coach would also cost about 3%.

Play areas are valued as being worth 3-8% of the fare. The utility/cost ratio is about 2.

Table 10.5 Value and cost of play areas

Play areas (or children's corners)	
Value	3-8%
Cost - space	3% at space elasticity = 0.5
Valuation/cost ratio	Approx. 2 (1-3)

10.3 Evaluation of performance

The two performance measures that are being evaluated below are increased average speeds and low noise and vibration levels.

10.3.1 Increased speed reduces costs

One interesting question is whether it is profitable to operate trains at high speed, given that high speeds are permitted by the infrastructure. The energy usage rises more rapidly than the speed. How, then, do train service costs vary with speed when it comes to passenger train services?

It is less expensive to run a (specific) train quickly rather than slowly, at least up to 250 km/h, in the Swedish case where electricity costs are low. Track costs are not included in these calculations and the other prerequisites are:

- The energy costs for propulsion increase with speed.
- The vehicle investment costs ²⁶⁶ decrease with an increase in productivity (time use).
- The maintenance cost of trains is partly distance-dependent and partly time-dependent.
- The cleaning cost is time-dependent in principle.
- The personnel cost for staff on board is time-dependent.

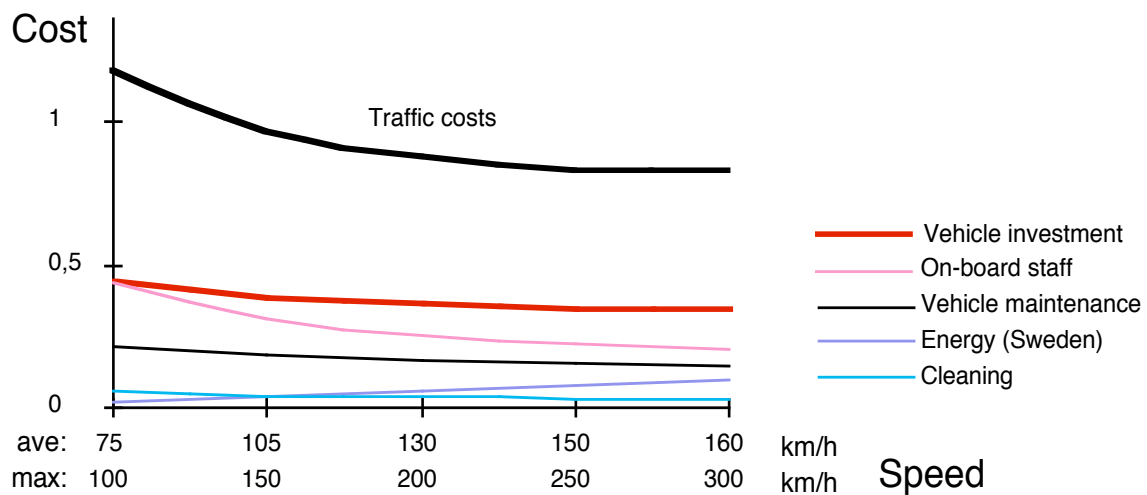


Figure 10.9 The cost of operating (one and the same) trains at different speed levels on a track that is designed for 350 km/h.

²⁶⁶ The cost of trains for higher speeds is often greater than that of low-speed trains, but the reason is sometimes that the cost of higher comfort and so on also contributes. In these calculations, marginal costs for increasing tractive power are included. The cost of comfort and on-board service activities should be dealt with separately.

A similar cost/speed dependence diagram, like the one above, was found in an interesting article by Breimeier²⁶⁷ comparing upgraded or new lines with tilting train solutions.

10.3.2 Low noise and vibration levels should pay off

Passengers prefer low noise and vibration levels.

It has been suggested that the inner environment can be too quiet, for those passengers who work, for example. They may talk about business that other people should not hear. For this and similar reasons, it could be argued that current trains are quiet enough or even too quiet (this has been suggested when it comes to the X2000).

Best/worst experiments show that very few passengers select lower noise or lower vibration levels as the worst attribute on any occasion, but they do select them as the best attribute.

Vibration levels have changed. On the one hand, they have been reduced because of improved track quality and new train designs. On the other hand, older passenger cars, such as refurbished and upgraded equipment, are run at higher speeds.

The valuation for "somewhat lower noise" or "somewhat lower vibration levels than in this train" is about 5-10%. If this is true, it would enable vehicle investment costs to be 5-20% higher, all other costs being equal (such as maintenance), if the need for lower noise and vibrations could be fully eliminated.

My own view is that people would still have a considerable willingness-to-pay for "lower noise and vibration than in this train", even in a far more steady and quiet train. We should therefore include only part of the 10% wtp, say half, which is 5%. We could then still justify an increase in the investment cost of 10% to obtain significantly reduced noise and vibration levels.

One complication is that new lightweight designs with new materials may cause more vibration and noise than current steel train designs. If we estimate the energy saving for some sort of train design and type of service (with many stops) as 25%, the train service cost savings would be somewhere in the region of $25\% * 0.06 = 1.5\%$. This example stresses the importance of solving noise and vibration problems in new train designs.

²⁶⁷ Kurz, H.R., Reemtsema, K.-D.; Anforderungen an die Technologieentwicklung des Systems Eisenbahn aus der Sicht eines zukunftsorientierten Fahrplans (in German), *Eisenbahntechnische Rundschau* 46, (1997) H.7/8 July/August, 1997

10.4 Evaluation of auxiliary systems; comfort and on-board service measures

The measures evaluated below belong to the interior fittings of the rolling stock. They affect comfort and on-board service factors.

Table next to seat

A table of reasonable quality next to the seat may cost around SEK 1,000 per seat. The train service cost would not increase by more than 0.5%, including investment and extra maintenance costs. The passenger valuation is around 2-7%. Tables are very beneficial.

Table 10.6 Value and cost of tables

Table next to seat	
Value of table	2-7%
Cost of a table	0.5%
Valuation/cost ratio	≈ 5-10

Climate equipment

A fan ventilation system with adjustable outlets can cost about SEK 20,000 to SEK 100,000 per coach. (The different price levels stem from the difference in information providers and probably performance.) Air conditioning for buses costs about SEK 150,000, but it is more expensive for trains. How expensive depends on how much air needs cooling and how quickly. Investment costs vary from SEK 300,000 to 500,000 per coach. The increase in operating costs is calculated using the project economy model. The cost level is entirely different if simple ventilation equipment or a climate system with heating and cooling is installed.

Improved ventilation is valued at +8% of the fare and AC at +10% by passengers. This value probably presupposes that there are no other negative effects such as too much cold, draught or noise from the equipment. ("A little more noise" is valued about as negatively as "air conditioning" is valued positively!)

Table 10.7 Value and cost of climate equipment

Better ventilation – climate equipment	
Value of better ventilation/air conditioning	8%/10%
Cost of air conditioning	≈ 2-4%
Valuation/cost ratio	2-5

Subdued lighting and reading light

Reading lamps at 70 seats cost SEK 30,000-125,000. This corresponds to a few tenths of a per cent of the total cost of train traffic. The valuation for subdued lights and reading lamps has varied a great deal from study to study: 2-8%.

Table 10.8 Value and cost of subdued lighting and reading lamps

Subdued lights and reading lamps	
Value	2-8%
Cost of individual reading lamps	< 0.5%
Valuation/cost ratio	> 4

Radio/music systems

Radio/music systems with outlets for headphones cost about SEK 50,000-100,000 per coach and are valued at 1-4% of the fare. The cost is calculated using the economic model.

Table 10.9 Value and cost of music outlets

Radio/music outlets at each seat	
Value	1-4%
Cost of individual reading lamps	≈ 1%
Valuation/cost ratio	≈ 1-4

Video equipment

To offer video at the seats in open salons can be done using about four monitors in the ceiling of each coach. The sound can be broadcast through the headphone outlets for the above-mentioned sound system.

A video system for Swedish trains could cost about SEK 100,000 per coach. However, the prices vary a great deal. The cost of running the equipment and showing films should be added to these initial costs. If films are shown in a cinema, the extra space cost must be calculated and added.

Radio/music outlets at all seats and video at some is appreciated at +4% of the ticket price, according to the InterRegio study. Another study (Rosenlind 1993) revealed that video is valued at +6% of the fare (when headphones are offered along with the film for SEK 20). The utility/cost quotient in this case is strongly dependent on the technical solution and the cost of keeping up the equipment.

Catering

There are many types of cost which relate to catering. Only two of them are included in this calculation – the cost of the space required and the cost of catering staff. It is assumed that the revenue from sales will cover the cost of the goods. The estimates relate to a train with about 200-300 seats with three to five cars.

For catering at seats, a compartment with an area corresponding to six to eight seats in a saloon is needed. One member of staff is required. This represents (approximately) 3% less space utilisation and 30% more staff, producing extra costs in the region of (1.5% + 6.5% =) 8%.

A café or bistro requires half a coach, equal to 10-17% more space. I estimate that one extra member of staff will be needed in this case as well. (If two are needed, one of them

should be paid for by the extra revenue.) The extra costs will be in the region of (6.5% + 6.5% =) 13%.

Table 10.10 Value and cost of catering

Catering (food and drink)	Free coffee + tea	At seat/food trolley	Café/bistro
Value	≈ 6%	≈ 10%	≈ 14%
Cost of space and staff	≈ 3-4%	≈ 8%	≈ 13%
Valuation/cost ratio	≈ 1.5	≈> 1	≈> 1

Both the evaluated levels of catering appear to pay for themselves, but the valuation/cost ratio is close to 1. In trains with fewer than 200-300 seats, the economy could be doubtful. On the other hand, a train without catering can be regarded very negatively by certain people (the hungry ones).

Free coffee and tea in each coach require an area in each coach equal to (at least) two seats, which means 3% fewer seats. This will increase the cost of the train service (traffic) by about 1.5%. This does not include the cost of supplying the coffee and maintaining the necessary equipment. We can guess that the final cost will be 3-4%. When it is valued at 6%, it should have the potential to be profitable.

10.5 Evaluation of design and quality

The value of good design and quality is difficult to quantify. In many studies with new or converted rolling stock, passenger appreciation appears to have been higher than the other, comfort-related measures are likely to explain.

10.5.1 Refurbishing/modernisation of interiors

Modern coaches are highly appreciated. The value presented in this thesis is about 8% of the fare. It is then very interesting to estimate the cost of creating an impression of modernity.

New rolling stock is maybe always too expensive, if the only argument is the impression of modernity.

Refurbishing the interior of one coach for SEK 1 M produces a cost increase of about 6%, if we assume that it is done every ten years. This is of the same order of magnitude as the value of modernity.

Table 10.11 Value and cost of refurbishing

Refurbishing of interiors	
Value	4-8%
Cost of modernisation every ten years (see text)	≈ 6%
Valuation/cost ratio	≈ 1

The order of the value for refurbishing will of course vary with the standard of the coach interior before and after. The upper value shown here (8%) is derived from the study of the IRmax coach, refurbished with partially 3+2 seating (See section 7.16). The lower value is derived from InterRegio car studies (See section 7.3).

The high appreciation of the Flexliner/ IC/3/ Kustpilen train in Blekinge reveals that good design is highly valued. In Blekinge Kustpilen was valued about 15% more highly than "standard SJ-train".

10.6 Evaluation of train concepts/train systems

Two decks or wider bodies are measures that relate to exterior train configuration, but they also influence the use of interior space. So these measures are evaluated as train concepts with several effects.

10.6.1 Double-deckers appear to be profitable

Lower cost per area of furnishable space

One of the hypotheses in this project has been that double-decker vehicles can reduce the train-transportation costs. It is therefore interesting to estimate the cost reduction potential. The following evaluation has been made using information from SJ on the distribution of investment and upkeep costs for new EMU trains.

In table 10.12, “factor“ represents the cost difference that is regarded as reasonable for the vehicle system in question.

Table 10.12 Evaluation of investments and maintenance costs for double-decker vehicles; “factor“ indicates how much higher the cost item is expected to be for double-decker vehicles.

	<u>Investment</u>			<u>Maintenance</u>		
	One deck	Factor	Double deck	One deck	Factor	Double deck
Running gear	12	1	12	17	1.1	18.7
Propulsion equipment	24	1.05	25.2	13	1	13
Brakes & pneumatics		1	0	15	1.05	15.7
Electrical assembly	11	1.25	13.8			0
Car bodies	14	1.25	17.5	1	1.25	1.3
Heating/sanitation	10	1.2	12	7	1.2	8.4
Interior	29	1.4	40.6	47	1.5	70.5
Total	100%		121%-units	100%		128%-units

These are the reasons for the order of the multiplying factors with a few comments on the separate factors:

- The purchase cost of running gear does not become greater in spite of the fact that the weight of the car increases. However, wear to the bogies is expected to increase somewhat (10% is assumed) due to the higher weight.
- The propulsion equipment is enlarged a little and this may possibly lead to an investment cost which is 5% higher. The maintenance cost of propulsion equipment ought not to be higher for double-decker trainsets.
- The braking system is not changed.

- The cost of electrical installations and assembly increases because two decks require more equipment. A 25% increase is assumed.
- It is assumed that the carbody will be more expensive because the structure is larger. SJ anticipates that the cost will rise in proportion to the weight, approximately 20%, but the somewhat more complicated design may lead to a somewhat larger increase (25%).
- Heating and sanitation (WCs) are assumed to be 20% more expensive; this is due primarily to a larger heating system.
- The cost of investment in interiors is taken to be 40% higher, in spite of an increase of 50% min the number of seats, as parts of the interior are the same in standard and double-decker vehicles. The upkeep costs, which include cleaning, are expected to rise in proportion to the increased area and seats, i.e. 50%. In any case, the cleaning cost will increase by 50% because the floor area is assumed to be 50% larger.

The estimate in figure 10.12, column 4, indicates that a double-decker vehicle ought to be about 20% more expensive to purchase and 25-30% more expensive with respect to maintenance costs. By way of comparison, Kurz & Reemtsema at DB²⁶⁸ have estimated the increase in purchase cost at almost 35%, but the estimation method they have used is not explicit.

For instructive reasons, the comparison of investment costs is also shown graphically.

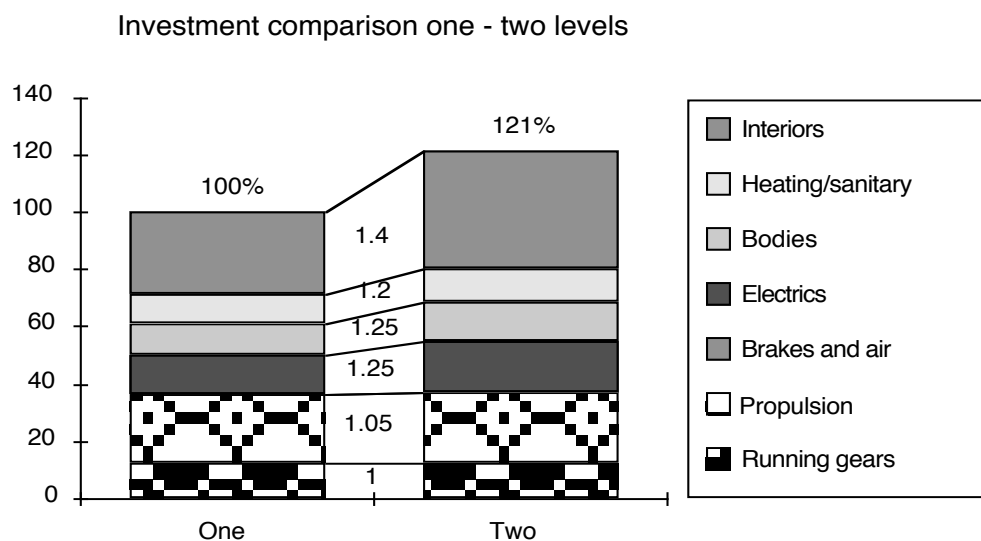


Figure 10.10 Graphical illustration of cost comparison one-level/bilevel vehicles.

If tenders for double-decker vehicles are requested at the present time, it is likely that the cost difference compared with conventional vehicles will be greater than 20%. This stems from the way the market works. Modern double-decker vehicles are relatively unusual and

²⁶⁸ Breimeier, R., Verkehrswirtschaftliche Grundlagen und vergleichende Betrachtungen zum Einsatz der Wagenkasten neigung und zum Streckenausbau, *Schweizer Eisenbahn-Revue* 4/1993, pp.166-173

the number of manufacturers is limited. The producer needs to cover the development cost of a new product.

An estimate using cost elasticity provides an indication of the improvement when transportation with double-decker trains is offered. Prerequisites:

- The double-decker train has 50% more space that can be furnished and 50% more seats.
- Elasticity for investment cost ≈ 0.3
- Elasticity for maintenance cost ≈ 0.17
- Elasticity for cleaning cost ≈ 0.07
- Unchanged cost of personnel, energy, track charges and so on

New cost (for d-d) = $1 + 0.3 * 21\% + 0.17 * 27.5\% + 0.07 * 50\% = 114\%$.

Assume that the utilisation of space is 50% higher in the double-decker train. This leads to a reduction in cost of 25% with space elasticity of 0.5. The cost of the double-decker train then becomes the cost per seat level $114\% - 25\% = 89\%$. This way of calculating makes a double-decker train *11% cheaper per seat-kilometre*.

A more careful calculation can be made by comparing a regular train with a double-decker, using the economic model. These calculations have shown that a larger train, four double-decker, or six regular, cars, has a lower cost per passenger-kilometre of almost 10%, while shorter trains and multiple units may save only 5% and in some cases less than that.

This calculation can be compared with figures from France relating to the double-decker TGV. It was claimed that this train is 15% cheaper in terms of investment per space offered²⁶⁹.

The cost data²⁷⁰ for the Swiss IC2000, see figure 10.11, also supports my calculation:

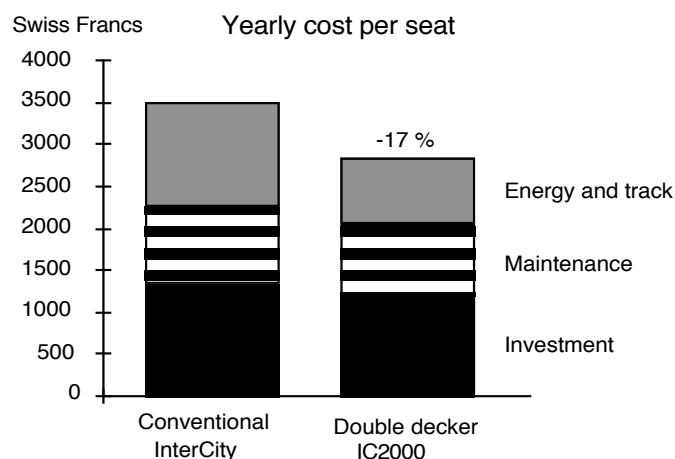


Figure 10.11 Cost figures double-decker/single-decker for the Swiss IC2000.

²⁶⁹ Lacote, F., Cléon, L., Double-deckers launch third generation of TGV, *Railway Gazette International*, September 1991, page 595

²⁷⁰ International Railway Journal, January 1994, page 35

According to my economy model, the three cost items, investments, maintenance and cleaning, as well as energy and tracks, constitute about 60% of the train-transport costs. When the fact that these items decrease by about 17% is taken into account, the savings are as follows : $0.6 * -17\% \approx -10\%$. This *10% reduction in the cost per seat-kilometre* is consistent with my cost estimates according to the previous calculation.

The cost reduction rate decreases for smaller trains and also if the size and cost of the locomotive is not reduced to the same degree as the (number of) cars. One important assumption is that a double-decker coach is supposed to have 50% more seats, implying that it should have a furnished area which is 50% larger. One difficulty may occur when designing double-decker multiple units. The space for equipment, such as propulsion and auxiliaries, may reduce the furnishable space. In these cases, the space for passengers may not increase by as much as 50%.

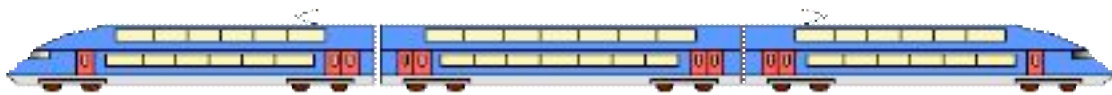


Figure 10.12 Outline of a double-decker EMU design (with small-sized equipment)

Contrary to the beneficial investment cost levels calculated above, Kurz & Reemtsema demonstrate an increase in the investment cost per seat of about 10%. Their results appear to be based on differing data. The increase in usable space is assumed to be only 35% and the number of seats per coach is only 20% higher than that of the single-decker train with which it is compared. The investment per trainset is assumed to be +35%, as has already been mentioned. Taken together, all these distinctions produce a different result than the positive result shown by the calculations presented above.

Passenger valuations of double decks – two levels

There is a complication when estimating the passengers' value of having two decks in a passenger car. That is; the existing double deckers have a design and an interior standard that may influence passengers' evaluation very much, perhaps so much that the valuation of the fact of having two decks/levels, can be snowed under the value of the interior design and comfort level.

Passengers' valuations have been investigated twice by KTH. The first time was when two Swiss double-deckers were tested in 1991 on the Stockholm-Uppsala line. In this case, the valuation for travelling in the double-decker cars turned out to be three to four per cent extra on the ticket price (Lindh 1991). The second time was in the autumn of 1998 when SJ tested a German double-decker trainset. This time, the double-deckers were tested on three lines; the Svealand line, the Mälars line and the Uppsala line. The extra value for travelling in a double-decker as such differed between 4 to 8% of the fare, given that the interiors were replaced by modern SJ interiors. Part of the positive valuation may be due to the novelty of double-decker trains in Sweden.

Double-deckers have a few drawbacks which are relevant to Swedish conditions at least²⁷¹. The maximum speed may be limited to around 200 km/h for short double-decker EMUs because of the side wind sensitivity and it will also be limited if carbody tilting is needed.

Conclusion: Double-decker trains should improve effectiveness reducing the costs by about 10% and simultaneously enhancing the level of attractiveness by a few per cent. The valuation increases as the costs decrease in a successful double-decker design. (This presupposes that very high speeds and/or body tilting are not required and that the increase in furnishable area is 50%.)

10.6.2 Wide body trains

Wide bodies with 3+2 seats next to one another could substantially reduce costs, but there is a fear that the level of attractiveness will be reduced. How do the cost and the value change when trains have five seats next to one another and wider car bodies?

The potential for cost reductions

It is natural to associate the analysis of the number of seats with an increase in car-body width, which permits the same seat width as in the 2nd-class coaches of today. A coach which is 3.4-3.5 m wide could be furnished with five seats of about the present width. The centre aisle could be somewhat narrower than today and the wall thickness should be kept down.

The following estimate has been based on SJ data relating to the distribution of investment and maintenance costs for different technical systems²⁷² in small regional EMU-trains. In table 10.13, “factor” stands for the cost increase that is regarded as reasonable for a wider car.

Table 10.13 Estimated differences in investment and maintenance costs for wide-bodied versus normal cars.

	<u>Investment</u>			<u>Maintenance</u>		
	Normal (%)	Factor	Wide car	Normal (%)	Factor	Wide car
Running gear	12	1	12	17	1	17
Propulsion equipment	24	1.03	26	13	1	13
Brake & pneumatics		1	0	15	1	15
Electrical assembly	11	1.05	11.6			0
Car bodies	14	1.1	15.4	1	1	1
Heating/sanitation	10	1	10	7	1	7
Interior	29	1.1	32	47	1.1	52
Total	100%		107%-units	100%		104%-units

²⁷¹ Railway Group KTH, Andersson,E., *Effektiva tågssystem för framtida persontrafik. Analys av förutsättningar och möjligheter för attraktiv tågtrafik.* (Efficient Passenger Rail Services for the Future, in Swedish – English version is under way, 1999), KTH Railway Group report 9702, 1997

²⁷² SJ Technical Division, figures obtained by phone.

The estimated valuation above indicates that wide-bodied vehicles are 5-10% more expensive to purchase and just under 5% more expensive in terms of maintenance costs. Using cost elasticities, we can calculate the new cost level. This means that the transportation costs should increase by $0.3 * 7.5\% + 0.17 * 4\% \approx 3\%$. This is illustrated in the following diagram.

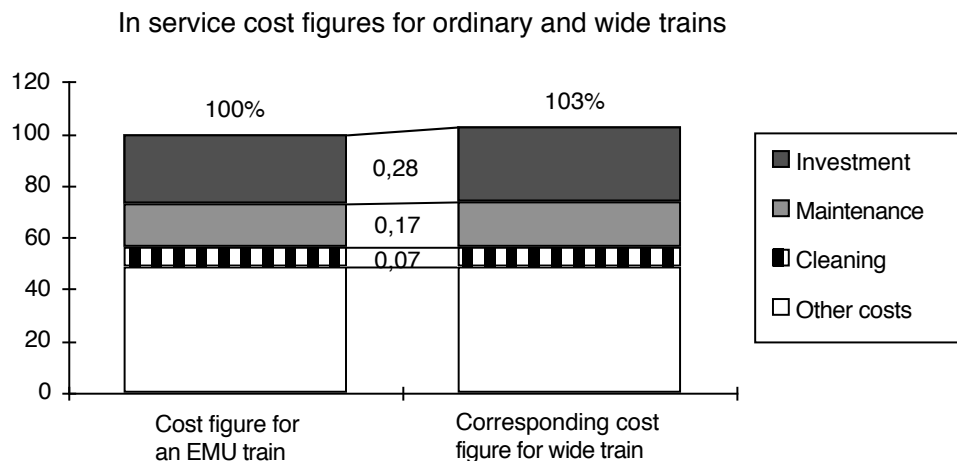


Figure 10.13 Graphic illustration of cost increase for wide-bodied trains in service (These cost figures do not take account of the possible increase in the number of seats.)

Kurz & Reemtsema at DB²⁷³ indicate an increase in price of 14% for wide-body trainsets (of the same length). The premises for their calculation are not explicit.

The increase in the number of seats reduces the costs in proportion to the space elasticity of 0.5. A coach with an extra row of seats ought to have 25% more seats, but, in some areas, e.g. near the vestibules, it is not feasible to have more than four seats side by side. So, if it is assumed that a wide-bodied coach has 96-98 seats instead of 100 and that this is compared with the 80 in the B7 coach of today, $97/80 = 121\%$ i.e. 21% more seats (Kurz & Reemtsema calculate 22% more seats).

The result is a 10% reduction in transportation costs at an elasticity of 0.5 for space, excluding the impact of the increase in costs for a wider-bodied train. If this cost increase of 3% is included, we arrive at $10-3\% = 7\%$ lower cost per seat-kilometre for wide-bodied vehicles with a 3+2 seating arrangement.

Passenger valuation of sitting in a 2+3 interior

Most of the parameters for calculating the values presented in table 10.14 have been taken from study number 10 about 2+3 seating and wide-bodied trains (presented in brief in Section 7.10).

²⁷³ Kurz, H.R., Reemtsema, K.-D.; Anforderungen an die Technologieentwicklung des Systems Eisenbahn aus der Sicht eines zukunftsorientierten Fahrplans (in German), *Eisenbahntechnische Rundschau* 46, (1997) H.7/8 July/August, 1997

Table 10.14 Values of attributes used for the evaluation of 2+3 seating

Attribute	Value) of fare (%)
Sitting by the window	+7.5
Sitting in the centre seat of three seats	-4.7
Sitting in a narrow seat	-2.4
(Not having your own armrest)	(-5.6)
The seat beside you is free	+11.6

The attribute of not having one's own armrest has not been used in the calculations for the diagrams below.

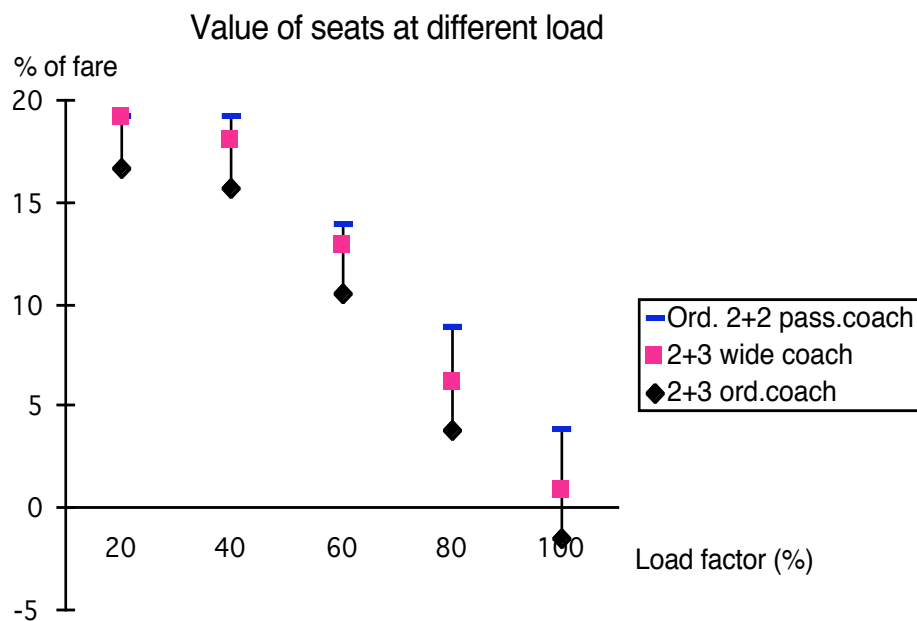


Figure 10.14 The (relative) value of getting a seat at different load levels. It can be seen that the value of comfort when having a seat decreases for all three alternatives when the load increases. The difference between the different designs is focused on here.

It can be seen that the large variation in seat value depends on, or correlates to, the load level. The value of getting a seat decreases by 15-20% from a situation in which there are few passengers on board and everybody has a window seat with no passenger next to them to the situation in which all the seats are taken. The difference between 2+2 and 2+3 seating is much smaller, within about 5%.

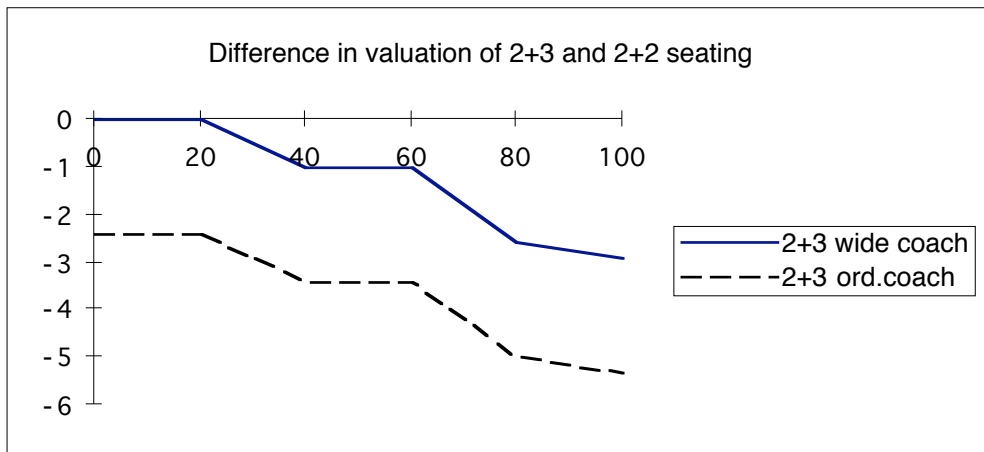


Figure 10.15 Difference in valuation of getting seats in 2+2 and 2+3 seating, for cars of ordinary width and for extra-wide cars.

The figure (10.15) illustrating the difference in valuation level shows that 2+3 seating is valued somewhat negatively by passengers. The valuation goes from minus 0-3% for a wide passenger car with ordinary seat widths and from about minus 2-5% when 2+3 seating is used in a passenger car of ordinary width.

Figure 10.16 summarises the cost and valuation for double decker and for 2+3 seating.

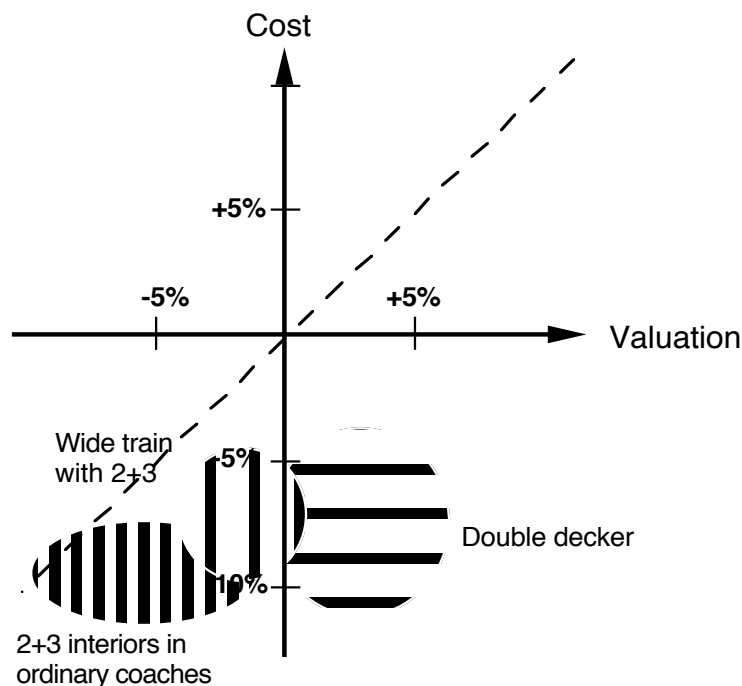


Figure 10.16 Illustration of costs and passenger valuations for 2+3 interiors and for double-deckers.

The cost/valuation ratio is best for double decker followed by the wide train with 2+3 seating. But even 2+3 interiors in ordinary coaches could be competitive.

10.7 The value and cost of trains in comparison to buses

The cost level for regional and long-distance bus services is often considerably lower than that of train services. One reason is quite naturally that rail transport uses tracks which are costly, at least on a medium and small scale. However, even when these costs are ignored, as they are in part in Sweden since the Rail Administration receives state funding for the infrastructure, the cost level for hardware and staff is high for trains.

One reason for the cost per passenger being higher in trains is the less effective utilisation of space in most trains compared with standard buses. It has therefore been interesting to find and study a bus service, in Blekinge, where buses with "train interiors" are used. These buses have a much lower seat density than conventional long distance buses.

10.7.1 Evaluation of high-standard bus (coach) service in Blekinge

The "Kustbussen" express coach has been running since the summer of 1993 in parallel with the train in Blekinge, as described in Section 7.4.

The interior of the buses are about as spacious as that of 2nd-class trains. The "Coast Bus" (Kustbussen) and the "Coast Train" (Kustpilen) both have a high standard, with air conditioning and music outlets at each seat (see the table 10.15).

Table 10.15 Data for the Kustpilen and Kustbussen train and bus

Factor	Kustbussen	Kustpilen
Vehicles	High-standard coaches	High-standard trains (IC/3)
Vehicle length	15 m	54 m ?
Number of seats	42 ?	144
Seats side by side	2+1	2+2
Seat pitch	77-87 cm	102 cm

The costs for the different traffic forms/services have been calculated using the train service cost model ("Tåganalys"). Output has been chosen as the average cost at a 35% occupancy level. The idealised traffic is a short inter-regional service covering distances of 100-300 km.

The costs have been calculated using different levels of space utilisation. That means that buses have been furnished with the same density as trains usually are and vice versa.

The cost of bus services then varies from SEK 0.27/pkm to more than SEK 1/pkm depending on space utilisation. The corresponding costs for the trains are in the region of SEK 0.47-0.85/pkm. However, it is also important to remember that, in order to obtain a 35% occupancy rate, the total number of travellers (the travel demand) has to be higher in case of train (alternatives). The following graph is made up to illustrate this.

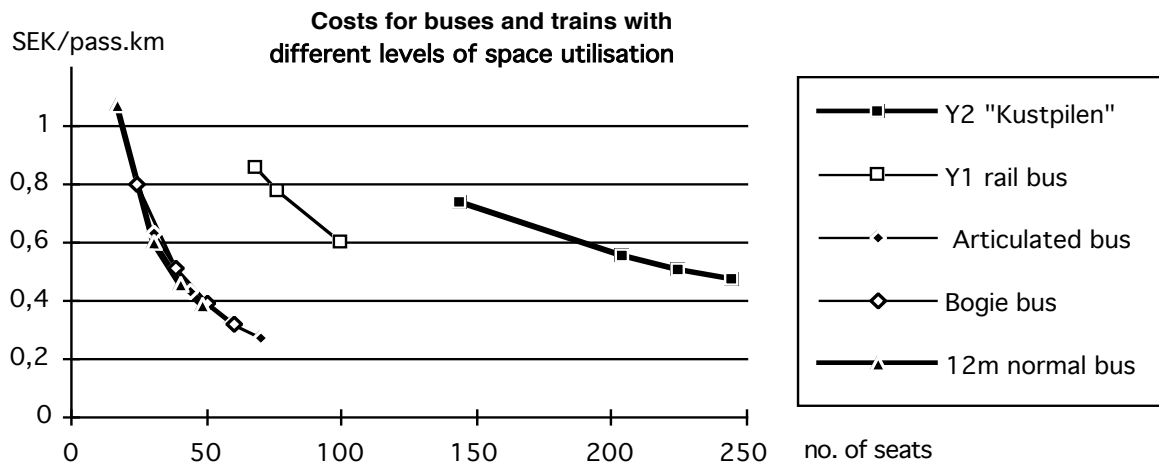


Figure 10.17 Costs per passenger-km for a normal bus (12m), a bogie bus (14-15m), an articulated bus and the two Swedish train types Y1 and Y2 (DMU trains originally with 75 and 144 seats) at different levels of seat density.

A summary of the cost picture:

- Trains need a higher travel demand than buses.
- Given that it is possible to obtain the same occupancy level, conventionally-furnished buses produce passenger-kilometres at half the cost of conventionally-furnished (Swedish) DMUs.
- Bus services with high-standard buses and the same seat density as in trains appear to be as expensive as train services.
- The opposite is not true. Trains with compact bus furnishing are still somewhat more expensive than conventional bus services.

Comparison of cost and willingness-to-pay levels for train and buses (in Blekinge)

As has been shown, train services are often more expensive, but willingness-to-pay may also vary for trains and buses and for various levels of seat density.

In the next table, the SP values for the various bus alternatives and standard "SJ trains" are presented in relation to the Kustpilen train, which explains why the figures are negative. These figures correspond to a 50/50 mixture of bus and train passenger values.

Table 10.16 Estimated values for different bus products in relation to Kustpilen

Factor and level	Aug. 1994
Express coach. compared with KUSTPILEN	- 30%
Express coach with spacious legroom (10-15 cm extra)	- 20%
Special express coach "Kustbussen" with (2+1) wide seats - " -	- 23%
Ordinary SJ train with modern cars- " -	- 13%

Passenger appreciation increases. Bus travellers' valuations of 10 cm more legroom in buses are about 5% and train travellers' valuations of more legroom in long-distance

buses are about 13% of the fare. The value of more legroom in coaches (long-distance buses) is estimated to be more than twice the cost.

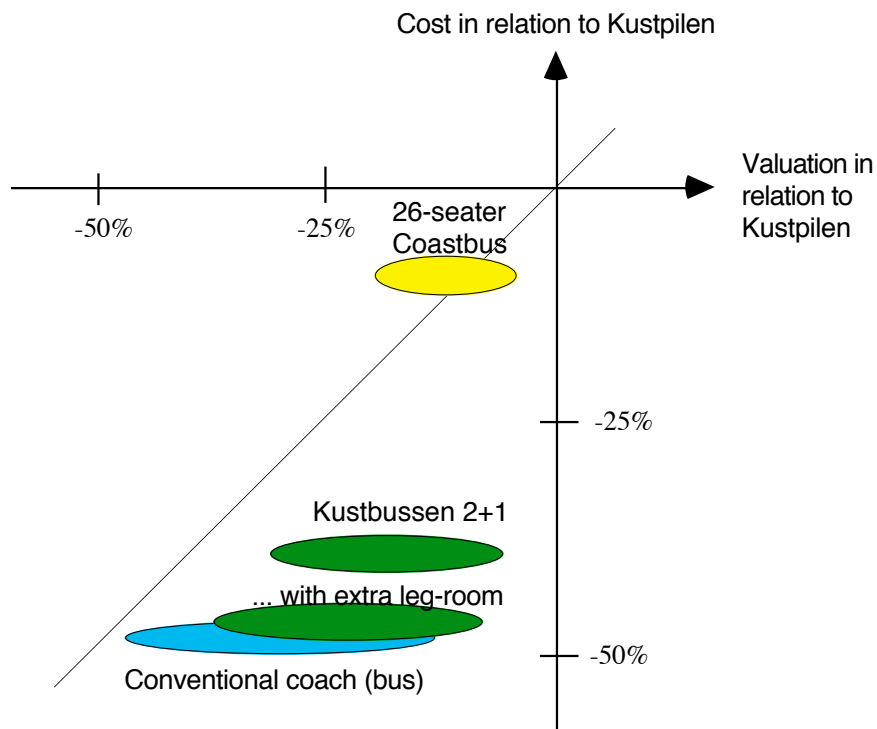


Figure 10.18 Estimated production cost and valuation of different bus service concepts in comparison to the rail bound Kustpilen service.

In figure 10.18, an outline for a comparison of train and bus costs and willingness-to-pay is made. The cost and valuation level for the Kustpilen train is indexed at 100%.



Figure 10.19 Long distance coach (bus) at combined rail and bus platform.

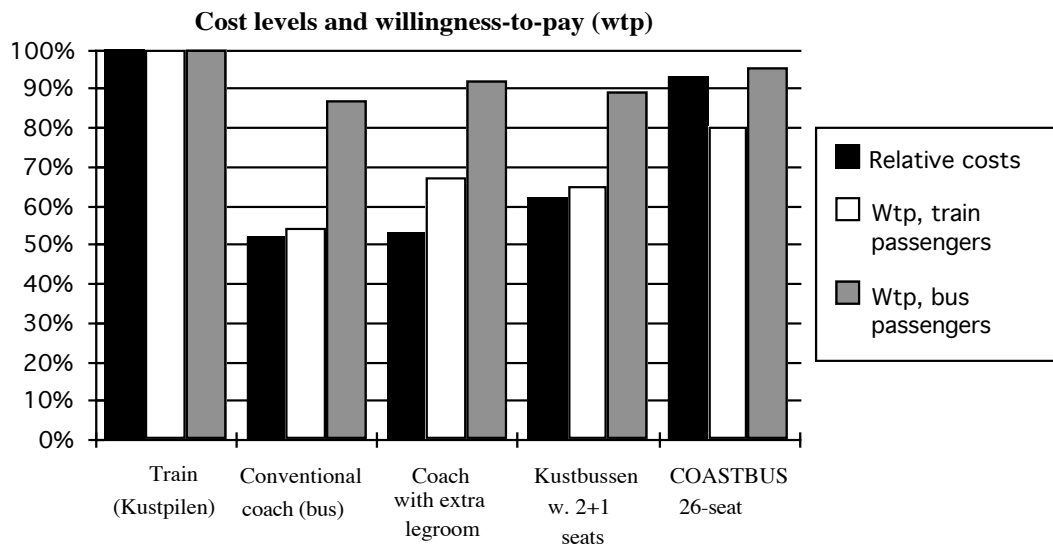


Figure 10.20 Costs and willingness-to-pay levels for the reference train, the Kustpilen, and various bus designs.

From figure 10.20, it can be seen that bus services using conventional buses are nearly 50% less expensive than train services, but the valuation of bus made by Kustpilen train passengers was also nearly 50% lower than the Kustpilen value.

Bus services with modern coaches with extra legroom were less negatively valued, although the cost difference is almost as large. Bus services with a 15m coach with 2+1 wide seats, as in the Blekinge "Kustbussen", cost about 62%, in comparison to the train. The valuation of the 2+1 alternative is perhaps lower than expected (when it has "train interiors"). The last bus service with 26-seater coaches is almost as expensive as the train service.

Comparing the cost and valuation of the above alternatives, it can be seen that the most "interesting" competitors to trains are bus services with coaches that have extra-large amounts of legroom and a high standard in other respects as well. In particular, those passengers who have already chosen the bus, but also train passengers, appear to value the cost reduction in these buses more highly than the "mode" characteristics. In reality, this production cost difference must influence the experienced ticket price level for the above conclusions to be valid.

10.8 Summary of values and costs of various measures

The various types of measure place themselves approximately in the manner shown below in an X/Y-diagram showing marginal values and costs.

Higher speed is placed below to the right, i.e. the costs diminish as the value increases. As a rule items of finesse and service are profitable, i.e. the cost rise is lower than the marginal value. A higher usage of space brings the costs down and appropriately done the value diminishes less than the costs. Note that the positions in figure 10.21 are not indisputable. Firstly there are uncertainties in the calculations and secondly the costs may be affected by choices of technique and technical development. Thirdly the value sets diverge in different sub markets.

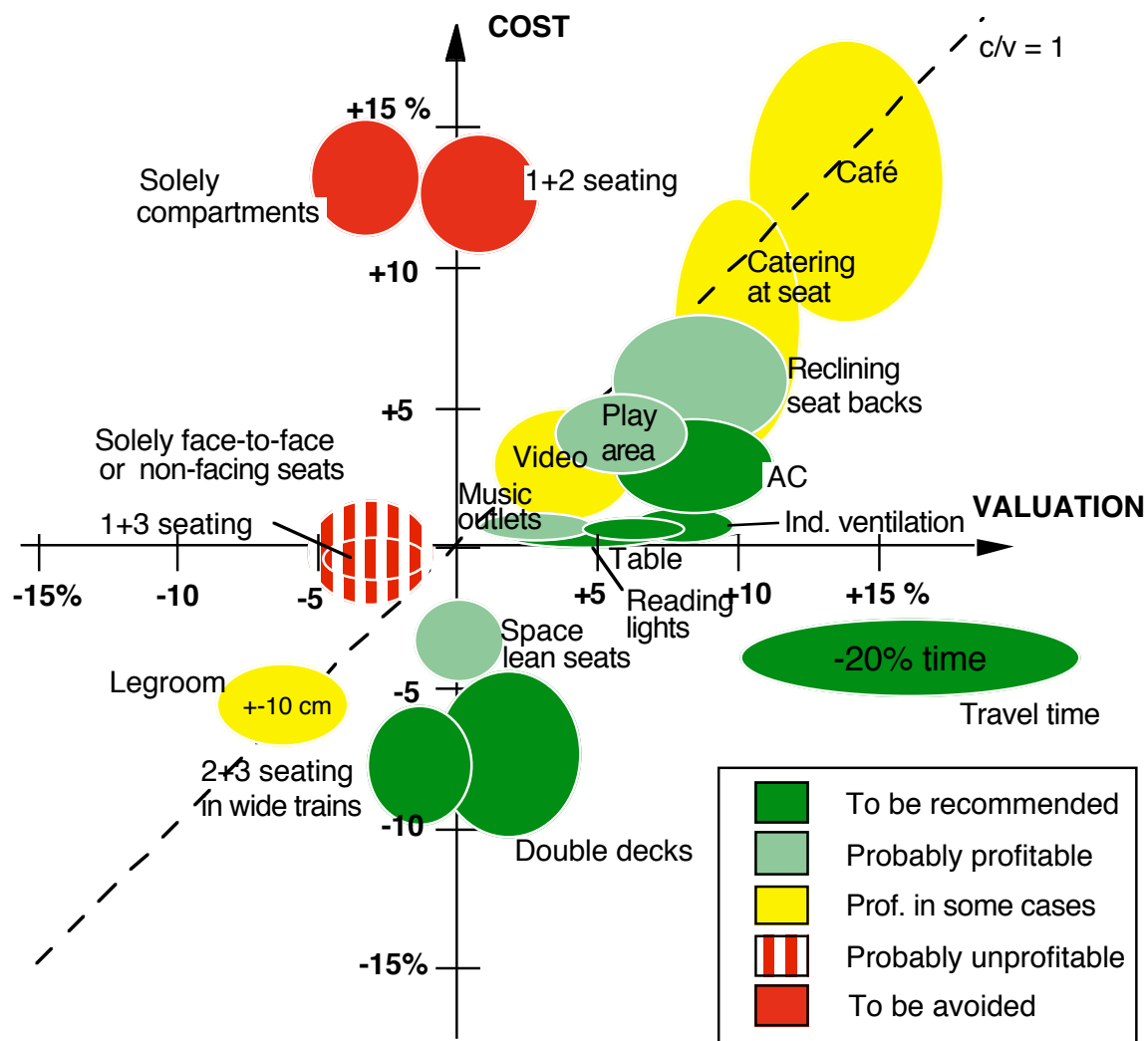


Figure 10.21 Ball-park marks for valuation (willingness to pay) and effect on the train service cost of different factors or undertakings.

One interpretation of the above is that the principle objective should be higher speeds, double-decker or wide cars/trains and items addressing comfort.

A 20% travelling time reduction increases willingness-to-pay by 10-20%, dependent on journey purpose (sometimes even more for certain business travellers). At the same time traffic service costs are calculated to decrease by 3-5%.

Passengers appear to value double decks in a slightly positive manner while three-plus-two seating, which is required for the effective use of wide bodies, appears to be slightly negative. The cost savings are of the same magnitude.

A 10% increase in seating density, corresponding to 10cm per seat at the original seating distance of one metre, would cut costs by about 5%. This is a significant cost reduction. However, on the other hand, the valuation of legroom is of the same magnitude.

A seemingly trivial measure, seats with space lean design, may save as much as 5 % of the total train service costs without reducing comfort. A somewhat more expensive seat is well compensated if the seat density can be increased about 10% with retained comfort experience.

Compartments with fewer than four seats side-by-side increase costs substantially. A few Swedish passengers do prefer compartments, but most prefer open saloons and the average valuation of compartments is negative. The conclusion is that compartments should be avoided as a general form of interior. The same is true for 2+1 seating in 2nd class open saloons.

The majority of the passengers display substantial willingness-to-pay for sitting face-to-back (most) or face-to-face (fewer). So interiors with only one of these furnishing alternatives is a comfort reducing mistake.

There are many other comfort and on-board service measures that should be profitable, such as good ventilation (AC or individual air outlets), a table at your seat, reading lights and music outlets.

Some measures are not suited to be presented in the this form of diagram (figure 10.20) but they will be mentioned in Chapter 11.

There are also many measures regarding train size and traffic service concepts that have not been analysed yet.

11. Discussion and conclusions

When this project began, the goal was fairly vague: *"This project will attempt to systematise passenger rolling stock with respect to the Swedish market in the future. The purpose is to find vehicle concepts that balance standard factors such as comfort, service-level and quality and their importance as stated by passengers by relation to the cost. ...What developments are most important to attract more passengers and what developments are important to cut costs?"*

The supply of train concepts and their components has been defined and systematised. A cost model for train services has been developed. This has been mainly used to identify important cost factors. The aim has been to identify factors that can guide the measures that should be taken to reduce costs in the first place. A concept of "cost elasticity for various input parameters" has therefore been defined and used.

This thesis is based on the assumption that the utility of various measures can be measured and transformed into monetary valuation figures. To estimate these figures, a large number of stated preference studies have been undertaken. This has produced a number of valuation figures for distinct attributes, as well as some knowledge of the value of combined attributes or "packages".

A simplified model for comparing costs and valuations of various measures has been defined and used to analyse the measures that appear profitable from this perspective.

The rest of this chapter includes findings and discussions relating to methods and measures. It deals with the effectiveness/supply and attractiveness/demand perspective, as well as the trade-off between costs and valuations.

11.1 The use of stated preference methods

The use of standard stated preference methods, such as the pairwise choice of alternatives with a main effects fractional design, seems somewhat problematic to use in the case of many secondary attributes, like the existence of reclining seatbacks or public telephones on board. The specific attributes under consideration are often related to comfort or on-board service.

One roll of secondary attributes to act as indicators of other, latent attributes like "opportunity to work" or "convenience".

11.1.1 Taste variation among passengers calls for consideration

The weight of these secondary attributes appears to be distributed differently from a normal distribution. Many people do not care at all about some of these features. In other cases, people have opposite opinions, about face-to-face and face-to-back seating for example.

Research on the role of taste variation in logit models is in progress at the Division of Transport and Localisation Modelling²⁷⁴, where models with normally-distributed attribute parameters are being tested.

The use of best/worst methodology with estimations of individual taste weights has shown the distribution of these weights among respondents. My findings are:

- People have different preferences for many attributes, especially secondary attributes.
- The frequency distribution is seldom normal but skewed.
- Many respondents do not appear to care at all, or very little, about certain attributes.

11.1.2 Use of two-level SP interviews

A good way of evaluating the weight of, and thereby the willingness-to-pay for secondary attributes appears to be two (or more) step interviews. At one step, the upper level, the *values of packages* of attributes, such as comfort indicators, are estimated. At the lower level, the value of the package is divided and distributed between the various attributes/indicators included in the package.

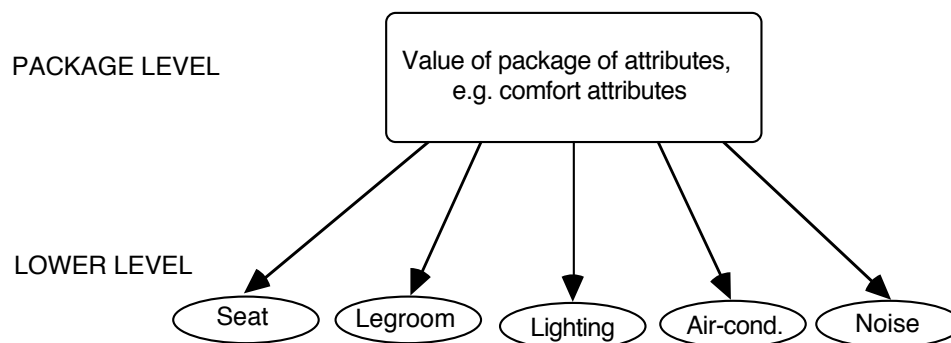


Figure 11.1 Two-level SP interviews

Good reasons for this may be that:

1. Each secondary attribute (those at level 2) is not normally distributed, but the sum of a number of such attributes can approach the normal distribution.
2. Package effects caused by budget restrictions and so on are reduced.
3. It may be easier to evaluate a larger number of attributes in one interview.

²⁷⁴ Algers, S., Lindkvist, J. et. al. *Estimating the Value of Travel Time by Means of a Mixed Logit Model*, work in progress (1998)

11.2 About passenger valuations

This section summarises general findings about passenger valuations.

11.2.1 Passenger valuations depend significantly on travelling time and ticket price

My alternative estimation models, in which I have introduced time- and price-dependent parameters for individual attributes, show that the utility often increases with time and/or cost. Estimating a constant value, expressed as SEK/journey, can be doubtful, or even wrong.

Valuations in relation to ticket prices work very well

I have generally estimated the relative monetary valuations: the value of attributes in relation to passengers' ticket prices. Variations in the relative valuations have then been checked by segmentation and this shows that the valuations in different segments are fairly stable in relation to their ticket prices.

11.2.2 Reduced values for a few attributes may be compensated for by increased values for others

An additive utility function involves attributes being compensatory. A reduced utility for one attribute can be compensated for by an equally large increase in the utility of another attribute. This is the assumption of the formal model.

Much of my work has been governed by this idea. The most important circumstance is that reduced space-related comfort may be compensated for by high comfort in other respects and high on-board comfort and quality fulfilment.

Unhappily, no real tests of the existence of compensation have been undertaken within the framework of this thesis. However, I do have indications in this direction. One example is the high valuations of SJ's experimental coach which had very dense seating but gave a fresh and modern impression. In this case modernity and freshness compensated for the lack of roominess.

11.2.3 Willingness to pay or to accept impairments

In this work preferences have been expressed as monetary valuations. In some cases, these valuations can be expressed as willingness to pay (wtp) but should in other cases instead be seen as monetary values for willingness to accept (wta). Which of these concepts, wtp or wta, that is applicable in specific cases depends on different factors.

One circumstance which points to wtp or wta is the way the valuation experiments are designed; if respondents were supposed to pay more for a better product or if the design included cost decreases and hypothetically impaired comfort or service. Many of the included studies have had designs in which prices have been varied both upwards and downwards. This is also the case for some of the attributes. For example, legroom has been both increased and decreased in the SP studies in which this attribute has been

studied. My intention has been to estimate the marginal sensitivity to the attributes *around* the respondents' reference level. It corresponds to the derivate in a point.

Another factor of importance when using the various valuations in practice is the reference levels the attributes of today's supply have. For example, it must be mentioned that many of the comfort and on-board service measures evaluated in SP studies in reality already match the high level of the corresponding attributes: seats do recline, legroom is fairly large, there are reading lamps and catering on most Swedish long-distance trains. The valuations then represent the negative preference/disutility passengers would experience if these features were taken away.

If people are aware of the standard of today's Swedish trains, their reference levels for comfort attributes are fairly high and the valuations shown in SP studies point to the risk that is taken if comfort is reduced. (A question that has not yet been studied is people's perception of what levels are offered today.)

To keep today's travellers require at least today's standard level at an unchanged ticket price level.

11.2.4 The standard of trains in relation to the developing competing modes

People's reference level for standard changes with time. Competing modes are being developed all the time. Cars and buses are becoming more and more comfortable and have more and more features. At the same time, it seems that the valuation of railway coaches decreases with age and the life of rolling stock is long. That means that there is a risk of an increasing gap between the valuation of train standard and the standard of competing modes.

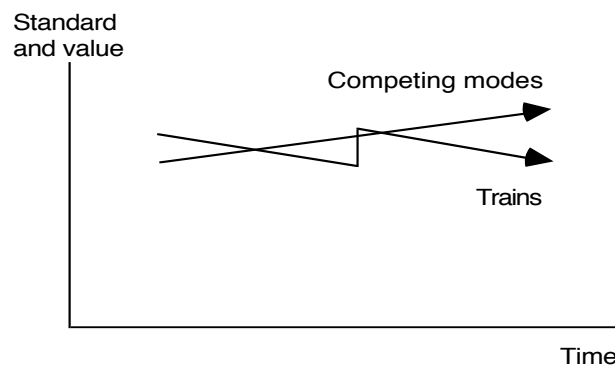


Figure 11.2 There is a risk of a gap between the standard of developing competing modes and trains. The vertical shift in train standard illustrates the modernisation of the rolling stock by purchase or refurbishing.

The gap could also be bridged by continuously increasing the standard in trains too and by refurbishing the coaches a few times during their service life.

11.3 Higher speeds are profitable twice

Higher average speeds reduce travelling times, which is highly appreciated. A 10% reduction in travelling time is valued on average about the same as a 7% reduction in ticket price. The relative value of travelling time is twice or more for business passengers.

If the track²⁷⁵ and the form of transportation permit higher (average) speeds and thereby shorter travelling times, the production-costs decrease as well, at least up to a optimum (cost minimum) speed level of 200 – 250 km/h. When the periods of rotation diminish, the same train and personnel can be used for more train-kilometres a day. One factor that may go against an excessive speed increase, at least for some train designs, is ride comfort. There is more on this in section 11.5.3.

Higher average speeds is the most meaningful measure to reduce costs and increase the value of train travelling at the same time. The way to achieve the increase in average speed include increased top speed but also increased acceleration and braking performance and reduced waiting times at stations.

²⁷⁵ In case the infrastructure does not permit higher speeds, costs for upgrading the track will arise. Such infrastructure costs are not included in this appraisal. In Sweden, as in many European countries, traffic services costs and infrastructure costs are being separated by one method or another.

11.4 The important role of effective space utilisation

From chapter 3, where the passenger rolling stock characteristics, the supply, is treated we learn that trains in different countries differ with respect to interior standard level and the use of space. Various modern train designs differ less with respect to technical performance measures.

An early finding in this project work was the importance of effective space utilisation. An economic model was developed and it was soon found that the most effective way cutting costs was to increase the use of space. The magnitude of the cost elasticity for space utilisation was found to be around 0.5, which is higher than for most other measures. It therefore became necessary to study passengers' value of space and thereby investigate space-related attributes.

One hypothesis has been that other comfort, service and quality measures can be traded off or can compensate for a more dense interior design. On the other hand, there are many measures to increase use of space that will not affect the passengers' valuation of the train at all.

11.4 1 Double decks and/or wide bodies should be used to increase space

By building trains with two decks and/or wider bodies the interior space can be increased relatively more than the cost. The train service cost per furnishable space decreases by 5-10% if double decks are used or if train bodies with about 50 cm extra internal width are used and an extra row of seats. This is a substantial reduction.

Double-decker trains are used in many countries; they include high speed trains in Japan and France. The profile is large enough for double decks in most parts of Europe apart from the British Isles. One problem is that the double-decker trains are not well suited for car body tilting.

In many existing regional double-decker trains the "extra" space is not used for enhanced comfort, but for increasing the capacity as much as possible. This could be a good idea. On the other hand, in double-deckers where space should be cheaper, the extra space could be used for on-board services and qualities that are more difficult to introduce in single-deckers. Such ideas are touched upon in section 3.2.

Wide bodies exist in Japan, for example, where normal Shinkansen trains are 3,4m wide on the exterior. Wider trains would be possible to use with only minor adjustments to the infrastructure in Denmark, Norway and Sweden. Even the Dutch and the German railways have so far shown an interest in wider train concepts.

Wide trains can be effective for all train sizes, even short EMUs, while double decks appear to have more benefits and a higher degree of cost reduction for larger trains (even though a cost efficient small double-decker railbus has been designed in Germany).

Passengers appear to value double decks in a slightly positive manner while three-plus-two seating, which is required for the effective use of wide bodies, appears to be slightly negative. It is, however, far less negative than many railway experts fear and less negative, measured in willingness-to-accept, than the calculated cost reduction.

11.4.2 Space efficiency and attractiveness also depends on furnishing and the division of seating

The first association regarding space efficiency is the amount of legroom, but:

Less legroom is questionable

Shorter legroom is one of the effective ways of cutting costs. A 10% increase in seating density, corresponding to 10cm per seat at the original seating distance of one metre, would cut costs by about 5%. This is a significant cost reduction. However, on the other hand, the valuation of the attribute legroom is of the same magnitude.

The conclusion is that on average, for the average passenger, a reduction in price barely compensates for less legroom.

The valuation of marginal legroom also accelerates with diminishing legroom, so it is possible to indicate an approximate optimal magnitude for legroom. This has been shown to be about 25cm, or what many Swedish trains have today. With an anticipated over-valuation of this, (as well as other) comfort attributes, the optimal legroom would be shorter, say 10-20 cm.

Space-lean seats have great potential

A seemingly trivial measure, seats with space lean design, may save as much as 5 % of the total train service costs without reducing comfort. The space lean seats should have thin backrests and an intelligent recliner mechanism and they should be designed so that one can easily stretch one's legs under the seat in front. A somewhat more expensive seat is well compensated if the seat density can be increased 5-10% with retained comfort experience.

Compartments are generally uneconomic

Compartments with fewer than four seats side-by-side – eight seats per compartment – increase costs substantially. A few Swedish passengers do prefer compartments, but most prefer open saloons and the average valuation of compartments is negative. The conclusion is that compartments should be avoided as a general form of interior.

A mixture of face-to-face and face-to-back seating

The majority of the passengers display substantial willingness-to-pay for sitting face-to-back (most) or face-to-face (fewer). So interiors with only one of these furnishing alternatives is a comfort reducing mistake. This is probably true of all European railways, even though the optimal mix may vary with the type of travellers and travelling purpose.

The passenger saloons should be divided to meet different train travellers' needs

The passengers have different needs and preferences. Some want to rest or work, while others want to socialise with colleagues, friends, family members or other co-passengers. To meet the needs and preferences of these various types of passenger, the passenger saloons should preferably be divided into different sections, for example:

- Read, work and rest sections. They should have a sufficient percentage of face-to-back seating.

- Company saloons including "talk corners". In these sections, face-to-face seating is preferable. Café furnishing can be tested here.
- Family sections including some sort of play areas for children. Also in these sections, face-to-face seating is preferable.

The existence of special sections is important not only for those requiring a special interior design but also for passengers who do not want to be disturbed by others. For example, the segmenting of passengers travelling with and without children shows that even those without children give a high value to special play areas for children. There is the same type of need for some sections which are free from use of mobile telephones.

In many countries today, and in Sweden until a few years ago, smoking was allowed in special sections of the coaches. Stated preference responses show that even smokers can accept smoke-free trains with just small "smokers' corners".

Tables at seats are important for the effective use of travelling time

The potential for the effective use of travelling time is generally higher in trains than in (ordinarily furnished) buses and aeroplanes. One important condition for using this potential effectively is to have high-quality tables at each seat in the train.

The effective use of time is also dependent on other comfort factors such as good ride quality and low noise levels.

11.5 Some conclusions about other train-related measures

One of the most important conclusions from this study is the first one that follows: It is convenient and advantageous to use standardised rolling stock for regional and inter-regional trains. The other conclusions about train-related measures describe appropriate features for these passenger trains.

11.5.1 Standardised rolling stock for regional and interregional trains

According to tradition, or possibly for cost reasons, trains for short journeys have been furnished with simpler interiors with a lower level of comfort than trains for longer journeys. It may seem logical that people sitting in a train for a longer period of time should have better comfort. The answers to questions about space and the level of comfort, as well as valuations, distributed between different categories of travellers, show that work commuters place a greater emphasis on seating comfort than other travellers do. This is explained by the fact that the commuters' travelling time *per year* is much higher than the average for the rest of train travellers

It is an advantage from the cost point of view if the same rolling stock can be used to a greater extent for both regional trains and long-distance trains. To date this has been regarded as uncertain or implausible, insofar that the interior of regional trains have been far too uncomfortable interior. Knowing that one large group of regional travellers are at least as rigorous imposed by the comfort demands as those of the long-distance travellers, one of the incentives for different rolling stock (interiors) disappears. The trains can be used more effectively during the week and the comfort standard ought to be high in the joint rolling stock.

Flexible interiors to meet varying market needs

Having a reduced number of train designs means that it is important to have a flexible concept that can meet varying market demands. One example is the reduced demand for business class at weekends and holiday periods. It would therefore be beneficial to have seating that can easily be converted to match the demands of business and leisure travellers.

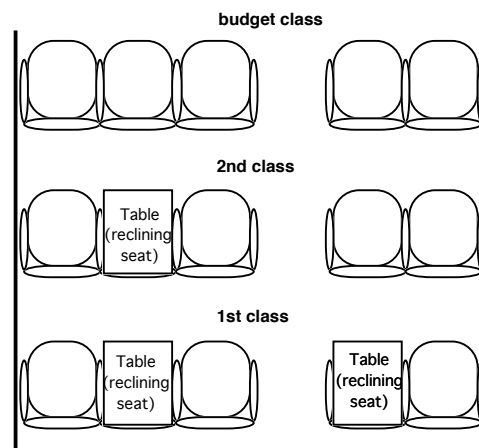


Figure 11.3 Proposal for a flexible 2+3 seating arrangement for wide trains.

Various on-board service concepts can be used to differentiate between market segments and to characterise different products or "classes" within a basic train interior.

Smaller trainsets

Smaller trainsets are cheaper per se than larger trainsets, but the cost per seat increases in general when size is reduced. A preliminary calculation (in section 4.4.2) shows that having just 1-2 vehicles per trainset could be economic if demand varies a lot according to a concave demand per run curve.

11.5.2 Most travellers require some kind of catering on board

It is important for the effective and flexible use of time and for the positive experience of the train journey that there is some kind of catering on board. The willingness-to-pay figures are not exceptionally high for catering, but they show some sort of average preferences among all interviewed passengers. Eating is a basic human need and, if it cannot be met in an attractive manner on a train journey, some travellers may choose other modes of transport.

Willingness-to-pay does differ a little between food trolley, café and restaurant but a more in-depth analysis is needed in each case to find optimal solutions. When it comes to catering facilities, the cost of space can also be the most important factor.

11.5.3 Travellers are willing to pay for a quiet train with good ride comfort

The valuation for low levels of noise and vibration is high. Sampled calculations have shown that it is unlikely that enough can be saved on costs in terms of lower investments, or energy costs to make it possible to ignore travellers' strong preferences with regard to low noise and vibration.

As higher speeds may lead to a deterioration in ride comfort, there is a risk that the positive value of the shorter travelling time will drop below the loss of value. One example is that a few people become travel sick in tilting trains and for these people the shorter travelling time probably does not compensate for the reduction in comfort.

Another contradiction is the high noise levels generated by auxiliary systems as air conditioning. In some cases, this can be assumed to reduce or fully trade off the positive appreciation of the cooled air.

11.5.4 Service equipment like video, music outlets, electronic signs, telephones and office machines can add extra utility

The idea behind including service features in the evaluation of passenger train concepts is that the increased value they create may compensate for reduced value in other respects, such as roominess.

My analysis shows that additional service equipment can add extra value to the journey for some passengers. The average values are higher than the cost of some of this equipment, but there appear to be technical quality problems that have to be solved.

11.5.5 Impression of modernity appear to have a high value

When new trains or refurbished interiors have been evaluated, they have always been given a higher value than the old reference interiors. In some cases, the objective comfort standards can hardly explain the positive utility because the reference coaches had in principle the same high standard level (reclining seats, big legroom, reading lamps etc.). My conclusion is that the impression of modernity plays an important role.

A similar type of impression is given by cleanliness. It plays an important role and it may even be that new trains are appreciated as much for their cleanliness as for their modernity. SP results show that modern, clean WCs are of extra importance.

To keep up with the modernity of competing modes and people's expectations, train interiors have to be modernised more frequently. It is especially important to keep the WCs modern and fresh. Regrettably, I have not managed to analyse how often such modernisation should be made.

11.6 The potential for cost reduction is even greater than is shown in this thesis

The economic model (Tåganalys) has been used for many analyses of cost-reduction potential. Some of the results have already been shown. Investigating further potential would require extended and partly different analyses.

In the KTH project "Efficient trains for future passenger services" calculations were made that show cost-reduction potential of up to 50%. These figures include the impact of modularisation, the use of standard components and more effective technologies. As these factors are not of primary importance in this thesis, it is interesting to investigate the cost-reduction potential excluding these factors.

11.7 Questions for further research

One general aspect when it comes to further research is the need to analyse a number of factors in more detail. There is a need for more detailed analyses of the costs but also for more trustworthy valuation figures. In both cases, there is need to use more exact models and, in the case of some studied aspects, it will be necessary to develop modelling still further.

11.7.1 Passenger rail supply and costs

One general comment on the structuring of the supply is that only those characteristics that relate fairly closely to rolling stock have been included. To make more extensive analysis other characteristics related to the traffic, to information and to accessibility, to mention a few more areas, should be included.

A few examples of supply-related questions which require more in-depth analysis now follow.

What are the real costs of railway operation?

It is difficult for a researcher to obtain the real costs of railway operation, as the figures are often secret. Exact figures are not always necessary, but for some types of analysis a better specification of costs is needed. One example is that, in order to analyse various types of train configuration in more depth, better cost estimates for shunting (rail yard staff and operations) are needed.

What is the cost of higher maximum speed?

There is a need for a careful analysis of the increase in vehicle construction costs when maximum speed increases. In my calculations, I have used approximate estimates we made at the Railway Group KTH.

In 1998, I had the chance to act as a referee for a scientific paper about the economy of high-speed trains. The author turned down high-speed operation partly because of the extra cost of the rolling stock. The author felt that high-speed rolling stock costs twice as much as ordinary rolling stock. This conclusion must have been made by comparing the investment costs for existing modern European high-speed trains with existing rolling stock of the conventional type. A comparison of this type has many pitfalls, such as different interior standards.

11.7.2 Travellers' preferences and methods of estimating them

An even better structure for passenger-related attributes is needed

The model for passengers' evaluation of trains, the supply, has included attributes that are similar to technical descriptions of the supply (e.g. travelling time 1 h 30 min, 10 cm change in legroom). This is illustrated in figure 11.4.

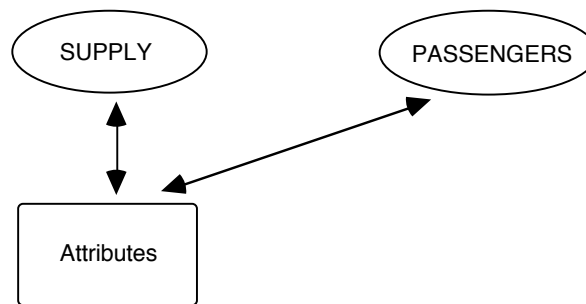


Figure 11.4 Attributes used in this thesis mostly relate to the supply side, even though an attempt has been made to distinguish between supply attributes and passengers' attributes.

The structuring of the attractiveness/passenger and the effectiveness/supply aspects is an attempt to use different descriptions. For attractiveness, attributes were chosen that would be of importance for passengers, but they were still of technical nature. For effectiveness, on the other hand, ordinary technical measures were used.

An alternative to the classification used here would be to include attributes that relate more to the passengers' notions or images of trains. These latent images or attributes could include for example convenience and flexibility. There would then be a relationship between the supply-related attributes and the latent, passenger-oriented attributes. This is illustrated below.

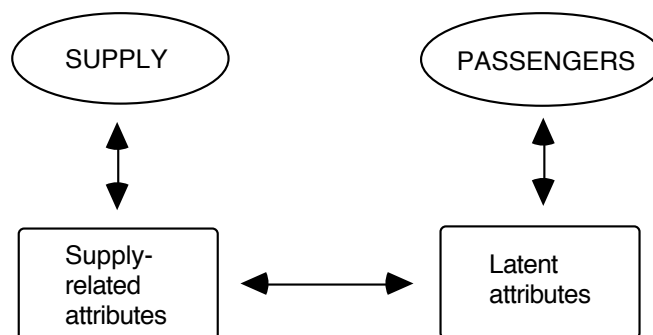


Figure 11.5 A model closer to reality would include latent attributes.

Morikawa has described an approach of this kind, but it has not been used (yet) by us.

In subsequent work about train-related qualities and valuations, a new approach should be developed. Latent attributes can be identified by qualitative interviews and/or by using factor analysis.

The trustworthiness of the valuation levels

The trustworthiness of the valuation levels needs to be improved. The main problem that has to be investigated further is the probable over-estimation of many comfort, service and quality fulfilment attributes. A study that really underlines this problem is the one by

Wardman²⁷⁶, presented in brief in section 8.4.6. If the results of this study represent the truth, the over-estimation by other studies may be very high. On the other hand, different SP methods and different studies, some of them within the framework of this thesis, appear to support one another; passengers really do place high values on comfort, on-board service and quality fulfilment.

Is the benefit of higher frequency underestimated?

In SP studies with existing passengers, the value of increased train frequency do not appear to be very high. Experiences from reality and estimations from revealed preference studies may show a higher importance of the frequency. I recommend to keep an eye on this factor.

What ways of tackling package effects are practical and justifiable?

Package effects have been studied to some extent, but there is a need for further analysis and other solutions to get around this problem. Some kind of validation of the degree of detected package effects would be useful.

One step could be to use stated conjoint designs that permit correlation between attributes, not only main effects.

How does the utility of various attributes vary among people?

During this work, the preconditions for stated preference estimations using the logit model have been questioned. It is normally assumed that all the individuals in a specific estimated model have the *same* valuation of the attributes included in the model. In all probability, the natural thing would be for individual evaluations of an attribute to differ, distributed according to some distribution function.

How great are the imperfections when using stated preferences with logit estimation for unlabelled alternatives?

In section 6.7, I have noted that the preconditions for the logit model are hardly fulfilled when unlabelled SP designs are used. This may be especially critical when evaluating secondary attributes for which people may have quite varied preferences. One way to study these circumstances in more detail would be to use Montecarlo simulation of similar SP experiments.

How should passengers' valuations be measured; in absolute or relative figures, related to cost or travelling time?

The way in which valuations are presented – in the form of Swedish kronor (SEK) or a percentage of the fare or as SEK per hour of travelling time – is not unimportant. In section 6.5, this is discussed and some analysis results are presented. There is need for a deeper scientific discussion and further insight into the advantages and drawbacks of the different representations.

²⁷⁶ Wardman, M., Whelan, G., *Rolling stock quality improvements and user willingness to pay*, ITS working paper 523, Leeds, March 1998

How can best/worst conjoint be justified and best used?

There is still a lack of some theoretical underpinning for the best/worst method. It is therefore wise to follow the international discussion and scientific conclusions about the best/worst and similar methods. At KTH, we can, for example, conduct further tests to compare the outcome and the complexity of these new methods with traditional stated preference methods.

How can we better integrate qualitative methods with quantitative preference methods?

Qualitative studies are better in some respects than quantitative studies like SP. To make more trustworthy studies, one should benefit from both paradigms. Many researchers and practitioners are already using fruitful combinations of methods and we have to practise and learn more about such combinations at KTH.

How about non-train travellers' evaluations of trains and train travelling?

It is important to define the evaluations of travelling by train which are made by car drivers and air passengers and non-travellers. This is more complicated than investigating rail passengers' preferences in terms of train services and train comfort. This knowledge is needed to make better forecast models and for more accurate socio-economic valuations of train systems. It is therefore useful to investigate whether or not non-train travellers have similar preferences to train travellers.

One related question is as follows: How can the results of SP studies be applied to a larger population which does not have the same information as the study population. This research question also relates to our prestudy of mental and physical accessibility to rail²⁷⁷. What are non-train travellers' perceptions of the train supply and its attributes? To what extent do they perceive various comfort, service and quality measures?

One area in which complementary methodology can be used is to investigate threshold effects. A specific factor may be decisive and restrict the choice of train. This can apply to travelling times or financial budgets.

11.7.3 Various train-related measures

Some train-related questions have not been sufficiently analysed. A few of them are listed below.

Can smaller trains with higher frequency be an economical traffic concept?

Smaller trains are more expensive per seat to operate. It is also more expensive to run many small trains rather than a few large ones. On the other hand, demand can be increased by higher frequency and this will increase revenue.

One calculation result, presented in the KTH prestudy "Efficient Passenger Rail Services for the Future", shows that really small trains – about 100 seats – can be the most economical solution in a situation when the traffic is differentiated. Every second train is

²⁷⁷ Shilling, Rolf, *Accessibility to Train - from information to station*, final draft 980609, KTH Traffic and Transport Planning, 1998

an express train or a more local train, each with a frequency of half an hour, altogether one train every fifteen minutes (in the presented example).

More cases with various assumptions have to be studied to investigate the relationship between train size and frequency from an economic point of view.

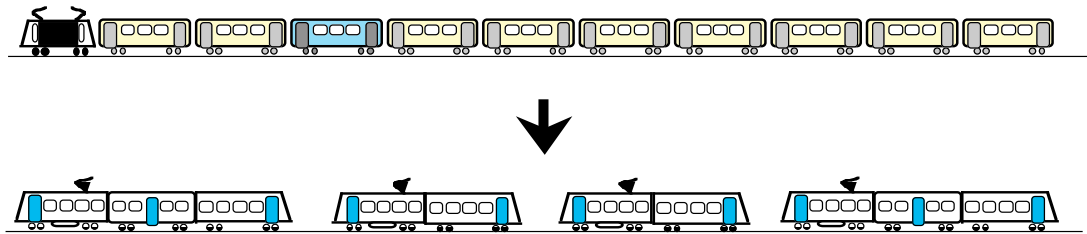


Figure 11.6 Can smaller trains in higher frequency be economical?

What is the cost benefit of train sharing and coupling?

Train sharing and coupling has benefits and drawbacks. The benefits include the opportunity to increase the average occupancy and to create timetables with fewer interchanges for passengers. The problems to be considered include delays because of sensitivity to disturbances. This question is important to the train designer because it relates to the optimal size of the trainsets and the level of connectability and the design of gangways between coaches and trainsets.

Maximum comfort in minimal space

We must learn how to make trains with less space per passenger but a high comfort experience: "maximum comfort in minimal space". For this important purpose, the Railway Group at KTH should work together with designers and the railway industry.

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Appendix 1: Railway map of Sweden

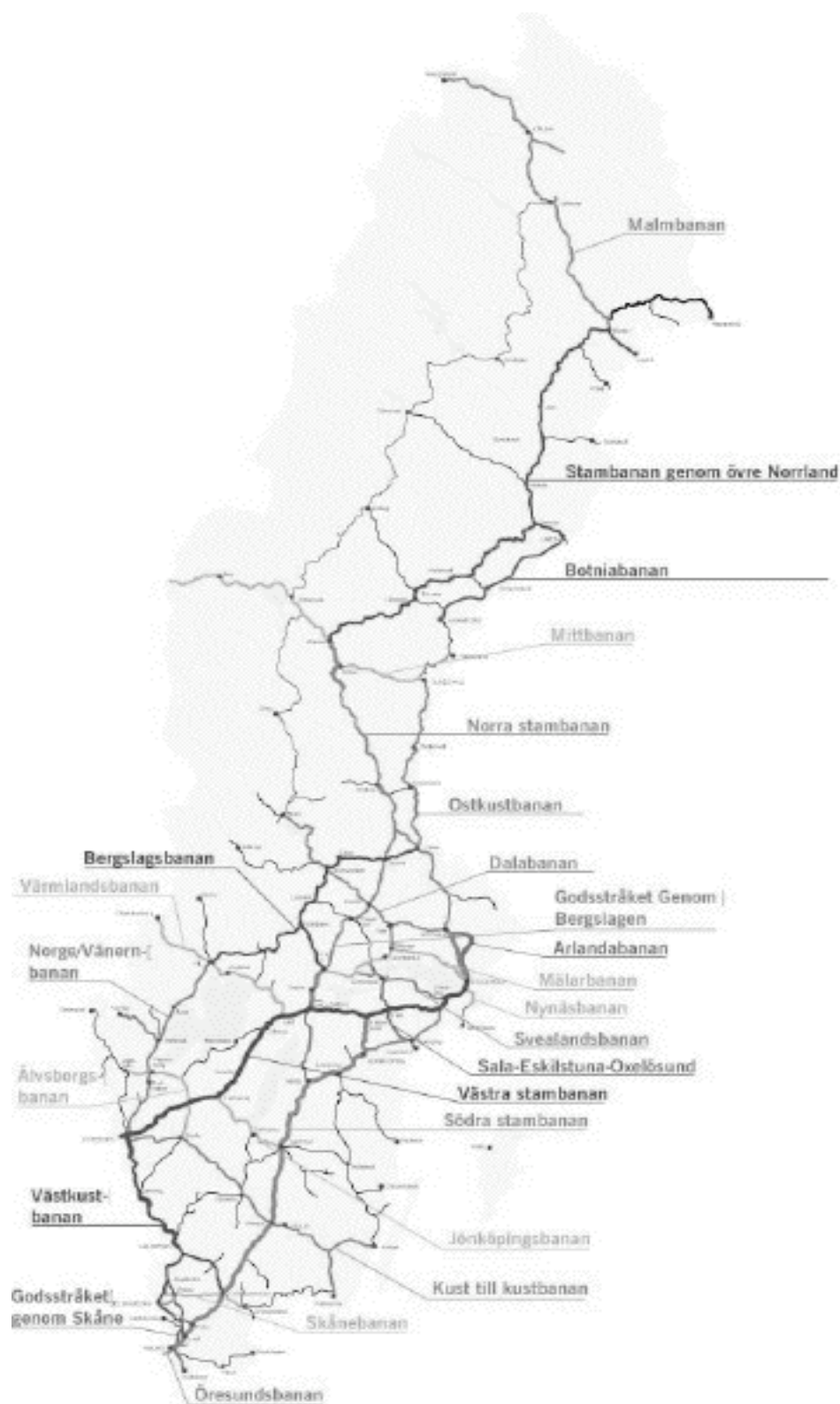


Figure Railway map of Sweden with lines that are being new or upgraded specially marked. (Source: the Swedish National Rail Administration, www.banverket.se).

Appendix 2: definitions

<u>Word or expression</u>	<u>Definition</u>
Alternative	An alternative is composed of a number of attributes which take certain levels. Also called profile or treatment.
Attitude	Predisposing tendencies to react to abstract stimuli. Can be explained as "biases" learned in a social context.
Attractiveness	"The power or quality of attracting"
Attribute	A factor which is evaluated by respondents. Other words are passenger carriage, vehicle and wagon. Both car and coach have been used but with slightly different meanings. Car is more technical, as in carbody, while coach has been used when relating to interior and comfort aspects. Car is more often used in America. Coach is used also for (road) buses with high comfort, as for example for the buses in Blekinge (section 7.4).
CASI	Computer Assisted Self accomplished Interview
Choice	The operational selection of a specific satisfier. Choice is the individual's <i>actual</i> selection.
Competitiveness	Competing means striving against (others) for victory. In the case of passenger rail, competitiveness can mean making a large percentage of rail services beneficial from a business economy point of view. Competitors offer bus and air travel.
Design	A set of alternatives, all differing by the levels of their attributes.
Effectiveness	"The power or capacity to produce a desired result" – Is this the right thing to be doing?
Efficacy	– Do the means work?
Efficiency	– Are minimum resources used (for a given output)?
Factor	A condition that influence choices or preferences. These conditions include socio-economic factors and alternative related attributes.
Occupancy rate	The proportion of the number of passengers and seats in a train.

Preferences	The ordering or scaling of alternative satisfiers of a need or set of needs. Preferences emerge from experience in search of need satisfaction. Preference is the individual's <i>ideal</i> selection.
Stated preferences	Methods used to measure people's stated preferences such as choices, valuations and willingness-to-pay for various decision alternatives including their attribute levels.
Evaluation	A measure of the qualities that determine merit, desirability, usefulness or importance (or value). In this thesis, the word evaluation is most frequently used for the act of judging in more general meaning.
Train service cost	The operators' cost for their train service: The sum of vehicle investment annuity cost, maintenance and cleaning, energy, on-board staff, rail fees plus some overhead costs for ticket selling etc. An expression that mean about the same is "traffic cost". "Operation cost" has also been found for this summation of costs, but in some references it excludes investment costs.
Valuation	The result of judging the worth or value of something. Synonyms are: value, account and worth <i>and</i> estimate and estimation. In this thesis, the word valuation is most frequently used as a measure of value or utility in economic terms.

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