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DEVELOPING CONSUMER ELECTRONICS PRODUCTS: PRACTICE AND PERFORMANCE IN JAPAN, NORTH AMERICA AND THE UK

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Developing Consumer Electronics Products: Practice and Performance in Japan, North America and the UK

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Abstract

This report summarizes the findings of an international benchmarking study into new product development, which was conducted by the Judge Institute, University of Cambridge, and funded by the Design Council and the EPSRC.

The study examined new product development performance and practice amongst 38 high-end audio companies in Japan, North America and the UK. Detailed measures were taken of many aspects of product development performance, including lead times, schedule and budget adherence, development hours, manufacturability, quality and sales performance. The study analysed how the product development process was managed in the three regions, particularly in terms of how interfaces between key actors – for example, Development, Marketing, Manufacturing and suppliers – were handled during in the development process.

Contrary to the findings of studies in other sectors, Japanese companies had longer lead times and required far more engineering hours to develop their products than did their Western counterparts. Lead times in Japan were 84 weeks compared to 71 in North America and 48 in the UK. However, although UK companies were able to develop new products particularly rapidly, their products displayed 20 times the levels of post-launch problems of Japanese products.

To some extent, these differences are reflections of wider differences in national patterns of innovation. The UK and North American firms were largely small to medium sized entrepreneurial firms. The Japanese units were generally specialist divisions of large corporations. Japanese engineers stayed with their companies for longer periods than did the more mobile engineers of the Western firms, which made it easier for them to develop high levels of detailed, company-specific knowledge. This facilitated coordination and the retention of knowledge, but posed obstacles to radical innovation. However, the Japanese system clearly carries advantages in terms of manufacturing performance and the combination of multiple technologies.

Developing Consumer Electronics Products: Practice and Performance in Japan, North America and the UK

Background

The research described in this report grew out of a desire to understand how the UK's innovation and product development capabilities compare with those elsewhere in the world. The work grew from a series of benchmarking studies of automotive manufacturing which had compared UK firms with their UK, Japanese and continental European counterparts on a whole series of measures – productivity, quality, on-time delivery and so on. The results, unfortunately, did not put the UK firms in a very flattering light (Oliver *et al* 1994, 1996). Some observers saw this result as further confirmation that the strengths of the UK lie somewhere other than in high volume, precision manufacturing. This is not a new idea, of course. The significance of the City of London as a financial centre and the UK's strengths in the invention (if not always in the exploitation) of new ideas are well recognized. However, although studies have examined the UK's innovative performance at a *macro* level (patent data, percentage expenditure on R&D etc) and at the *micro* level through case studies of individual innovations, systematic, firm-level data on new product development practice and performance are rare. Thus, in late 1994 the Design Council approached Cambridge with a simple question – was it possible to develop a series of measures that could be used to provide benchmarks of the UK's position in terms of product development performance and practice? This report describes the research project that was the response to this request.

The Challenge of New Product Development

The capacity to develop winning new products represents a crucial source of competitive advantage. The reasons for this are not difficult to see. Products can differ enormously in many important respects – price, image and aesthetics, quality, technical superiority and so on. In addition, the timing of product launches may be crucial - there may be enormous price premiums on products that are first to market, hence the great interest of many companies in reducing time to market (Brown and Eisenhardt, 1995; Cooper and Kleinschmidt 1996).

Yet creating new products can be a challenging process. Although lone innovators and businesses built around single winning products can be successful in their own right, to

develop and launch a succession of products over the longer term requires the combination of many skills, capabilities and activities. These include the capabilities to:

- Read current and future market requirements and understand user needs (some of which may not even be articulated)
- Develop or acquire key technologies that to be incorporated into new products (for example new materials) or into new processes to produce these products
- Co-ordinate the activities of different specialist groups, all of whose expertise is needed to create new products
- Prepare the product or service for manufacture or delivery
- Manage processes of introduction into the market and provide after sales support.

The process of product development can be viewed very differently according to one's vantage point. Professional specialists, such as designers may be pre-occupied with what they see as constrained thinking about product possibilities, a preoccupation which stems from the perception, common amongst many professional designers, that aesthetics and other issues are not given sufficient attention during the product development process. Groups such as professional engineers, on the other hand, may hold up their hands in horror at what they perceive to be the disorder of the product development process, and produce procedures, design rules and so on in order to address this. Senior managers, responsible for processes (and costs) that can be far from easy to control, are likely to show great interest in methods to monitor and review the development process – and so on.

This report is not based on the preoccupation of any particular professional discipline, but views product development from an *organizational* perspective. By this we mean that the focus is on the processes by which the activities of the actors who contribute to the development process are co-ordinated and controlled. This involves analysis of the information flows within the development process – for example from the market (via customer requirements) through to concept development, product specifications and finally into the end product. Of course, this flow of information has its corollary in terms of the specialist groups whose efforts are all needed to transform an idea into a product – Marketing, Development, Manufacturing, Sales and so on. In complex products comprising multiple technologies (such as motor vehicles), development teams comprise hundreds of people from many specialist engineering disciplines. Co-ordinating these specialists can be an awesome task.

This perspective has been termed an "information processing" perspective (Clark and Fujimoto 1991, Fujimoto 1999). In concrete terms, this involves identification of the various actors – typically specialist groups – involved in the product development process and examination of how their efforts are co-ordinated. Our earlier studies of manufacturing demonstrated that the performance differences between high and low performing units were rarely attributable just to differences in technology. More often than not, it is differences in methods of organization that explain performance. In particular, many companies struggle when it comes to managing the interface between different functional specialists (such as personnel from Marketing, Design and Manufacturing) or between the company and groups in the external environment (such as customers and suppliers).

International Performance Comparisons

Perhaps because of the difficulty (and cost) in conducting detailed international comparisons of new product development performance, relatively few such comparisons exist. Most tend to be US-Japan comparisons, with a particular focus around the automotive industry. The best known of these is Clark and Fujimoto's (1991) study of product development performance in Europe, Japan and the US, some of the key results of which are shown in Table 1.

Table 1: Japanese Product Development Performance

	Japan	US	Europe
Adjusted lead time (months)	45	61	59
Adjusted engineering hours per project	1.7m	3.4m	2.9m
% of 'black box' parts from suppliers	62%	16%	29%

Source: Clark and Fujimoto (1991)

Compared to car makers in the US and Europe, Clark and Fujimoto found that Japanese car makers had shorter lead times for the development of new models, used smaller product development teams and had levels of engineering productivity that were double those of Western companies. They argued that several factors explained the Japanese performance superiority, including greater use of suppliers in product development, the overlapping of stages of the development process, heavy weight project team leaders who led multifunctional teams, and close linkages between Development and Manufacturing. Thus, Clark and

Fujimoto were not only able comment on *performance* differences in product development, but to link these to patterns of *practice*.

This study was modelled on the Clark and Fujimoto study, but with two important differences. First, we specifically set out to compare *UK* product development performance against international benchmarks, following our brief from the Design Council. Secondly, we set out to compare product development in a sector other than the automotive industry, where much work had already been carried out. These objectives presented many challenges, which are described in the section that follows.

Designing the Study

Key challenges in any benchmarking study are the problems of *comparability* and *anonymity*. Comparability is addressed by only including companies who conduct closely similar activities – producing similar products, delivering similar services and so on – in order to achieve true 'apples to apples' comparisons. Of course, this can work against anonymity, as many types of product are only produced by a small number of firms. These challenges are exacerbated if international comparisons form part of the brief - sectors that are comparable across countries must also be identified.

From its inception, one of the key aims of this study was to compare UK product development performance and practice against class-leading international benchmarks. For many products this meant comparison with Japanese and US firms, and so initial product searches focused on products that were (a) comparable and (b) reasonably complex with (c) multiple producers in each country. Complexity was an important criterion due to our interest in the organization of product development. We sought products whose development required a variety of skills so that development was a team effort, not just something involving one or two people. Early candidates in these searches were automotive products, mobile phones, white goods and consumer electronics products.

When the above criteria were applied, the number of feasible products narrowed dramatically. Automotive products were eliminated due to the fact that studies in this area already existed, and to the heavy concentration of ownership in the auto industry, meaning that many automotive products that are manufactured in the UK are developed elsewhere. Mobile phones were eliminated because of the interdependencies across engineering centres around the world,

which made it difficult to assess different contributions to the new product development process. There were not enough producers of white goods in the UK for a feasible benchmarking study. The development of most of the mass-market consumer electronics products we investigated occurred almost exclusively in East Asia. However, *high-end audio* products were an exception to this; there were a reasonable numbers of high-end audio companies in each region, and so this sector was selected for the study.

Audio products were considered suitable for a number of reasons. As mentioned previously, because we were interested in the *organization* of the new product development process, products had to be sufficiently complex to require a range of specialist skills to develop and produce them. The development of audio products typically involves electronics, mechanical, and acoustic engineers as well as industrial designers and, in some cases, software engineers. There are a substantial number of bought-in parts, so there is scope to investigate supplier involvement in the development process. Audio products are relatively complex and manufactured in reasonable volumes, and can therefore reveal design-for-manufacture issues.

The identification of companies in each of the three regions was undertaken via contacts with trade associations, address lists from trade fairs and other sources, discussions with industry observers and examination of products in the marketplace. Companies with 50 employees or more who developed and manufactured high end audio products (amplifiers, CD players and loudspeakers) were targeted. Initial visits and interviews were conducted with 38 companies, of which 21 agreed to take part in the full benchmarking study. Detailed information was obtained on 31 new product development projects, as shown in Table 2.

Table 2: Companies and Projects

	Total Number of Companies interviewed	Number of companies (benchmarking data)	Number of NPD projects
Japan	8	3	4
UK	14	7	10
North America	16	11	17
Total	38	21	31

All companies who provided benchmarking data were visited at least twice, and completed two types of questionnaire – one which covered basic information about the company (or business unit) as a whole, and which related to a specific, recently completed new product

development project. Each company provided data on one or two projects. The results are presented under the following headings:

- Product Development Performance (product desirability and reliability, process speed and efficiency)
- Company Characteristics
- Project Management
- Industry Structures

We shall consider each of these in turn.

Product Development Performance

One of the challenges in assessing companies' prowess at creating new products is that success can be measured according to many different criteria. First, there are the *products* themselves - their aesthetics, technical performance, price and value. Secondly, there are the *processes* that create products – development lead times, or time to market; efficiency (the resources, such as labour and materials) which went into the creation of the product, and so on. Criteria such as aesthetics may be balanced against other considerations such as the need to produce products consistently and in volume. Thirdly, there are the outcomes of the process for the company. Did the product make money? Was it a loss leader, which established the company in a new market? Did it yield valuable lessons and allow the firm to develop new capabilities that can yield advantages in the future?

Table 3 shows the performance measures employed in the study. The characteristics of the product – desirability, functionality and reliability – were gauged by actual sales against target, product awards and warranty claims.

Process measures covered three main areas: speed, efficiency and control. 'Speed' referred to development lead times. 'Efficiency' was measured three indicators – engineering efficiency, cost, and the smoothness with which the product was handed over to manufacturing. 'Control' covered three indicators of planning accuracy – schedule and cost deviations and numbers of changes to the original requirements. Other outcomes included margins, revenues, and self-reported evaluations of success of the project.

Table 3: Summary of Key Performance Measures

Key Performance Area	Key Attributes	Measures Taken
Product	Desirability Functionality Reliability	Sales against target Awards in the trade press Warranty claims
Process	Speed	Concept to Production time (weeks)
	Efficiency	Engineering hours per new part Cost per new part in £ Time for productivity to settle Time for quality levels to settle
	Control	Percentage deviation from schedule Actual vs forecast product costs Late changes in requirements
Other outcomes	Earning capacity of product	Product cost as % of RRP Development cost as % of gross profit Self-reported success

Tables 4, 5, and 6 and Figures 1 and 2 summarise the position of each country on the three sets of performance measures.

Product Performance

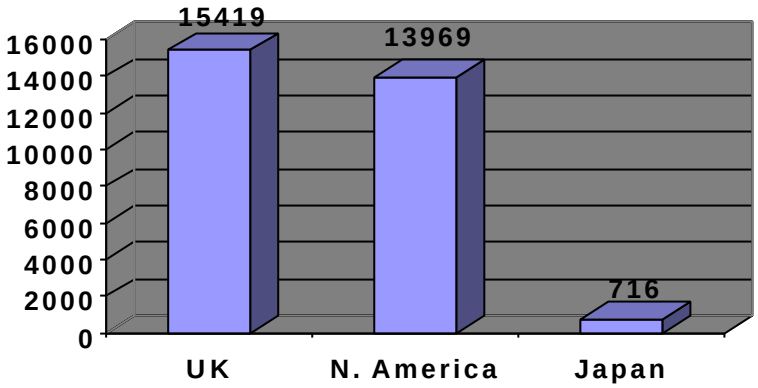
In terms of sales against forecast, products in all three regions exceeded their sales forecasts quite substantially - in the order of 20-30 percent. At one level this is indicative of the market acceptance of the product, but clearly any deviation from forecast also suggests shortfalls in processes of reading the market and of product planning. The Japanese products exceeded sales forecasts by around 22 per cent; UK and US firms did rather better, or worse, depending how one looks at it, with sales approximately 30 per cent ahead of forecast.

Table 4: Product Performance

	Japan	UK	N. America
Deviation between Forecast and Actual Sales	+21.7%	+29.8%	+28.7%
Percentage of products winning an award	75%	33%	41%
Average number of awards per product	2.7	1.0	1.4
Number of warranty claims (ppm)	716	15,419	13,969

The Japanese products gained the most recognition in the specialist audio press, with 75 per cent of products receiving awards, compared to 30-40 per cent for the Western companies. Absolute numbers of product awards were also higher for Japan.

Figure 1: Warranty Claims, in PPM

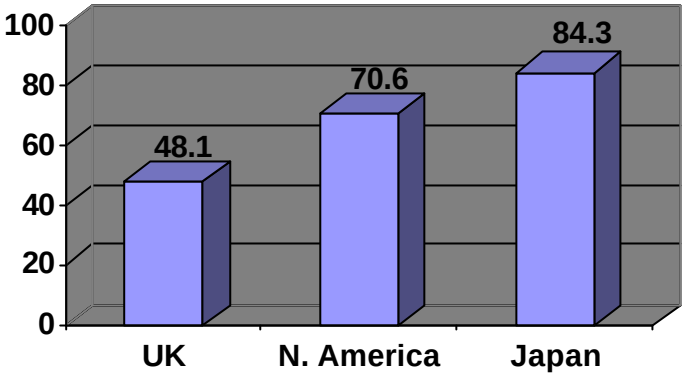


The final measure of product performance was the number of claims made under warranty. Clearly not all such claims have their genesis in poor product design – returns may be due to errors by users, faults caused by carelessness in shipping and so on, although to some extent these too can be designed out of the system. Such limitations aside, warranty claims are indicative of the reliability of products when in the hands of users, and are likely to be particularly sensitive to design–for-manufacture effort. As Figure 1 shows, Japanese products showed much lower return rates than products from the UK or the US, with a differential of approximately 20:1. The reasons behind this large differential will be discussed later.

Process Performance: Speed

Development lead times are frequently used as a measure of product development performance, and Japanese companies are renowned for their short development lead times and product life cycles, particularly in the automotive industry. Contrary to this stereotype, Figure 2 shows average development lead times to be *longer* in Japan than in the West, at 84 weeks compared to 48 in the UK, and 70 in North America.

Figure 2: Development Leadtimes, in Weeks



The short lead times of UK companies are striking, but so are the much higher levels of warranty claims, noted in Figure 1. Thus the short lead times may be symptomatic of 'short cuts' in the earlier stages of the development process, which manifest themselves as problems later.

Process Performance: Efficiency

The measures of process efficiency are concerned with how many hours, and how much money, is required to create a new product. Unlike Clark and Fujimoto's influential study of the automotive industry, this study found Japanese firms to be *less* efficient than their UK and North American counterparts on the two main measures of development productivity, namely engineering hours per new component part and development cost per new component part (Table 5).

Table 5: Process Performance: Efficiency

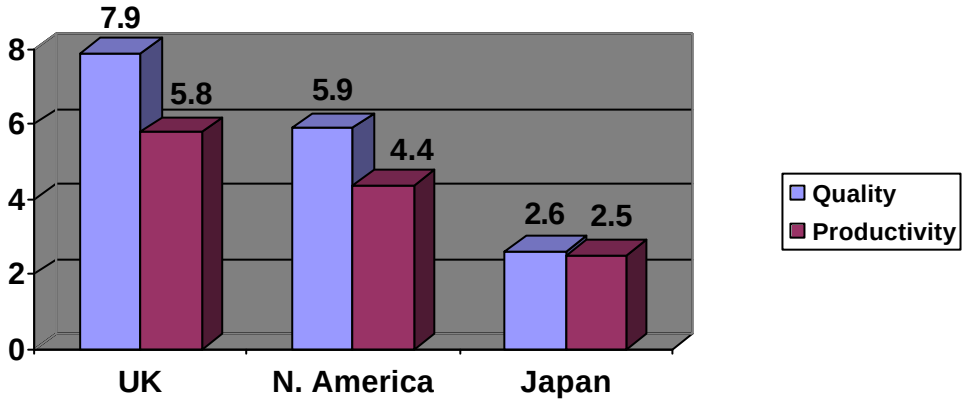
	Japan	UK	N. America
Number of engineering hours per new part	106.1	19.5	41.1
Development cost per new part (in £)	£3,723	£1,057	£1,846

The measure of development efficiency/productivity was derived by taking total engineering hours (corrected for any development work which was sub-contracted out) in relation to the number of *new* component parts in the product. New component parts were used as a proxy for product *complexity* and *novelty*. This was based on two assumptions. The first was that more complex products have a higher number of parts, and will therefore require more

development effort. Comparisons therefore need to take this into account. The second assumption was that more novel products require more development effort than do less novel ones. In the case of electronics products, the number of new component parts in a product was used as an indicator of its novelty.

The measure of development cost efficiency is based on a similar calculation, but is based on the money spent to create the product (total development cost), not the development hours consumed. Development cost and development hours clearly track each other quite closely, with Japanese companies spending two and a half times the engineering hours per part of their North American counterparts, and more than five times the hours of the UK companies.

Figure 3: Time for Production to Settle (Weeks)



A further indicator of development efficiency is the speed with which manufacturing settles down following the launch of new product. Clearly, reduced productivity or quality problems in manufacturing can have a significant impact on both costs and the speed with which products reach the market.

Figure 3 compares the three regions on the time it takes for productivity and quality to settle to normal levels. On both measures, Japanese projects stand out from their UK and North American counterparts. Japanese products achieved normal levels of quality and productivity within two to three weeks of the start of mass production, and, as we saw in Figure 1, settled at an external defect rate of approximately 700 parts per million. UK and North American products typically took two to three times as long for production to settle down, and suffered a final external defect rate some 20 times higher than that of the Japanese products. Moreover,

the Japanese defect rate was inflated by the inclusion of a product that had been engineered and developed in Japan, but was manufactured in Europe. According to the company, this had significantly increased problems in manufacturing.

It is clear that a number of factors lie behind these patterns of manufacturing performance. The Japanese companies paid great attention to manufacturability issues, and in one case nearly 50 percent of the development hours on the project were consumed by manufacturing engineering. This emphasis may be partly attributable to the higher production volumes of the Japanese producers, which mean that problems in manufacturing carry far greater cost implications. In addition, in the Japanese companies the Engineering and Manufacturing functions tended to be administratively and geographically separate; in some instances subcontractors were used to manufacture the products. Intuitively, one would expect this to aggravate manufacturing problems, but this separation also forces very disciplined interaction between Manufacturing and Development – the combination of higher volumes and geographical separation left little room for a mentality of 'We can sort it out later'.

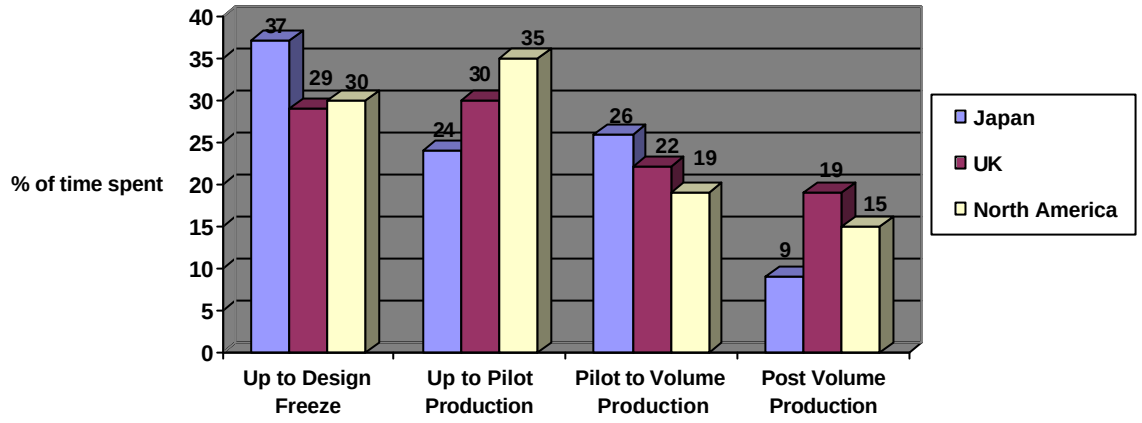
In contrast, in the Western firms Development and Production tended to be on the same site, fostering an ethos in which manufacturing issues were sometimes resolved during the early stages of production itself, rather than before volume production commenced. One US firm in the study had traditionally operated with Manufacturing and Engineering adjacent to each other in the same building. Manufacturing had then relocated to a lower cost location some distance from the original site. The people at the new facility were younger, less experienced and more transient than the staff at the old site. This had an immediate impact in two ways. The first impact was attributable to the loss of the tacit knowledge of the previous workforce. Development found that there was a knock-on effect on product design, which suddenly had to be much more standardized and 'fool-proof' from a manufacturing point of view. Secondly, it became much more difficult to develop and maintain a rapport and common understanding between Manufacturing and Engineering, which in turn impeded problem-solving. In this case, the disadvantages posed by geographical isolation could be offset by the opportunities offered by technologies such as video-conferencing, but only partially so.

Another aspect to this is the distribution of development hours between the various stages of the development process. We sought information on this by considering the development process as comprising four main periods of time:

1. From initial concept up to the freeze of the basic design
2. Design freeze to pilot production
3. Pilot production to volume production
4. The first six months of volume production.

The distribution of development time across these four periods is shown in Figure 4.

Figure 4: Distribution of Development Effort



The Japanese pattern shows that greater time is spent 'upfront' in the product planning and concept development stages. This is consistent with other reports of Japanese decision-making style, in which relatively large amounts of time are spent in planning, leading to smoother implementation later. Japanese effort is also relatively high between pilot and volume production. From the interviews we conducted it was clear that the Japanese companies extracted a tremendous amount of learning from their pilot production runs, and in the light of this worked hard to make adjustments to their manufacturing processes so that volume production could commence rapidly and smoothly – so-called "vertical start-up". In contrast, the US and UK firms spent less development time upfront and on pilot production, but a lot of time on the detailed design. As a consequence, more time then had to be spent resolving problems after production commenced. A production manager in one of the UK companies commented:

> "We haven't thought through the whole thing as a process…We're always late ... we don't identify what is existing and what is new ... you add all the problems together and that's how long it [development] takes".

He went on to describe how his company typically recruited people who were very bright, but who then tended to focus on their particular areas to the neglect of the integrity of the whole

system. One consequence of this, he recounted with some frustration, was that he knew that of every 100 units shipped out, six would come back.

Process Performance: Control

Three measures of process consistency and control were used in the study – the deviation of actual progress from the original schedule; the deviation of actual product costs (per unit) from the target costs, and the number of late changes in the product requirements. These measures of deviation partly indicate the quality of the planning process, but also indicate a company's ability to rapidly solve problems during the development process. Thus, a low deviation in terms of the original project schedule may indicate that the project was meticulously planned in the first place, and that most contingencies were anticipated. It may also indicate that the company was able to deal with problems quickly and effectively, therefore enabling projects to keep to the schedule (Table 6).

Table 6: Process Performance: Control and Consistency

	Japan	**UK**	**N. America**
Percentage Deviation from Schedule	+15.5%	+4.6%	+15.4%
Actual vs Forecast Costs	+0.9%	+4.3%	+3.1%
Late changes in requirements	4.8	1.1	0.8

North American and Japanese projects ran later than UK projects, with actual lead times approximately 15 percent longer than those anticipated. Although UK projects were relatively punctual, their high levels of post-production problems imply that this may be because potential difficulties were ignored earlier in the process. In all three countries actual costs ran ahead of forecast, with Japanese companies showing the best conformance to target costs and UK companies showing the worst. Companies' positions on this measure may be linked to differences in lead times; the longer Japanese lead times may be a result of greater efforts to achieve the desired product performance levels within the original cost targets. It may also be that the more specialist brand identity of many of the Western producers allowed them to protect margins in the face of cost overruns by increasing prices. Western firms may thus trade product costs against lead times.

Late changes in product requirements were much higher in Japan than in the West, with projects suffering an average of five changes in requirements late in the development process. At first sight, this contradicts the accepted wisdom about Japan, namely that meticulous planning up front leads to greater stability later in the development process. One explanation is that the sales of the Japanese companies are typically spread across many markets, so Japanese product developers often receive market intelligence from several sales regions. These multiple market requirements require substantial efforts to reconcile into coherent product requirements, and thereby take longer to stabilize. This was particularly true of products that were targeted at both Europe and the US, where tastes were very different; one Japanese company described the difficulty of reconciling competing product requirements from these two regions. In contrast, Western producers generally targeted their products at audiophile niches and pursued a more design-led approach compared to their Japanese counterparts. The ethos in many of the Western companies was to produce products that conformed to pure audiophile values and then push these out onto the market. When asked about his company's marketing strategy an interviewee in a UK company commented:

> "If the Managing Director wants it in his living room, we make it."

Other Outcomes

The final set of measures we shall consider concern other outcomes of the development process, in particular the performance of each product and project in financial terms. This was assessed in three ways. The first was product cost as a percentage of the retail price of the product, which is an indicator of the gross margin on each unit. This is a function of the price the product is able to command in the market (an indicator of desirability) and the price at which it can be produced (an indicator of efficiency). The second measure is development cost as a percentage of the gross profit earned by the product, which is a measure of 'return' on development 'investment'. Finally, we asked companies to subjectively assess the success of the project. These results are shown in Table 7.

Japanese product costs as a percentage of recommended retail price are slightly lower than those of their Western counterparts, indicating that the Japanese firms are making slightly better gross profits per unit than UK or North American firms, before distribution costs are taken into account. UK companies recouped their development costs most quickly.

Table 7: Other Outcomes

	Japan	UK	N. America
Product Cost as % of RRP	21.2%	22.6%	25.9%
Development Cost as % of Gross Profit - First 6 months	19.5%	15.2%	21.7%
Self-reported success (1=unsuccessful, 5=highly successful)	4.2	4.1	4.1

Gross profits for the UK products in the six months following launch were six or seven times greater than development costs, compared to five times greater in the case of Japanese and North American products. Interestingly, despite the substantial differences on our objective measures of performance, the companies' subjective assessments of their projects were remarkably similar – a testament to the limitations of self-reports.

The performance data clearly challenge the idea of across-the-board Japanese development superiority. However, it is also clear that, intentionally or otherwise, there are trade-offs taking place between different elements of development performance, particularly between measures such as of development speed and efficiency and attributes such as manufacturability and product costs. These trade-offs vary from region to region with the Japanese companies favouring early problem-solving (but keeping the door open for changes in product requirements for longer), and paying close attention to product costs and manufacturability. UK companies, in contrast, develop products very rapidly and stick to the schedule relatively well, but have more quality problems and have to devote more time to problem solving later in the process.

Company Characteristics

Although Japan is best known for mass market, rather than high-end, audio products many of the major Japanese electronics corporations also offer products at the high end of the sector. Partly due to the sampling method employed by the study, which sought to select products in a similar price range, the recommended price of the products was remarkably similar in all three regions, varying from £2,200 to £2,800 per unit. Product life cycles for these products were also similar at approximately four years in all three regions.

There are some small, independent audio companies in Japan although in recent years several of these have been struggling and some have been acquired by non-Japanese companies. The high-end operations of all the major Japanese corporations in the study were organized into relatively self-contained specialist divisions. These divisions were small in relation to the size of their parent companies, and were in many ways comparable to the stand alone companies of North America and UK. Even so, the average turnover of the Japanese high-end divisions was approximately 14 times higher than in the stand-alone companies of North America and 30 times higher than in the UK (Table 8).

Table 8: Company Characteristics

	Japan	UK	N. America
Annual sales (average for last three years -£)	£378,810,360	£12,682,843	£28,028,800
Number of employees (averaged over last three years)	1,082	115	174
Profit margins (averaged over last three years)	0.9%	5.4%	6.5%
Mean annual growth (average over last three years)	+2.5%	+9.1%	+15.4%
Percentage of sales exported	59.2%	69.5%	43.4%

The North American companies showed the strongest growth and the highest profit margins, reflecting the buoyancy of the North American market at the end of the 1990s. A number of the Japanese companies in the study had been making a loss, and the average profit margin on sales for Japan was less than one per cent. UK firms showed the highest export ratio of the three countries, with nearly 70 per cent of output exported.

Any individual development project is embedded in a wider innovation system both within an individual company and within a national context. Such systems reflect the resources that are put into innovation, and the structures within which innovative activity is enacted. The scale of product development activity in the companies in each region is shown in Table 9.

The relatively small scale of operations in the UK can clearly be seen in Table 8, particularly in relation to the Japanese companies with their large development departments, substantial portfolios of projects and intense patenting activity. However, individual Japanese development engineers actually have less severe loadings than their Western counterparts. There is less than one project per member of development staff in Japan compared to two in

the UK and three in North America. Loading development staff up with multiple projects can lead to competing priorities, with the associated dangers of curtailed problem solving and schedule slippage, particularly on projects that are not seen as strategically important.

Table 9: New Product Development Patterns

	Japan	UK	N. America
Number of people in development	208	12	19
Number of development projects started in last three years	162	25	16
Average number of patents per company (registered in last three years)	430.0	0.9	13.9
Development projects started per member of development staff	0.7	1.8	3.0
R&D expenditure as a % of sales	5.7%	4.8%	5.7%
% of sales from products launched in last two years	84.7%	68.8%	44.5%

Expenditure on R&D as a percentage of sales is identical for Japan and the North America, with the UK lagging approximately one percentage point behind the other two regions. Japanese companies display more aggressive, innovation-led strategies with 85 per cent of sales attributable to products launched in the last two years - 20 per cent higher than in the UK and nearly double the figure of the North America.

Project Management

Table 9 shows the characteristics of the project teams in the three areas. Here, the general picture is of uniformity, rather than variety, across the three regions. Development teams were small and tight and involved only a relatively restricted number of people, typically four to seven depending on the stage of the development process. Japanese companies tended to involve slightly more people at the early stages of the process, and fewer in the later stages.

The number of projects that each team member was servicing simultaneously was lower in Japan (at three to four 'live' projects per team member, compared to five or six in the UK and North America). The difference in size between the Japanese companies and their Western counterparts is significant here. Smaller companies, with narrower resource bases, of necessity have to have most people involved in most projects. Thus, although Japanese companies as a whole had wide portfolios of projects, Japanese development teams were able to devote their attention to projects in a more focused way than could many Western development teams.

Table 10: Project Team Characteristics

	Japan	UK	N. America
Number of people involved in early concept	7.0	5.5	4.4
Number of members in the core team	3.9	5.9	4.3
Number of members in the wider team	8.2	10.0	9.2
Number of live projects per team member	3.3	5.6	6.2
Average years of experience in company	13.3	8.6	7.1
Average years of experience in the industry	14.0	12.2	11.6

Long term employment, which has been characteristic of the major Japanese corporations, was reflected in the number of years of experience of development engineers with their companies, Japan's levels being double those of the West. However, although Western engineers had less company-specific experience than their Japanese counterparts, the length of their experience in the audio *industry* was not so different. The value of company-specific, compared to industry-specific, experience was a matter of debate in many companies. Labour turnover amongst development engineers means the loss of important tacit knowledge, but may also aid creativity through the injection of fresh ideas and perspectives.

Supplier Involvement

The benefits of supplier involvement in the development process have been forcibly extolled in the literature and Clark and Fujimoto concluded that this was a major source of advantage in Japanese automotive product development. In this study, the characteristics of the supply bases in the three regions were remarkably consistent in terms of the number of suppliers (approximately 20 to 30 in all cases), with Japan and North America showing longer track records of working with their major suppliers. In some of the Japanese companies, key suppliers were divisions of the same company, a phenomenon that was absent in the West.

It was difficult to ascertain how great an advantage such 'in-house' suppliers represented, or indeed if it was an advantage at all. Certainly, close relationships help with the exchange of tacit or commercially sensitive information. The percentage of suppliers located overseas (with whom close relations were clearly difficult) was much higher for the UK and North America than for Japan.

Table 11: Supplier involvement

	Japan	UK	N.America
Number of suppliers	27	26	19
Number of previous projects involving main supplier	13	5	10
% of suppliers overseas	20.0%	38.7%	41.5%
% of development work conducted in-house	87.4%	93.5%	88.3%

The percentage of overseas suppliers to Japanese companies was inflated by the presence of some manufacturing outside Japan. There were some cases of offshore manufacturing amongst the North American companies, but in the UK virtually every facility was stand alone, conducting both development and production in the UK.

Industry Structures

The question with which this research began was 'What are the characteristics of high performing product development systems?' Before too long, another question was more salient: 'Why are nearly all the electronics companies in Japan relatively large and nearly all the UK and North American ones relatively small?'

In the case of some consumer electronics products – televisions are the prime example – Western producers have progressively given up ground to Japanese producers, up to the point of virtual extinction. In other product areas (such as video recorders) the initial invention occurred in the West, but commercialization was largely the prerogative of Japanese companies. High end audio is somewhat anomalous, in that the strong brands, at least in the eyes of audiophiles, are not Japanese. Indeed, many audiophiles are scornful of Japanese products (in much the same way that British motorcyclists used to scorn Japanese motorcycles in the 1960's). Many British and US audio products sell well in the Japanese audiophile market.

This raises several interesting questions. Will the history of the audio industry be similar to that of the motorcycle and TV industries, with the major Western producers retreating before a Japanese onslaught? If so, the majority of non-Japanese companies in this study may be

viewed as specialized players, playing a defensive strategy by serving market niches too small or inaccessible to be of interest to the Japanese giants.

The other interpretation is that Japanese and Western companies started out in high-end audio at the same time but followed different trajectories. Most commentators agree that the trigger for the launch of the hi-fi market was the 33rpm long-playing record, which provided a high quality reproduction medium. In the West the main interest in taking up the possibilities offered by this technology came from musical purists and hobbyists, who, frustrated by what they perceived to be the inadequacies of existing products, built systems for their own use, but then found a wider market for these products. The ethos that provided the initial impetus for these products is still very much in evidence in many of these companies today – a belief that mainstream products do not offer the best sound quality, but that their own products do. What is interesting is that in the West these companies have rarely grown into substantial corporations, though there are one or two exceptions to this in the US.

Japan also has its share of small independent audio companies, but the lion's share of output comes from the high-end divisions of the major companies, who typically produce not only audio products but a range of other electronics products as well – TVs, VCRs, personal computers and so on. Although we found a strong audiophile mentality in the high-end audio divisions of many of these companies, their modus operandi was quite different from the small entrepreneurial Western firms in the study. The Japanese firms typically possessed significant international marketing functions who attempted gather and synthesize information from the (often diffuse) markets for the company's products around the world, and to integrate this information into a coherent set of specifications. This was one of the key differences between the Japanese and Western models. The scale of the Japanese electronics corporations also placed them in a much stronger position to develop and exploit new technologies, or to integrate existing ones (eg. Web TV and desktop entertainment) both of which represent a convergence between computing and home entertainment. In contrast, the Western producers were largely confined to pushing at the edges of the performance envelope using existing technology.

Conclusions

This report has explored a number of issues surrounding new product development within a particular industry. The strength of the conclusions is inevitably limited by the small number of observations, but the findings raise important questions about the interplay between new product development practice, performance and corporate and national context.

First, in the international comparisons, the UK firms performed well on measures of speed and efficiency during the development cycle itself, but appeared to pay a price for this in terms of post launch problems. It may be that new product development performance may be better conceived as a 'profile', with individual projects high on some indices and low on others, rather than as a unitary entity.

Secondly, the focus on a single product area throws differences in national and organizational context into sharp relief. There were many similarities in how companies in different countries went about the task of developing high-end audio products, particularly in terms of the composition and size of the development teams that they used. However, there were differences too. Cumulative company-specific experience in Japanese teams was much higher than in Western ones, due to the continuing tradition of long term employment in Japan. This undoubtedly carries benefits in terms of the capture and retention of tacit knowledge and assists in transferring learning from project to project. However, it also poses greater obstacles to radical innovation relative to the more fluid Western model, in which labour mobility across firms and across sectors is more commonplace. Supplier involvement in development, despite the rhetoric in the literature, was generally low in all companies, though less so in Japan. Those companies who were targeting their products at a mass market showed noticeable differences in their product strategies from those focusing exclusively on the audiophile market. Both technology push and market pull strategies were in evidence, both successful in their own ways.

Thirdly, in contrast to Japanese superiority in innovative performance reported in the 1980s, at least in the automotive industry, we see a much more mixed picture. On the measures of manufacturing performance the Japanese companies in this study outperformed their Western counterparts by a significant margin; their products also came in much closer to their original cost targets. However, on most measures of development productivity and speed the Japanese

lagged their Western competitors by substantial margins. Perhaps this is inevitable given a product strategy emphasizing value and reliability. Again, this points to a need to conceive of the product development process as one that is beset by dilemmas and trade offs – which different companies, in different contexts, resolve in different ways.

Fourthly, the recession in Japan was clearly taking its toll, and the Japanese companies showed poor financial performance compared to their Western counterparts. This problem was particularly acute for those Japanese companies that did not have proprietary technology. There were signs of a 'hollowing out' of development and manufacturing capabilities in Japan as operations moved off-shore to lower cost locations. These difficulties have also been manifested by a number of foreign take-overs of Japanese audio companies.

Finally, there is the question of the link between company specific patterns of new product development and national innovation systems. This study began as a comparison between Japanese and Western practice in individual companies, and indeed individual new product development projects. However, it soon became clear that there were distinct patterns found in each country. One very obvious example of this was company size. Virtually all the Western high end audio firms were small, entrepreneurial companies, but most of the Japanese firms were divisions of large corporations. Although many staff were audio enthusiasts in all regions, a 'hobbyist' mentality was strong in the West.

In many respects these patterns reflect typical Western/Japanese approaches to innovation. In Japan the norm for the organization of innovation in many industries has been a three or four way division of labour. Large, central R&D facilities look after basic research; engineering and development facilities focus on the commercialisation of the ideas emerging from the basic research; manufacturing and sales divisions handle the production and distribution of the product once it has been developed. This is very much a corporatist, inclusive approach.

In general, UK and North American firms were small, entrepreneurial start ups, often centred around particular seedbeds, such as universities or recording studios. These firms produced for specific niches, and developed and produced products with strong brand names that were focused on restricted 'audiophile' markets. Substantial growth was not, in general, a significant objective for these firms. Clearly, such factors significantly shape the manner in

which innovative activities are conducted, and further underline the need to identify issues of context and contingency when interpreting new product development practices.

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