Global Online Trading System (GoTrade)

Gunnar Cuevas, Matthew Dale, Asmaa Idrisu, Jonathan Lee, *Students, George Mason University*. George Donohue, Andy Loerch, *Faculty Advisors*. Michael Parodi, *Sponsor (Edgewood Asset Management, LLC.)*

Abstract— **Our project addresses the following problem: no platform exists allowing investors the ability to trade on international markets from a single location. The twelve leading online investment programs (by trade volume) provide access to U.S. security exchanges only. A second, related problem is the lack of a fully automated investment portal availing itself of new technologies. Many of these technologies are utilized by leading security exchanges.**

The electronic communications network (ECN) provides a widely used example of important new technology. ECN's allow both institutional and individual investors a network with automatic matching of buy and sell orders, excising any third party. Currently, NASDAQ ECNs handle more than 40% of trade volume, a number expected to increase. These streamlined trades show evidence of reduced fees resulting from lowered transaction costs. Also with ECN's, we see initial signs of increased individual order matching speed. This evidence demonstrates the good chances for developing a global, fully automated trading system.

The GoTrade team objective is to develop the initial design, simulate, and conduct analysis of an online trading system that provides global market access to any potential investor with an internet connection. The team plans to design a system that is secure, fully automated, and situated to optimize connectivity to global markets based upon expected user population distributions and current global internet infrastructure. To keep the project manageable, we limit our research to the NASDAQ, London, and Hong Kong Exchanges.

We plan to build a model of our system in Arena and test the performance versus cost of various design alternatives. The factors most important to our system are performance and cost. This determination was made after survey elicitation, interviews with online investors, and consultations with our sponsor and technical advisors. The trade-off analysis associated with these measures will aid in determining the final system configuration.

I. INTRODUCTION

THe implementation of electronic communication networks (ECN) by leading exchanges around the world marks a significant departure from traditional trading mechanisms. These computerized networks quickly match buy and sell orders from investors all over the world and operate at all hours of the day. These advancements provide innovative firms the ability to develop systems that grant their customers direct access to the market without having to go through a variety of third parties (such as a specialized or market maker) to execute their orders.

This paper presents a feasibility study for implementing a system that fully automates the online trading process by utilizing ECNs. An analysis of current online trading platforms, thorough research of IT and networking hardware and software components, interviews with network security experts, and consultations with Edgewood Management as well as other industry experts regarding financial methods and trade regulations led to the system design included in this report. Alternative designs were generated as well and are primarily a function of user capacity.

This paper provides an overview of the initial design, simulation, and analysis of an online trading system that provides global market access to any potential investor with an internet connection. Due to time constraints and a plethora of issues related to exchange connectivity, we limit our system to connections with the NASDAQ, London, and Hong Kong exchanges.

A. Statement of Need

The reach of the today's online trading technology is not sufficient for the current growing demand from investors coming not only from the U.S. and Europe but also from many developing economies. Although many online trading services exist, not one offers fully automated trading services and direct access to global security exchanges. Advanced technologies are being deployed at many world exchanges that are changing the way trade orders are matched and processed. Existing methods and the firms that have benefited from are growing antiquated in light of these new developments. Global internet infrastructure can now support high speed connectivity from almost anywhere in the world, yet not one low-entrance-fee trading service has optimized system locations that would enable investors to directly access many international exchanges with minimal trade routing speeds

There is a need for a centralized, secure, one stop investment portal that enables international investors to access the majority of markets around the world.

II. SYSTEM DESCRIPTION

A.. Current System Diagram

Below is a diagram depicting a top level view of how a trade is executed using existing technologies and services. The main purpose of this diagram is to show the multiple steps and transaction fees associated with conducting and routing the majority of trades to both domestic and foreign markets (depending upon the user location).

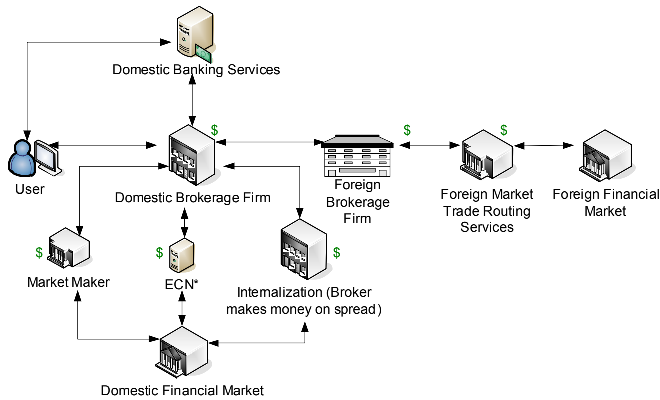

Figure 1. Current Systems Diagram

Major weaknesses of the above model (figure 1) include the following: Market maker and internalization functions are performed by individuals, requiring long periods of time to clear orders. In some cases the time to execute an order can take up to twenty four hours. This can result in significant differences in the sale price versus that quoted when placing an order. Another major weakness involves the multiple fees associated with purchasing a security on a foreign market. Domestic and international brokerage firms charge a fee, making this process much more costly.

B. Proposed Systems Diagram:

The following diagram (figure 2) represents a top level view of the proposed GoTrade system design. Features that address the current system design and objectives for GoTrade system design are included below the diagram.

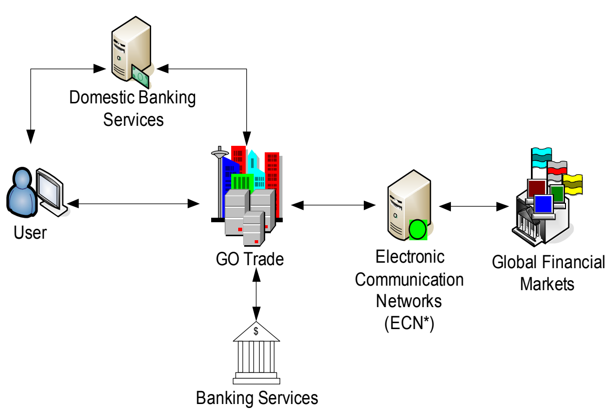

Figure 2. Proposed Solution: Top Level GoTrade Diagram

Some important features of the GoTrade system include the following: By using a Virtual Private Network (VPN) the system is capable of integrating all necessary functions from one location; Encryption algorithms can secure the system to communicate safely with users, banking services, GoTrade locations, and Electronic Communication Networks (ECN); Fully automated brokerage, trade execution, and banking services; Secure and confident environment with direct access to global markets for any investor with an internet connection.

C. External Systems:

The following external systems diagram (figure 3) shows a basic view of how the GoTrade system interacts with external systems. Each primary function is broken down to many sublevels that detail all necessary functionality of the system. The sublevel diagrams were generated in CORE and are far too extensive too include in this report. The major external systems are the user's domestic banking system, the banking system for GoTrade, and the electronic communication networks (ECNs).

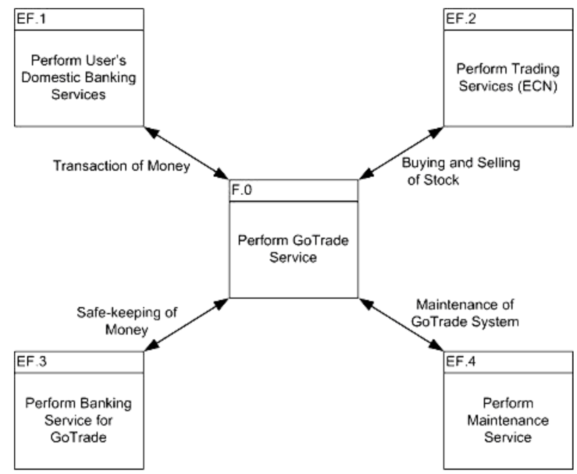

Figure 3, External Systems Condensed Diagram

Primary inputs enter the box below from the left and following clockwise, are the controls, outputs, and mechanisms to the parent function F.0 (Perform GoTrade Services). This is shown below in figure 4.

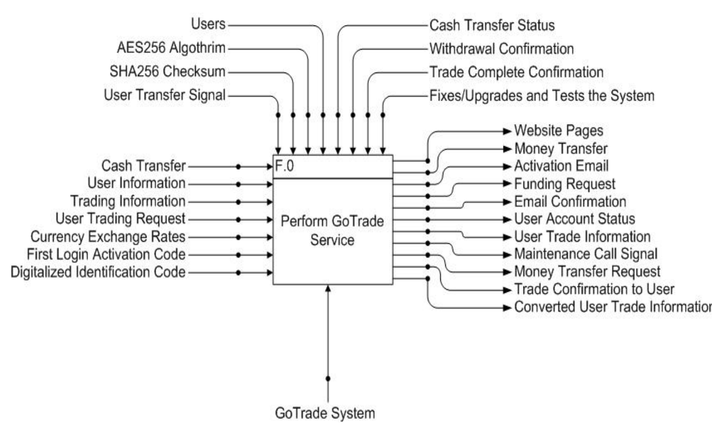

Figure 4. F.O Perform GoTrade Service Condensed Diagram

An example sub-sub- function F.3 (Perform Trade Routing Services is shown in figure 5 below: This diagram shows the flow of some inputs (currency exchange rates and trading information) to outputs (i.e. user trade information) from above through the sub-function F.3. Generating these detailed diagrams was compulsory in determining necessary hardware and software configurations as well as the inputs needed for a proper simulation and the outputs used for a trade-off analysis.

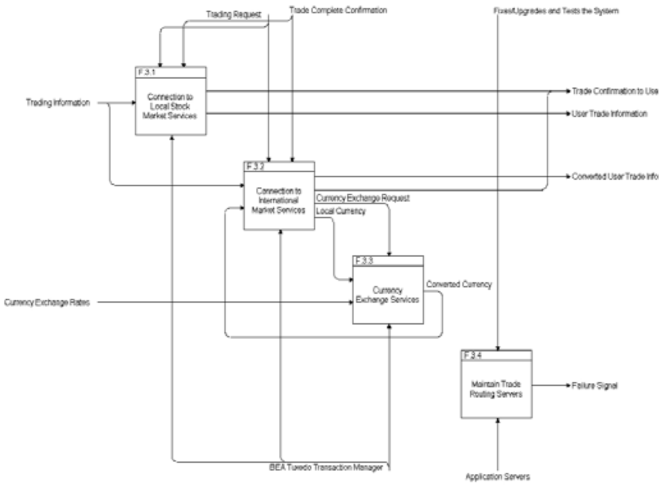

Figure 5. F.3 (Perform Trade Routing Services Diagram)

D. Functional Architecture:

A simplified view of the functional decomposition is shown in figure 6. This figure shows the basic interactions between the functions within the GoTrade system.

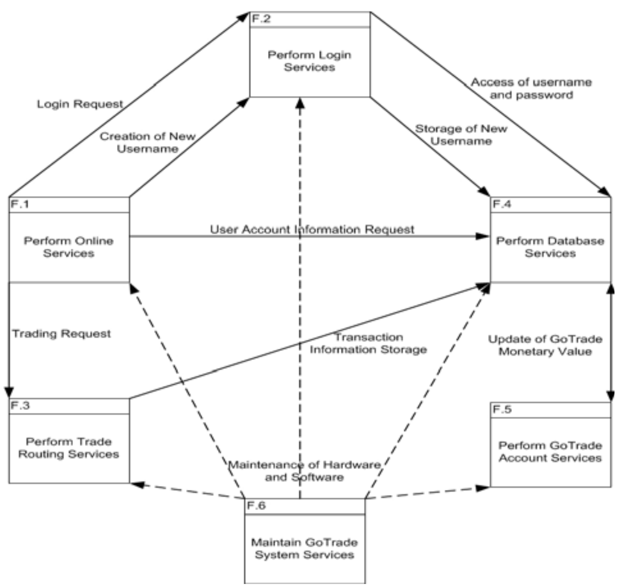

Figure 6. F.0 Basic Functional Decomposition

E. Generic Physical Architecture:

Physical components necessary for implementation of the GoTrade system are extensive, but a top level view can show the major components compulsory to the design. Servers, storage, networking hardware, and back-up form the umbrella from which all other necessary hardware components can be classified. This is shown in figure 7.

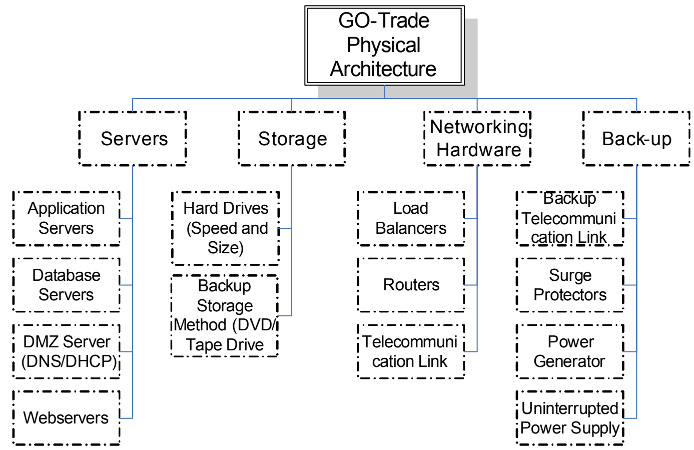

Figure 7. GoTrade Physical Architecture

F. Operational Architecture:

For every function of the GoTrade system, the operational architecture was developed as well. Often is the case that interactions between sub-functions and the data necessitating these functions require logical arguments to perform properly. By defining these logical interactions and developing the GoTrade system operational architecture, the team was able to model the functionality, activities, system behavior, operational elements, and information flows required to accomplish the desired system functionality. An example operational architecture diagram for the sub-function F.1 (Perform Online Services) is shown in figure 8.

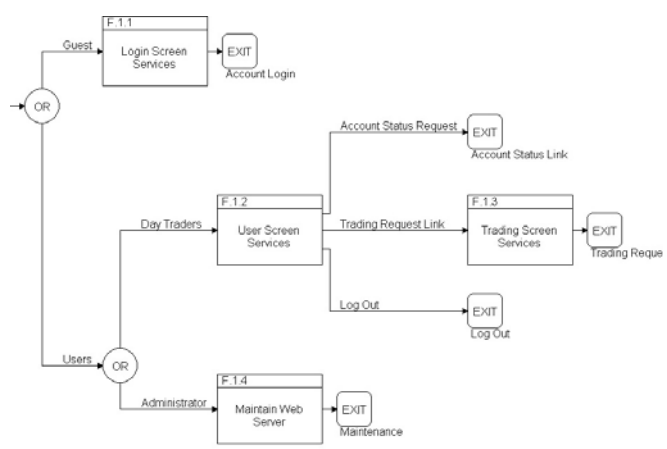

Figure 8. F.1 (Perform Online Services) Operational Architecture

III. VALUE HIERARCHY

A. Methodology

SPSS Answer tree statistical software tool was used to generate decision trees from data which was collected using surveys the team distributed to 55 people with and without online trading experience. The CHAID (Chi-Square Automatic Interaction Detection) algorithm was used to determine the splits of the tree; CHAID considers all possible splits of all possible predictor (input) variables and selects the one (split and variable) having the smallest p-value associated with the appropriate statistical test, if that p-value is small enough. SPSS identified three main variables as having the lowest p-values and thus the variable most relevant to stakeholders in the system. Namely; 1) The cost of using the system; investors would prefer to be charged less to invest within and outside the US. 2) Performance; the speed, security, accuracy, and reliability of the system was a major concern.

B. Utility Function / Value Hierarchy Diagram

From the methodology described above, The GoTrade system value hierarchy (figure 9) was constructed using weights assigned to certain parts of the system based on their level of importance to the stakeholders. The first level shows that system performance and cost are the most important features of the GoTrade system.

Each top level feature is further broken down into two or three levels. To maximize the performance of the system, it is necessary to maximize system reliability and availability, and minimizing operational time. All the weights of the top level features add up to one, and all sub features of each top level feature also add up to one.

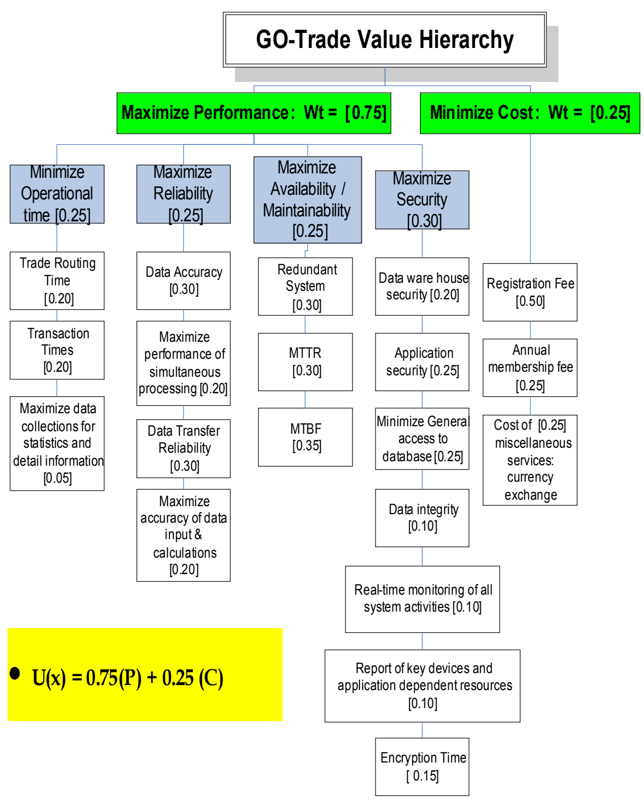

Figure 9. GoTrade Value Hierarchy Diagram

C. Utility Function

Using the weights obtained from the value hierarchy, the following utility function was created that allowed the team to analyze the "utility" of the design alternatives on an equivalent scale. The weights associated with each of our top 2 objectives were determined using an Analytical Hierarchy Process (AHP) approach.

Based on the 2 objectives of our system P, and C, a pair wise comparison matrix A was formed, where the number in the ith row and jth column gives the relative importance of Oi compared to Oj. A scale from 1-9 was used to classify the relative important of Oi versus Oj, with 1 meaning the objectives are equally important, then 2-9 indicating the level of dominance of Oi over Oj. Nine meant that Oi was absolutely more important than Oj. The following pair-wise comparison matrix was developed:

	Performance	Cost
Performance	1	1/3
Cost	1/3	1

Upon normalization of the matrix, and averaging of the rows, we determined that the weight for performance equaled 0.75 and cost equaled 0.25. This led to the following utility function: where P=performance and C= cost:

$$U(Alternative_i) = 0.75(P) + 0.25(C)$$

IV. RISK MANAGEMENT

The GoTrade design team identified known or postulated events or factors that could prevent program objectives (cost, schedule, function, performance, or quality) from being met.

A. Consequence Table

The first step to developing a comprehensive risk mitigation plan was to establish a consequence matrix. The consequences are categorized as shown in table 1 below. Ranges of consequences affecting cost and performance were defined since they are the main criteria in the value hierarchy.

Description	Category	Criteria
Catastrophic	I	Could result in death of employee or permanent disability, loss exceeding $1M, irreversible sever environmental damage, violation of law or regulation, loss of number of users, loss of data, loss of availability, loss of performance, loss of equipment.
Critical	II	Partial disability of employee, hospitalization charges, loss not exceeding $1M, loss of data, loss of performance, reversible software or hardware malfunction.
Marginal	III	Loss of employee for less than 15 days, loss not exceeding $200K.
Negligible	IV	Employee injury or illness resulting in a lost work day, loss not exceeding $10k.

Table 1. Risk Management Consequence Table

B. Ranking Categories

Next, risk ranking categories were defined. These detail methods by which each level of risk should be addressed. These categories are summarized in the table below:

Risk Rank	Category	Description
Unacceptable	I	Should be mitigated with engineering and/or administrative controls to risk ranking of III or less within a period less than 1 day
Undesirable	II	Should be mitigated with engineering and/or administrative controls to risk ranking of III or less within a period greater than a day but less than 1 week
Acceptable with controls	III	Should be verified that all procedures are in place
Acceptable as is	IV	No mitigation required

Table 2. Ranking Categories Table

C. Likelihood Frequency Matrix

Table 3 shows the level of frequency for the occurrence of an item. For calculation purposes the system's life expectancy was assumed to be 10 years. Converting into frequencies dividing by 10 yields that level A is likely to happen once a year. The summary of frequencies and the respective scale is shown below:

Description	Level	Criteria
Frequent	A	Likely to occur than more 10^-1 in that life
Probable	B	Will occur several times in the life of an item, with probability less 10^-1 but greater than 10^-2
Occasional	C	Will occur some time in the life of an item, with probability of occurrence less than 10^-2 but greater than 10^-3
Remote	D	Unlikely, but can reasonably be expected to occur, whit probability of occurrence less than 10-3 but greater than 10-4
Improbable	E	Unlikely, possible, whit probability of occurrence greater than 10^-5

Table 3. Likelyhood Frequency Matrix

D. Likelyhood Based on Different Levels of Protection

The last criteria for the risk mitigation plan are the likelihood ranges and the levels of protection for the typical scenario. This is summarized in the table below:

Likelihood Range	Typical scenario
Level 1	Initiating event of failure
Level 2	One level of protection
Level 3	Two levels of protection
Level 4	Three levels of protection

Table 4. Likelihood Based on Level of Protection

E. Risk Matrix

The resulting matrix from the above criteria in table 5, where red is high risk event, yellow is medium, and green is low.

		Consequences			
		IV	III	II	I
Likelihood	1	C	B	A	A
	2	C	B	B	A
	3	D	C	B	B
	4	D	D	C	C

Table 5. Risk Management Matrix

F. Risk Mitigation

The following table 6 summarizes the risk mitigation plan.

Risk Type	Action Required
A	Risk mitigation to risk level C or D
B	Risk mitigation required to risk level C or D
C	Risk mitigation to risk level D is optional
D	No further mitigation is required

Table 6. Risk Mitigation Actions

G. Example Risk Analysis

The following is an example of how the risk mitigation plan could be used for a security related issue:

Risk to the system: Transmission of data between users and GoTrade is compromised. Middle-man attack. Data intecepted and altered. 90% of these occur from the inside.

		Consequences			
		IV	III	II	I
Likelihood	1				
	2		X		
	3				
	4				

Table 7. Example Risk Mitigation Scenario (Level 2III)

Impact to the System: Sensitive user information compromised user identity theft. Trade information altered.

Mitigation Approach: Use two-way secure sockets layer (SSL). Create certificate for GoTrade and user signed by third party secure server (Verisign). Also use public key infrastructue (PKI) technology. All messages sent signed by sender's private key. Receiver can check that signature using public key issued by Verisign. Create a checksum for all message sent. Ensures that no-one modified the original message. Checksum goes through a one-way hash, using the Secure Hash Algorithm (SHA256).

V. SIMULATION AND MODELING

The purpose of our modeling and simulation effort was to perform a phase 0 feasibility and design study and make a FSD investment recommendation based upon a trade-off, net present value (NPV), and return of investment (ROI) analysis.

Software used included ARENA for simulating performance of various hardware configurations, Microsoft Excel for compilation and manipulation of all data (costs, performance parameters, etc.) related to the system, and Crystal Ball (add on to Excel) for iterative simulations of various cost and performance ranges based upon their respective distributions.

A. Data Gathering Methods

The majority of data relating to our hardware and software performance parameters were found among the extensive resources of the Transaction Processing Performance Council (TPC). The TPC is a non-profit organization that "defines transaction processing and database benchmarks and delivers trusted results to the industry."[1] The specific benchmark that was most relevant to our system was the TPC-E benchmark. The council established this benchmark to simulate the on-line transaction processing (OLTP) workload of a brokerage firm. "The TPC-E benchmark uses a database to model a brokerage firm with customers who generate transactions related to trades, account inquiries, and market research. The brokerage firm in turn interacts with financial markets to execute orders on behalf of the customers and updates relevant account information."[1] The TPC-E metric is given in transaction per minute (tpm) and represents the number of trade-result transactions a complete server-based system can sustain over a period of time.

The results we analyzed consisted of 219 server-based system configurations that were submitted by a variety of vendors including IBM, HP, and other leading companies in the server-solutions industry. We ultimately narrowed down the analysis to 75 system configurations that closely matched our system design.

B. Data Analysis

First, all dominant alternatives were eliminated. Systems in currencies other than U.S. dollars were not considered into our analysis. Also, systems configurations with an availability date of more than 2 years were excluded from our analysis.

Using techniques of Operation Research, the weights of the systems being evaluated were found by fitting the data to distributions using Crystal Ball. It was found that the Gaussian distribution was the most representative of the data. After normalizing the results, the weights of both attributes (Tpm and total system cost) for every competing system configuration were compared.

Chart 1 shows a pareto curve that will be used for sensitivity analysis and provides information about the dominant systems in terms of price versus performance. Further analysis will be conducted once our simulation is completed.

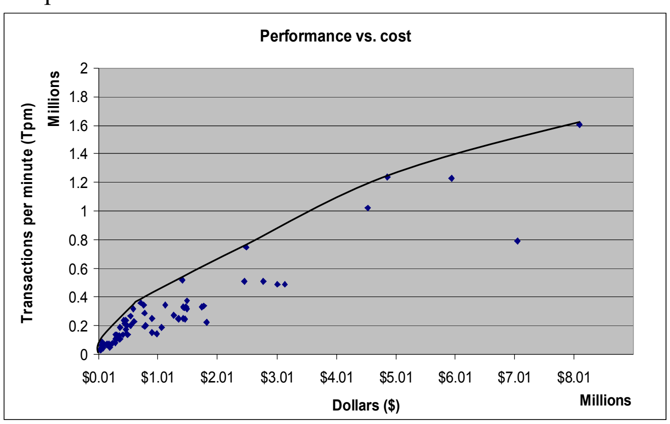

Chart 1: Pareto Curve

C. Arena Simulation

Once performance parameters implemental to our system are extracted from the above analysis, we plan to simulate various configurations for GoTrade and have developed a model in Arena for doing such. We hope to find potential bottlenecks from various configurations, test to performance of redundant systems, and determine system performance requirements in terms of transactions per minute needed based upon expected user capacities. Figure 10 below shows the top level view of our system model and platform for simulation:

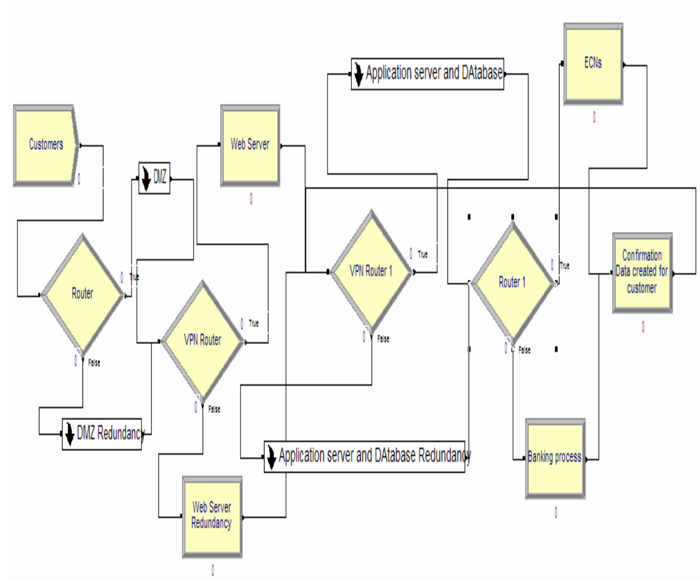

Figure 10.

Each white rectangle above represents sub-models that are too large to present in this report..

D. Conclusions

Final recommendations for systems configuration, net-present-value, and return-on-investment calculations are dependent upon our analysis and simulation results, which as the time of this paper submittal deadline, are a couple of weeks from completion.

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