A Method for DEVS Simulation of E-Commerce Processes for Integrated Business and Technology Evaluation

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Abstract

Performance evaluation of electronic commerce processes requires an integrated vision of the capacities offered by computational resources, website functionalities, and resulting financial outcomes. Simulation is a tool that allows trying out alternative business configurations before implementation. This requires a method that articulates models construction, representing the relation between business and technological resources. DEVS is a modeling framework for discrete event simulation based on systems theory and which offers resources to model complexity and stochastic behavior. This work is intended to propose a DEVS models design method for simulating electronic commerce processes. This method is implemented in DEVSJAVA tool and is proved by developing a B2C real case study involving a retail company of electronic items, information technology, and household goods.

1 INTRODUCTION

Current business scenario is developed in the concept of digital economy, which requires the latest technological developments to meet customer requirements and be ready to adjust to continuous changes imposed by markets. The use of computational technologies as an infrastructure to implement electronic commerce processes becomes a competitivity alternative that creates value, increases the reach of potential customers, and minimizes partner integration [Soto Acosta and Meroño Cerdan, 2009].

Performance problems of business processes on the Internet present unpredictable characteristics because, on the one hand, traffic volume behavior is uncontrollable and, on the other hand, these processes must meet user requirements with high service quality and competitive technology costs [Menascé and Almeida, 2000]. In other words, improvement in electronic business performance is associated with investment in technology and thus with its costs, benefits, and risks [Love et al., 2004].

Before implementing an e-commerce or an improvement, it is convenient to assess costs related to applications, hardware resources, and organizational changes, considering benefits as return on investment.

Business process simulation constitutes a significant tool to understand the essence of business systems, identify opportunities for change, and evaluate the impact of proposed changes on key performance indicators. It also allows trying out market decisions with alternative business configurations without interrupting current system operations [Giaglis et al., 1999].

A key feature of this kind of models is the need of interaction among different study units as a result of the integration of business strategies and implemented technologies. For this purpose, representation techniques capable of modelizing complex systems are required. DEVS (Discrete Events System Specification) is a formalization framework that enables interoperability, reusability, and flexibility. Its hierarchical and modular modeling allows complexities representation by depicting individual system components and couplings among them.

The object of this work is to present a discrete event modelization and simulation method for evaluating performance of both electronic commerce transactions at business level and computational resources with the aim of predicting behaviors or changes in system configuration to optimize investment.

2 RELATED WORK

[Schmid and Lindemann, 1998] propose a reference model for electronic commerce, which is formed by four views: a business view, another view related to the services the website can offer to achieve the business goal, another view regarding transactions carried out by processes, and the last view is related to the infrastructure that implements and processes transactions.

[Menascé and Almeida, 2000] suggest an Electronic Commerce Reference Architecture structured in four layers: the upper blocks consisting of e-business strategy and related service offered by the site; and the lower blocks comprise technological resources like workload, and software and hardware that support electronic business implementation.

Thus, metrics can be obtained from the interaction between layers of the technological approach. They provide support for the functionalities required by business model in the upper layers. These metrics are useful for decision making.

As regards the construction of Electronic Commerce models and their simulation, [Menascé et al., 2000] propose the CBMG (Customer Behavior Model Graph) diagram to model customer sessions in e-commerce websites. It consists of transaction graphs and transition probabilities between states or functions that allow establishing the functional model of the site and customer workload. Output models include traditional metrics (Response Time, Throughput, and Utilization) and other metrics related to a business perspective: the revenue throughput (money/second) that computes average income in terms of real sales and potential lost revenue, which is related to losses due to customer actions such as adding products to the shopping cart but leaving the site without buying.

Formal methods that describe process behavior by defining syntactic and semantic structures are available to represent simulation models.

Discrete event modeling and DEVS simulation framework proposed by Bernard Zeigler involves hierarchical, modular, and object-oriented model development [Zeigler and Sarjoughian, 2003] with the possibility of building simulation models based on component, scalability, and reusability hierarchy. Parallel simulation functionalities were also incorporated, so that input and output sets (bags) are managed. As regards concurrence, there may be cases in which internal and external events occur simultaneously. Confluence transition function, thus, is introduced so as to organize the execution sequence [Zeigler and Sarjoughian, 2002]. The best model representation of actual systems requires considering stochastic behaviors, so that traditional DEVS functions can represent non deterministic behaviors. [Castro et al., 2010] propose STDEVS (stochastic DEVS) and show its advantages for stochastic systems modeling.

DEVSJAVA is an object-oriented software tool with JAVA programming language and free availability for academic applications with license agreement. It allows DEVS models implementation and counts on an experimental framework and graphical outputs [Palaniappan et al., 2006].

As aforementioned, there are reference architectures for the proposed simulation methodology. However, no updated model has yet been developed for electronic commerce simulation from an open simulation tool and with a perspective of business metrics integrated to technological capacities as a business tool.

3 PROPOSED SIMULATION METHOD

3.1 Simulation Method Reference Architecture

The Reference Architecture for model construction and simulation parameterization is presented in Figure 1.

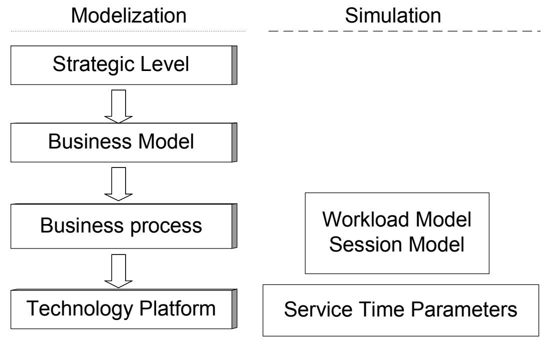

Figure 1. Reference Architecture

The architecture depicts two basic parts: modeling and simulation. Modelization consists of four levels, whose correlation from the upper to the lower one brings about the model construction.

At strategic level, the system under study is defined by business planning. On this basis, business model is built, setting out the organizational structure, defining products or services, identifying business actors and their roles, and configuring business networks.

For business process, it is necessary to describe the overall view of operations among participating actors, identify transactions implemented by website operations, and establish interactions internal logics. At the last level, computational and communication platforms are detailed because they constitute the technological support for commercial transactions.

Then, it is necessary to know model parameters, specifying both customer workload and session models. Customer arrival frequency is analyzed to find the probability distribution of request arrival time, which represents workload. On the other hand, the use of CBMG diagram is proposed for session model, for designing transaction integration, and for settling the various sessions as state transitions with their occurrence probability. Information is obtained by monitoring the website and establishing frequencies of access to different transactions; and thus probabilities are calculated.

As regards computational resources, each resource parameter is the mean service time of each processed transaction. This information is obtained through monitoring and treatment of gathered data.

3.2 Simulation Stages

Electronic commerce operations must be ready to comply with unpredicted customer requests, whose emergence does not follow a deterministic behavior. They must be also capable of responding under competitive pressure and technological changes. They must therefore be prepared to serve requests randomly and restructure themselves dynamically.

In this context, these operations are faced to asynchronous business events, such as the arrival of a customer sales request, a payment, and searches for data about products, among others.

Based on the architecture described in Figure 1, a modelization method for simulation is proposed.

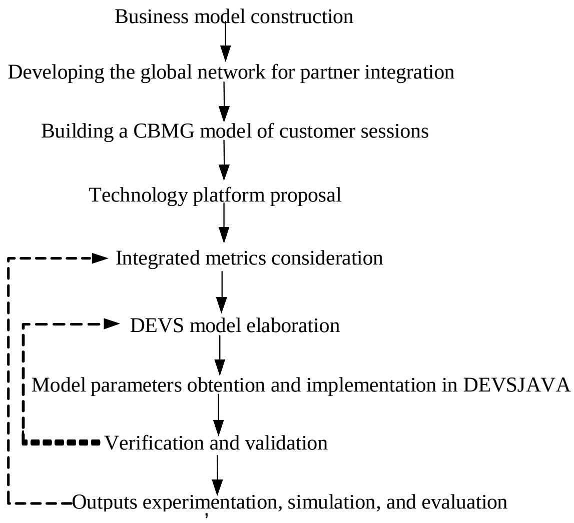

Figure 2. Modelization and simulation stages

Once business model and strategy are defined, interacting partners and business transactions are considered. A global network is built with partners and roles to show interactions among business operations, such as e-commerce integration with supplier for inventory control, or outsourced electronic charging service. Commercial transactions and customer sessions on the website are represented by CBMG model, which allows identifying some type of customers or workload on the website as frequent or sporadic.

CBMG shows transition between states or functions of the website with an occurrence probability. In other words, if customers are in Search state, there is a probability that they will move to transaction Select Product or to other states or to another function. Once customer sessions are defined, configuration of computing and communication resources of the technology platform is proposed, and their performance metrics are included.

According to the above discussed, DEVS model is built, including simulation input variables parameters. It is then implemented in DEVSJAVA. Model logic is verified, and it is validated with actual data. Thus, the various experimentation scenarios are proposed to carry out simulation.

As shown in Figure 2, cycles can be produced at some stages by returning to previous ones.

3.3 DEVS Electronic Commerce Model

3.3.1 Proposal of DEVS model basic entities and couplings

DEVS model is organized in two structures as shown in Figure 3: Experimental Framework and e-commerce system. Experimental Framework is a coupled model of atomic models Generator and Transducer.

Generator provides the system inputs -customer request arrivals at an e-commerce website-and informs this to Transducer to compute the amount of time each customer remained on the site. It is responsible for monitoring simulation execution.

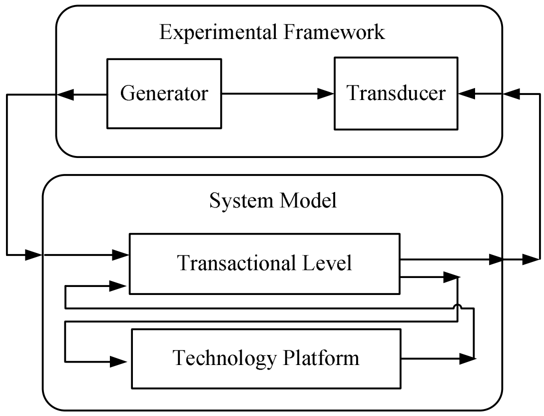

Figure 3. DEVS entities

E-commerce model has a transactional level that implements CBMG. Technology platform level is composed of network and hardware resources, where customer transactions are executed.

As regards technology platform model, the construction of a structure diagram is suggested to identify each resource and its couplings.

3.3.2 DEVS model construction

For building DEVS model, a statechart diagram of the transactional atomic model is considered in Figure 4, which represents internal and external transition states.

It takes CBMG as a reference and has two functions: (i) receive customer requests and send them to technology platform to be processed, and (ii) receive requests that were processed by technology platform and send them to the next randomly selected transaction. Therefore, the output function becomes stochastic.

As regards output ports, a set of n output ports selected according to probability of transition to the next transaction is considered. In addition, a port that sends requests to be served in technology platform is also considered. Possible states are *passive* and *sending*, which correspond to special cases called *permanent* (time ∞) and *transitory* (time 0).

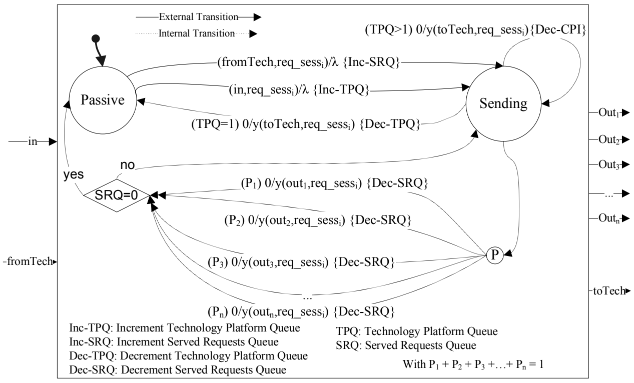

Figure 4: Transactional atomic model

To understand stochastic behavior, internal and output transition functions are detailed.

$$\delta_{\text{int}}: \begin{cases} \delta_{\text{int}}(sending) = sending & if \quad TPQ > 1 \\ \delta_{\text{int}}(sending) = passive & if \quad TPQ = 1 \\ \delta_{\text{int}}(sending) = sending & if \quad SRQ > 1 \\ \delta_{\text{int}}(sending) = passive & if \quad SRQ = 1 \end{cases}$$

$$T = \{trans_1, trans_2, \cdots, trans_n\}$$

$$P_{\lambda,out} = \{(trans_1, p_1, out_1), (trans_2, p_2, out_2), \cdots, (trans_n, p_n, out_n)\}$$

$$\lambda_{P,out}: \begin{cases} r = random \quad U[0,1] \\ \lambda(sending) = (out_1, reqsess_1) & if \quad r < p_1 \\ \lambda(sending) = (out_2, reqsess_2) & if \quad r < p_1 + p_2 \\ \lambda(sending) = (out_n, reqsess_n) & if \quad r < p_1 + p_2 \cdots + p_n \\ \lambda(passive) = (toTechnology, reqsess_i) & if \quad (in, reqsess_i) \end{cases}$$

This representation includes queues treatment to show the algorithm scheme. Requests received by the input port are operated with Technology Platform Queue, which is increased by receptions and decreased by processing. So is Served Requests Queue operated, which is increased when receiving a request served by technology platform and is decreased when requests are sent to the next transaction.

Statechart diagram of technology platform models describing the semantics is shown in Figure 5.

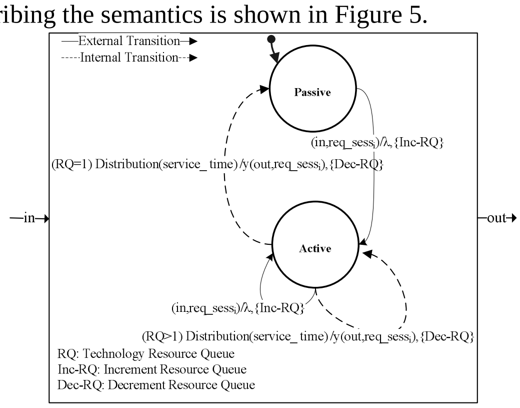

Figure 5. Technological resource atomic model

Here, service time is a value that depends on a probability distribution, and therefore the stochastic function will be time advance function. So:

$ta(s): S \to R^{+}_{0,\infty}, with \quad Distribution_{ta}$ is Stochastic Time Advance Function.

4 CASE STUDY

The presented case study shows the application of the proposed method to a real case of B2C electronic commerce in a company that has branches in several cities and trades both in the traditional way and including an electronic commerce website. The company is devoted to the retail of electronic appliances and goods, information technology and household goods, fittings, music, and movies.

4.1 Business Model Consideration

In this case, the main aim of company website is marketing, and thus products are advertised, product information is provided, and purchasing and post-purchase services are offered. Purchase method is not online. Customers select products and send a purchase request by e-mail. It is received by the company who makes a phone call to complete the operation. The company does not have business partners involved in website operations.

Business strategy consists of proposing an advertising board with products catalog, services for interaction with customers, and sales execution by phone.

A DEVS simulation model is built to evaluate technology platform performance in relation to benefits and return on investment for this case study.

4.2 Customer Session Model

Relevant website transactions are: browse home page, select menu options, make direct searches, visit catalog, see promotions, select product, and send purchase order. Customer sessions are shown by CBMG in Figure 6.

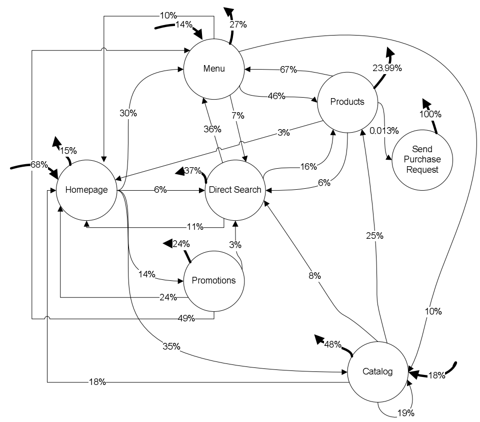

Figure 6. CBMG for customer sessions

4.3 Metrics Consideration

4.3.1 Metrics at technological level

For this case study, technological metrics are posed:

- Throughput X = number of completed customer requests per sec.
- Response Time R = mean time to respond to customer requests in sec.

4.3.2 Metrics at business level

In terms of decisions, it is convenient to think of a balance between technology platform performance and investment cost. For that reason, a business metrics is posed according to Equation 1 of equilibrium point.

Investment Cost = Amount of Purchased Products x Average Net Income per Product

Equation 1: Equilibrium point

According to the average quantity of products sold every month, an average income is estimated. Investment Cost and Monthly Net Income are compared, and equilibrium point is analyzed. The resulting value indicates losses when return is lower, and profits when return is higher. It is important to take into account the time taken to obtain that return.

4.4 E-Commerce Model and its Implementation in DEVSJAVA

Entry to the commerce website could be by Home Page, Catalog, or Product. Then Generator has three output ports (Home, Catalog, and Product) with customer requests. They are connected with Experimental Framework output ports (outCatalog, outHP, and outProduct). Created requests are assigned to output ports by probability, as shown in Figure 6.

Each created request by Generator is communicated to Transducer by output port New. Input Port Stop of Generator is connected with Output Port Out of Transducer in order to receive finished simulation message.

Experimental Framework input port called toTransducer receives solved requests from Business Model and is connected to input port called Solved of Transducer, where metrics are computed.

There are also connections between Transactional Model and Technological Model to execute customer requests.

Transactional Model is coupled with several atomic models of transactions Home, Menu, Catalog, Promotion, Search, Product, and Send Request. Each atomic model has an input port "in" where requests are received from another transaction. Transactions Home, Catalog, and Product also receive requests from Experimental Framework through ports toHome2, toCatalog2, toProduct2. Input port inTech receives served requests; output port toTechnology sends a request to be served by Technological Model; and output port toTransducer is connected with port outTransducer of Transactional Model to send completed requests.

Input ports toCatalog, toHome, toMenu, toPromotion, toProduct, toSearch, and toSendRequest of Transactional Model are connected with output port out of Technological Model in order to receive served requests according to applicant transaction.

Technological resources are parallel clustered servers, organized by a center queue represented by a load balancer. Load balancer manages the reception of arriving requests with a sequential assignment by servers. Load balancer is responsible for keeping in the queue those arrivals that cannot be served, and thus servers are modeled as delay centers.

Thus Technological Model is a coupled model consisting of an atomic model called Coordinator and four Server atomic models. Technological Model receives a request through port "in" for execution. This port is connected with port "in" of Coordinator that evaluates idle server availability in order to send requests to port toServer of Server Atomic Model. Otherwise, requests wait in queue until a server becomes idle.

Server Atomic Model sends served requests through port out to Coordinator and it is received by input port fromServer.

Processed requests are sent to the next transaction through ports out of Coordinator.

The real case study has only one server, and thus the cluster is represented by a unique server. By analyzing possible improvements, however, it is necessary to consider more than one server. The full model in DEVS JAVA is shown in Figure 7.

4.5 Model Verification and Validation

Model parameters are obtained by monitoring data of the business website with Google Analytics tool. A probability distribution function of time between customer arrivals is obtained. It is an exponential distribution with a media of 21.89 sec. Server service time is a uniform distribution with a 0.5-second minimum and a 1.5-second maximum.

Verification technique is based on tracking the code execution and analyzing log files with output metrics and variables. Validation is carried out by comparing simulation results to those obtained in the real business site.

Data corresponding to December 2011 are taken into account; and average values per day are calculated. Table 1 shows average values for number of customer arrivals per day, response time, and number of purchasing customers per day, for both the real system and simulation.

Differences are: 3.57 percent for number of customers, 7.8 percent for response time, and 0.7 percent for sold products, for both the real system and simulated website.

It is observed that according to simulation with the original monitorization parameters and in comparison with results obtained in the real system, the model adjusts to the system and then e-commerce simulation is valid.

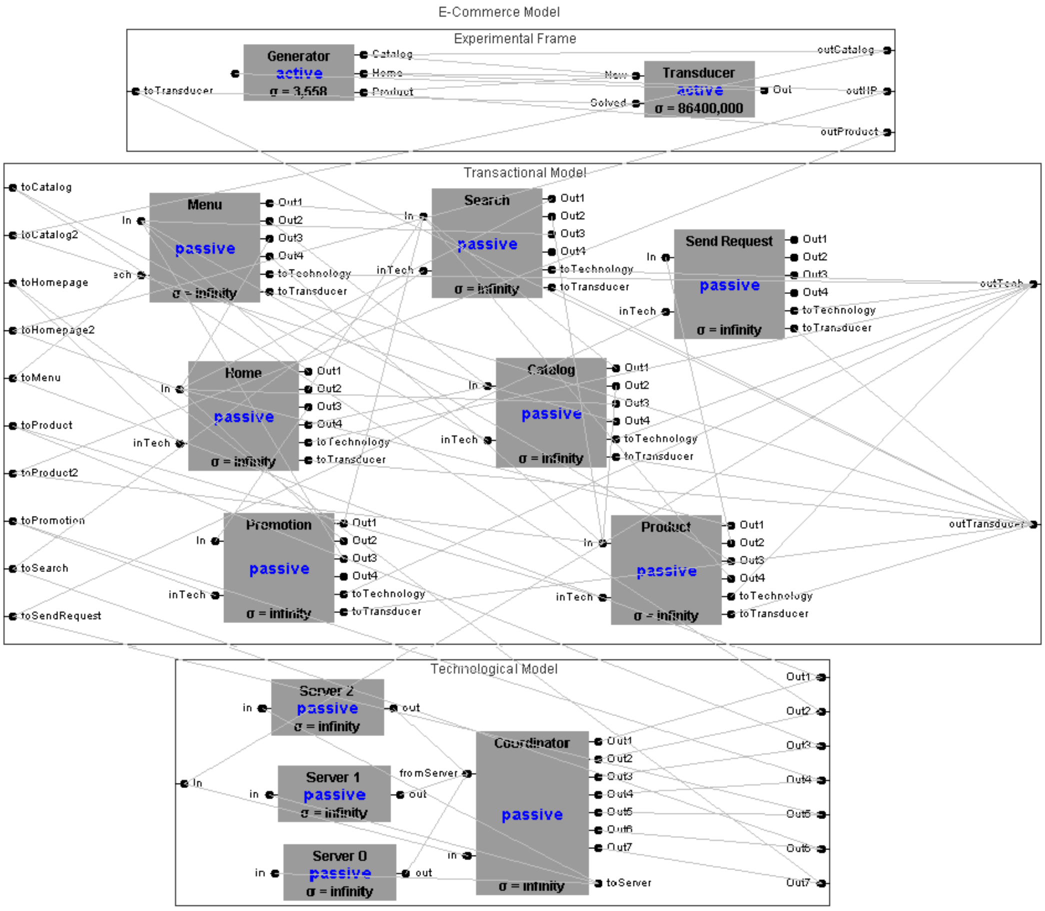

Figure 7. Company E-Commerce DEVSJAVA Model

Table 1: Comparative data of real and simulated case

Data	Real site		Simulated site	
	Average	Standard deviation	Average	Standard deviation
Number of Customers	4033	1003	3889	1039
Response Time	5 sec.	0.912 sec.	5.39 sec	0.698 sec.
Purchasing Customers	4.98	0.89	5	1.05

5 SIMULATION RESULTS

Business metrics are obtained by simulation. Quantity of sold products is estimated in 5 per day and 150 per month.

Investment cost for business site implementation is U$D 90.000. The most frequently sold goods during the monitorized month are: notebook, cold split air conditioner, and cell phone, with a net income of U$D 17.400.

According to Equation 1 of equilibrium point, a negative amount of U$D 72.600 is obtained. It is then concluded that a six-month income would be needed to recoup the invested amount. The invested capital would be recouped by the seventh month.

Response time is an indicator of performance technology platform. Research on response time indicators on the American site http://www.keynote.com was carried out. The site is devoted to retailing electronic goods [KE 2012] and books, music, and videos [KBMV, 2012]. Response time periods lower than 7.9 sec. are considered recommended. Those periods lower than 10.6 sec. are considered satisfactory, and higher values are unsatisfactory. According to these values, a 5.39-second response time obtained by study case simulation is satisfactory when considering 21.89 sec. for time between arrivals to the website, but for lower customer request arrival times, system performance becomes poor.

The company considers that the actually reached number of monthly sales is not significant. It is then interested in strategies to increase the number of visiting customers and sales.

As a first simulation scenario, system behavior is to be known so as to increase the number of customers by reducing time between arrivals and maintaining technological resources. Number of arriving customers for the elapsed time between arrivals is shown in Figure 8. A

50% reduction of time between arrivals leads to a 90% increase in the quantity of arriving customers per day.

According to the number of arriving customers per day, the amount of sold products is obtained, considering that 5 percent of the selected items on the website are sold, which is shown in Figure 9. A 90 percent increase in the amount of arriving customers to the website leads to a 60 percent increase in the quantity of sold products.

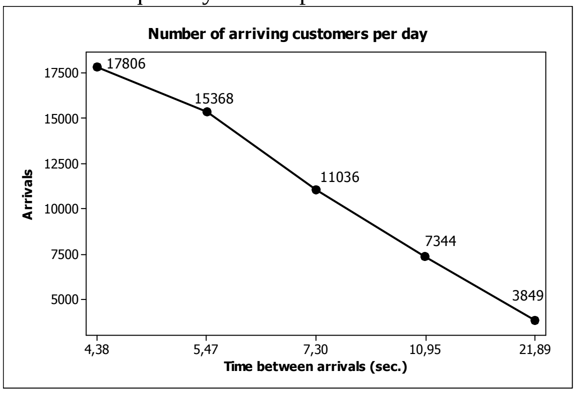

Figure 8. Number of arriving customers per day for each time between arrivals

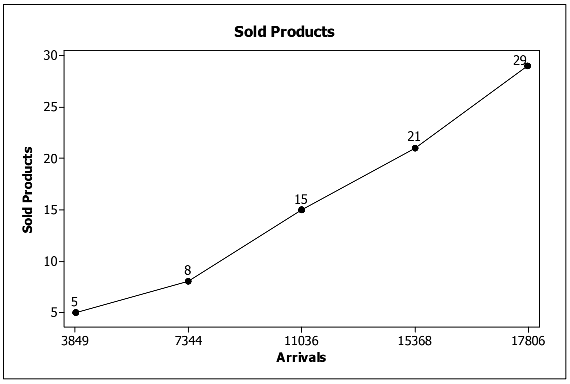

Figure 9. Quantity of sold products per day

Average response times per request vs. arrivals are shown in Figure 10. A 90 percent increase in the number of arriving customers is observed if compared to the original system, and response time becomes unsatisfactory. It is dramatic when the number of arriving customer is increased by 4.61 times and response time is 10 times higher than the original one.

Moreover, 10.95 seconds between arrivals lead to 8 sold items per day, which is not significant in terms of financial benefit.

A second scenario considers a second server with similar characteristics to those of the existing one in order to respond satisfactorily to an increasing number of customers. A cluster of two parallel servers is thereby considered to assist e-commerce transactions.

A third scenario proposes shifting from the existing technology to a unique server with a reduced service time in a uniform distribution for a 0.3 sec. minimum and a 0.7 sec. maximum.

Figure 11 and Table 2 show response time vs. arrivals for the two proposed scenarios to improve performance. Results are satisfactory response times for the whole range of arrivals.

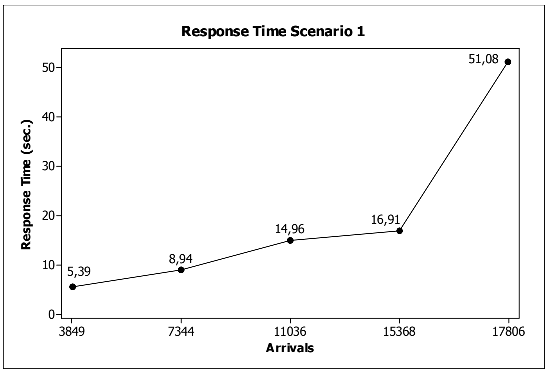

Figure 10. Response time for Scenario 1

Table 2: Response time vs. Arrivals of Scenarios 1, 2, and 3

Scenario 1		Scenario 2		Scenario 3	
Average (sec.)	Standard deviation (sec.)	Average (sec.)	Standard deviation (sec.)	Average (sec.)	Standard deviation (sec.)
5.39	1.244	4.10	1.48	2.41	0.988
8.94	1.005	4.61	0.98	3.31	1.43
14.96	1.23	4.82	1.47	3.90	0.924
16.91	1.45	5.24	1.221	4.17	0.991
51.08	1.74	5.98	0.958	4.90	1.429

In this way, substituting the existing server by another one with greater capacity seems the best business and technological performance improvement for the original business model. Its response times are lower in relation to those of the proposal for incorporating a server with the same capacity to form a cluster.

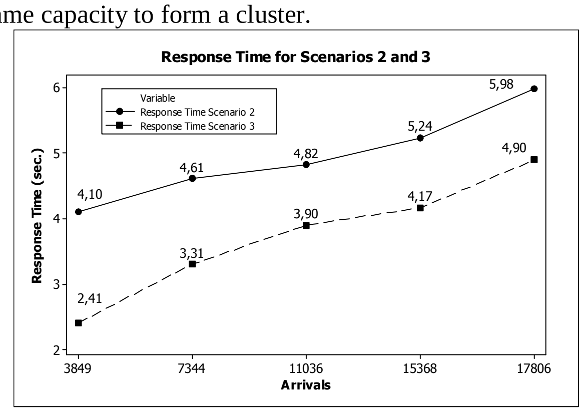

Figure 11. Response time for Scenarios 2 and 3

Electronic commerce experiences of companies have shown that by incorporating online electronic payment by credit cards, the number of customers who do buy is increased by 3%. This situation is thus simulated with a 3% increase in the number of customers that after staying in transaction Product continue to send the purchase request, taking the initial configuration as a reference (Section 4.4). Simulation shows that the number of sold products per day is increased from 5 to 77, and thus investment would be recouped by the first month.

It is then concluded that the introduction of online electronic payment in business website services rather than payment via e-mail is convenient to guarantee purchases. Also, it is important to highlight that the alternatives subjected to the significant increase in the number of customers are not controllable. Marketing and sales promotion strategies may be an alternative but their outcomes are uncertain.

6 CONCLUSIONS

This work presents a method for modeling and simulating electronic commerce on DEVS Formalism with specific applications to stochastic and in parallel cases. A workload is specified by GBMG, which represents customer sessions on a business website with transactions being executed by a technology platform. All these components are included in DEVS.JAVA tool for predicting resource and business behavior and performance. A simple case study of a real company is considered to prove the proposed method. Simulation results help to analyze different scenarios in order to select improvement techniques from an integrated perspective of technological results and financial benefits.

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