Modeling knowledge reuse in technical support operations

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Abstract: There is an increasing concern on the part of corporate sector of the importance to harness knowledge as their most valuable resource. The purpose of this work is to identify the effects of knowledge reuse in service systems. In order to achieve this, a system dynamics model of a Brazilian software-house's technical support service is presented, emphasizing on the use of knowledge bases and its effects over the service system. It concludes that i) the model aids the designer in evaluating several aspects of the system as well as its performance, including the effects of knowledge reuse and ii) based on the simulation results, knowledge management enhances service system performance.

Keywords: Service System Design, Knowledge Management, Knowledge base, Knowledge reuse, System Dynamics

Introduction

Intangibility, simultaneity and non-stockability clearly differentiate service operations from manufacturing ones (Gianesi & Correa, 1994). It has been suggested that service operations depends intensively on the human capital involved. Usually, service systems are based on a large number of interactions with both consumers and suppliers in which value co-production is an inherent property (Tung & Yuan, 2007). According to Maglio et al. (2006), "service systems are value-creation networks composed of people, technology, and organizations".

Cook et al. (2002) suggest that only with the understanding of the underlying principles of human interactions, service design can be approached with the same depth and rigor found in manufacturing operations. When the service system involves knowledge-intensive activities, qualified human capital grows in importance, as well as the need to strategically manage its large volumes of information and knowledge.

Service operations knowledge is crucial for bringing positive outcomes and superior organizational performance. Knowledge Management is the discipline that addresses those issues, by acquiring knowledge mainly from human sources, by codifying this knowledge in order to be able to store it in knowledge-bases, and by re-using the knowledge stored in the company's processes (Uriona et al., forthcoming). .

[1] The authors wish to thank the National Council for Scientific and Technological Development (CNPq) for supporting this research through the PEC/PG Program as a "**Bolsista da CAPES/CNPq – IEL Nacional – Brasil"**

Knowledge bases are of extreme importance for service operations, since its human-intensive nature, if correctly implemented and managed, therefore the need for them to be considered under service design and production phases.

The design phase is essential for product development, establishing how the requisites will be incorporated in the final manufactured goods or services. If the effects of knowledge bases on a particular service system can be visualized and discussed on this phase, several investments can be saved and the chance of a successful implementation and results increases, by foreseen the positive/negative impacts knowledge reuse may have over the system.

Thus, how can knowledge reuse and its effects be visualized in service operations before service delivery/production? In manufacturing product design, it is common to evaluate scenarios and alternatives related to product development. However, in service design, due to its intangible nature, this evaluation is harder, making scenario-testing more difficult. While, in goods production is common to build physical models that materialize the conceived ideas, service design may use simulation techniques.

According to Banks (2000), simulation imitates the operation of a real-world process or system during a period of time, based on the creation of an "artificial history" of the system, where outcomes may help to infer real system operations. For Sheu et al. (2003) simulation offers important advantages over mathematical tools, like value-ranges flexibility in controlled parameters and real system behavior capture.

The purpose of this work is to identify the effects of knowledge reuse in service systems by using System Dynamics as a support tool, which allows complex system simulation through stock and flow metaphors.

In order to achieve this, a software-house's technical support service is modeled using System Dynamics. This activity has been described as knowledge-intensive and human-based (Uriona, 2008).

The next section deals with the concepts of knowledge reuse. Third Section develops service system design, highlighting the need to promote knowledge management initiatives when it is considered a requisite. Fourth section develops the system dynamics concepts used in the model. Model application is developed in Section 5, considering a knowledge-intensive service system design in a software-house. Finally, in Section 6, the conclusions of the paper are presented.

Knowledge Reuse as a feedback process

There is an increasing concern on the part of corporate sector of the importance to harness knowledge as their most valuable resource. Many researchers have argued that the capability to manage knowledge is the most important source of competitive advantage (Nonaka and Takeuchi, 1995; Drucker, 1997).

The management of knowledge can be broken down in some phases, compounding the so-called knowledge transformation cycle, Uriona et al. (forthcoming) proposes the following phases: knowledge creation, formalization, store, share and use.

McElroy (2002) consolidates the cycle´s phases in the KMCI model (Exhibit 1). It includes a series of feedback loops for organizational memory, beliefs, claim and business-processing environment. McElroy also sustains that organizational knowledge is held subjectively in the mind of individuals and groups and also objectively in explicit forms.

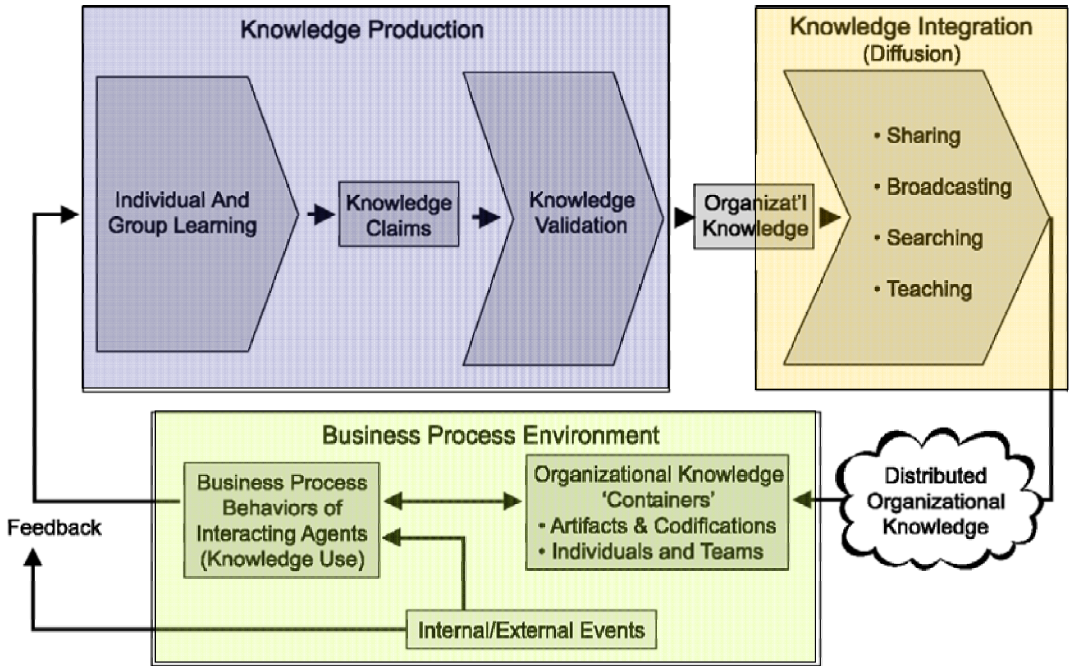


Exhibit 1: KMCI Model. McElroy (2002)

The knowledge production processes feeds the organization with new knowledge through individual and group learning, and with knowledge formulation, codification and evaluation.

The knowledge integration processes introduces the new knowledge to its operating environment, and via Single-loop Learning and Double-Loop Learning (Argyris and Schon, 1978) replaces old knowledge or re-starts the Knowledge production processes for acquiring more knowledge.

As seen on Exhibit 1, Organizational Knowledge Containers, namely Knowledge Bases have a direct impact on business process behavior – by using knowledge previously acquired and codified – which in turn, feeds back on individual/group learning.

We infer that the more knowledge stored in artifacts compounding knowledge bases, the more the impact on business performance, through process behavior.

Service System Design

Similarly to goods manufacturing, service operations are composed of several components. However, these components are mainly non-physical, characterized by a combination of processes, human competences and other resources (Goldstein et al., 2002). In new service development or in service re-design, managers and designers must make decisions with different levels of complexity about each component of the service (Goldstein et al., 2002)

Service system design has been pointed out by Chase & Apte (2007), Hidaka (2006) and Maglio et al. (2006) as a promising research field, considering also, the relevancy of simulation and modeling techniques in helping analyzing these tasks.

Heineke & Davis (2007) discuss the relationship between the need for global service expansions and the use of information and communication technologies with geographically dispersed resources. These factors establish new challenges for service managers and increase the importance of design and monitoring tasks for high quality services.

Reinforcing the importance of investing in adequate HR management, constituting an essential asset in service organizations, Dial (2007) points out that, in contrast to manufacturing operations, services are highly dependent on operator's experience and intuition, thus, having an inferior overall productivity than of manufacture activities. The author suggests the adaptation and application of manufacture concepts and methodologies in service operations in order to raise productivity indicators.

This paper – supported by the ideas exposed – recognizes the importance of knowledge management in service operations, and points out the need to guarantee the necessary resources in design phase. System Dynamics, as detailed in the next section, is explored as a tool that seeks to help designers and to foreseen system's behavior for each project scenario, and more importantly, to analyze the effects of knowledge management initiatives in the service operations.

System Dynamics

System Dynamics (SD) was developed by J. Forrester in 1961 (Forrester, 1989), as a methodology for understanding complex systems behavior, through soft and hard simulation. According to Sterman (2000):

> "System Dynamics is a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems. System Dynamics is also a rigorous modeling method that enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations".

It evolved from the application of control theory to the study of dynamic social systems. Its premise is that the behavior of a complex dynamic system is the result of its structure (causal relationships, feedback loops and time delays) (Sterman, 2000; Oliva & Sterman, 2001).

Feedback loops are defined by information acquisition over system state and for actions causing changes in that state. Its modeling involves accumulation processes (stocks) and flows, as well as time delays and non-linear relationships. (Gonzalez & Dutt, 2007).

Sengir et al. (2004) discuss the importance of System Dynamics for behavior and structure analysis in social systems. Feedback loops, differentiate system dynamics from other approaches, by characterizing non-linear social relationships. Stocks and flows of information, people and other resources allow the study of systems with high levels of dynamic complexity and the study of timing issues in organizations.

Some of the advantages brought by this approach in modeling complex dynamic systems are listed by Hollmann & Voss (2005): i) "stock and flow" diagrams provide and intuitive vision above the structure of the system in study; ii) all the dependencies and relationships are visualized graphically, facilitating the understanding of the processes; iii) simulation tools, like iThink, allow model variables modification interactively, in a so-called "control panel", facilitating scenario-testing and analysis.

The Case Study

The Organization: An Overview

AltoQi Tecnologia em Informática is located in Florianopolis, Brazil. The firm develops, markets and supports software solutions for the construction market, comprising architecture, structural analysis and engineering in concrete applications as well as hydraulic, electric, fire sprinkler and gas layout projects.

Due to the complexity of its products and of its application domain, their costumers generate large demands for specialized technical support. The firm maintains an engineering and technical team that needs to be adequately trained in using the product as well as in the project areas covered by the software products.

Nowadays the company counts with 11 workers in its technical support department, mostly engineers, divided in three engineering areas: civil, electric and hydraulic. This team answers the requests of approximately 17.000 users.

The services are made via telephone and email. On an average month, the team answers around 81 calls per day with a mean of 13.8 minutes per call, likewise, around 32 email replies with a mean of 27.6 minutes per email.

According to the Products and Services Department Manager, currently, the support team has not been able to answer all of the customer demand. Daily, several calls are lost and email requests seldom are answered on the same day due to the amount of emails accumulated. These issues reduce customer satisfaction levels and also affect team´s morale.

Another problem faced by this Department is turnover. When experienced workers leave the team, they take with them knowledge that was acquired in their activities. They are replaced with new workers that reduce overall performance, since these new workers will usually be slower in their activities and will require more help from the experienced colleagues until they leverage their knowledge.

The team´s manager and the company´s boardroom believed that an implementation of a knowledge reuse strategy may aid in the problems explained. It is expected that knowledge recovery and reuse applied to case-solving will serve to improve team performance in future support services, by reducing service times and by improving its quality. It is also expected that knowledge codified would diminish the effects of turnover in the team, aiding in the training of new team members.

The System Dynamics Model

This section illustrates the use of a system dynamics model as a support tool for service system design, emphasizing the possibility of simulating the knowledge management effects over the system performance. The service analyzed from the practical field is a technical support service, usually found in software developing companies. The data supplied by *AltoQi Tecnologia em Informática* allowed establishing the following requisites:

- ⇨ Opening requests are received via telephone and e-mail. Telephone support service has priority over e-mail support service.

- ⇨ The objective of the system is to reach zero non-attended telephone calls (zero *WaitingCalls*) at the end of the day.
- ⇨ E-mail inbox is shared across the attendants and it is also desirable to be zero (0) *WaitingEmail* at the end of the day.
- ⇨ Knowledge management: at the end of a service, the attendant responsible should feed the knowledge-base, aiming at making forthcoming services more agile.

It is beyond the scope of this paper to define the knowledge management strategies and tools used in the company. The term “knowledge base” is used in this paper to represent a knowledge repository that grows as the feeding process goes on. It is expected that this knowledge repository will facilitate future attendances, if supported by adequate knowledge representation, retrieving and reusing techniques.

Besides improving service system performance, the establishment of a knowledge base must facilitate rookies training, reducing the expected effects of turnover. In knowledge-intensive activities, such as technical support services, this aspect is of fundamental importance, since attendants must accumulate a large volume of knowledge - regarding functional characteristics of the software as well as technical knowledge from the application domain - in order to successfully execute the activity

The example used aims to demonstrate that the structure needed to promote knowledge management initiatives is a part of service system design and that – as the rest of its components – it represents operational and financial costs that must be compensated or, preferably, being overcome by the benefits brought by its use. The developed System Dynamics model helps the service designer in evaluating these cost-benefit ratios by considering several demands versus capacity scenarios.

The Model

Exhibit 2 shows the macro-model of the service system in study. The modules that constitute it are: Phone Support, E-mail Support, Workforce, Knowledge Base and Performance Measurement.

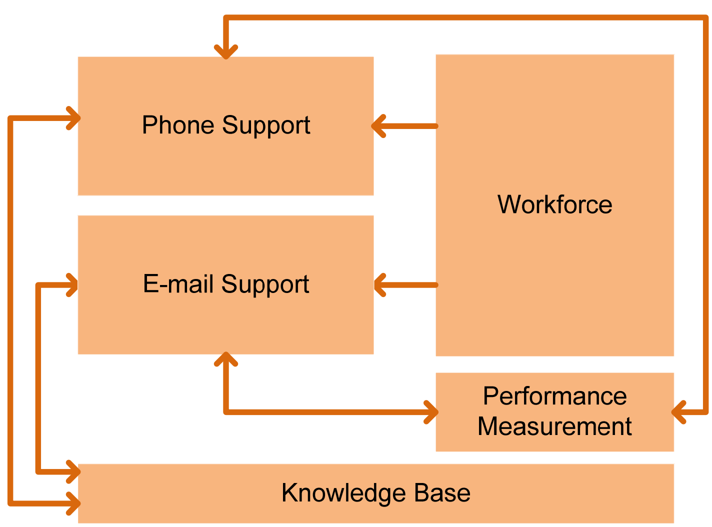


Exhibit 2: Macro-Model of the technical support service

Exhibit 3 shows the system dynamics model in iThink language. The five areas of the model are described below.

- ⇨ **Phone Support**: the number of calls received daily is regulated by the *IncomingCalls* inflow. The stock *CallsToAnswer* is emptied by *AnsweringCalls* and *LosingCalls* outflows, this last-one represents excessive demand. The phone calls effectively answered are accumulated in the *CallsAnswered* stock, that serves as a feeding source for the *KnowledgeBase* stock.
- ⇨ **E-mail Support**: *IncomingEmail* flow feds daily the *EMailInbox* stock. Differently from phone-calls, e-mail inbox doesn't necessarily empties-out, since it doesn't count with an outflow other than *ReplyingEmail.* The amount of emails answered each day depends on the remaining time the attendants have after answering all of the phone-calls. Same as the *CallsAnswered* stock, the *EmailReplied* stock feeds the *KnowledgeBase* stock.
- ⇨ **Workforce**: The stock *AttendantsInService* varies depending on the quantity of calls and emails to answer. This policy helps to maximize the use of the workers as well as their time, both reflected on the *TotalCosts* stock. The *HiringRate* parameter depends exclusively on the amount of calls, reflected on the *AnsweringCalls/CallsToAnswer* ratio. On the other hand, the *TimeAvailable* stock is shared in order to answer calls and reply to e-mails. This depends initially, on the quantity of *CallsToAnswer*, if there is less than 5 calls to answer, immediately an amount of time becomes available to answer emails, however, if e-mail inbox has a quantity larger than 50 emails, an extra time becomes available to answer emails, in order to reduce the amount of emails in *EmailInbox*, leaving less time to answer phone calls.
- ⇨ **Knowledge Base**: The *KnowledgeBase* stock is feed-up via knowledge processing, which uses *CallsAnswered* and *EmailReplied.* The *KnowledgeProcessingCall* and the *KnowledgeProcessingEmail* need a minimum amount of data and information stored on *CallsAnswered* and *EmailReplied* in order to be useful, a 1000 for each one. The *KnowledgeBase* then, is used to reduce the *TimePerEmail* and the *TimePerCall* parameters.
- ⇨ **Performance Measurement**: This area helps to measure key-performance indicators for the support service. These are: *WaitingCalls* that represent the amount of calls left in the waiting line each day; *WaitingEmail* that represents the amount of emails left in the *EmailInbox* without replying each day and *TotalCosts* that represent the costs due to workforce demand.

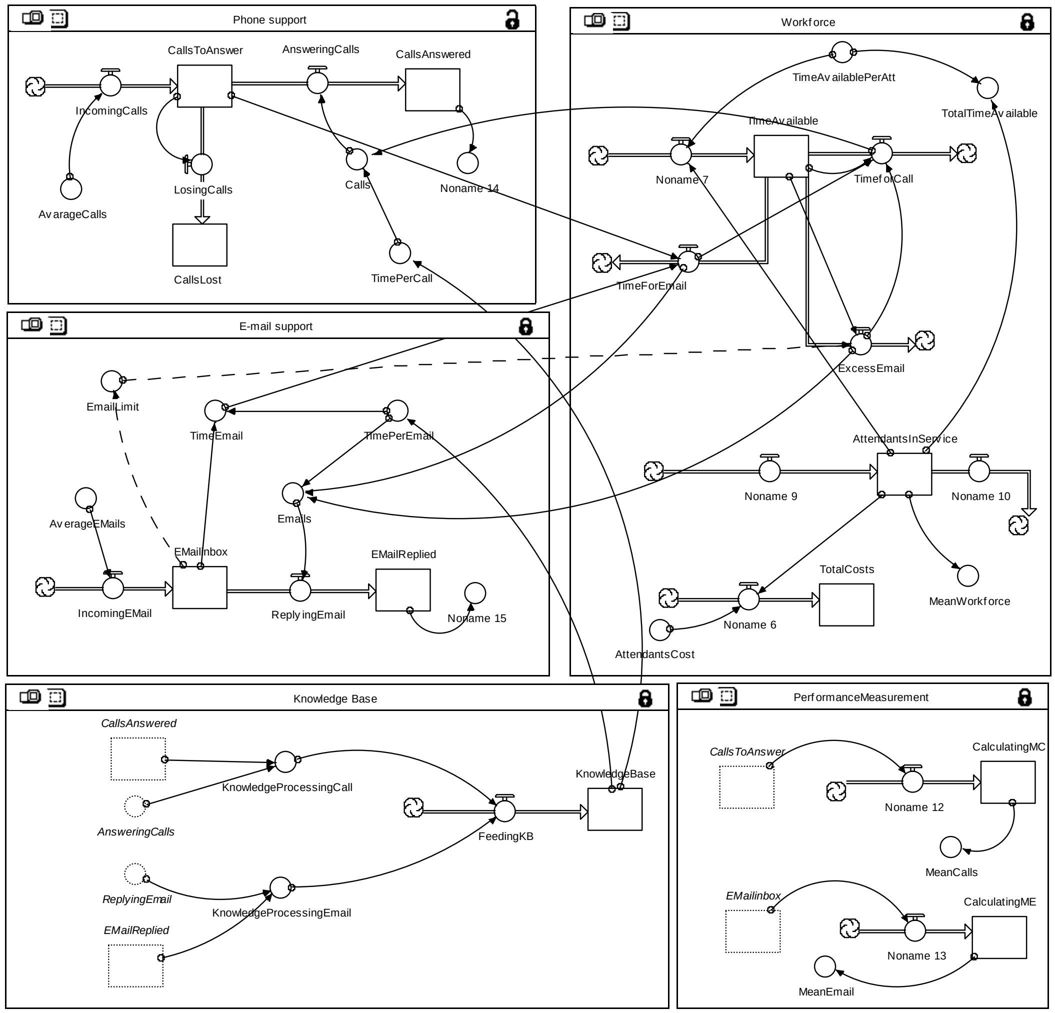
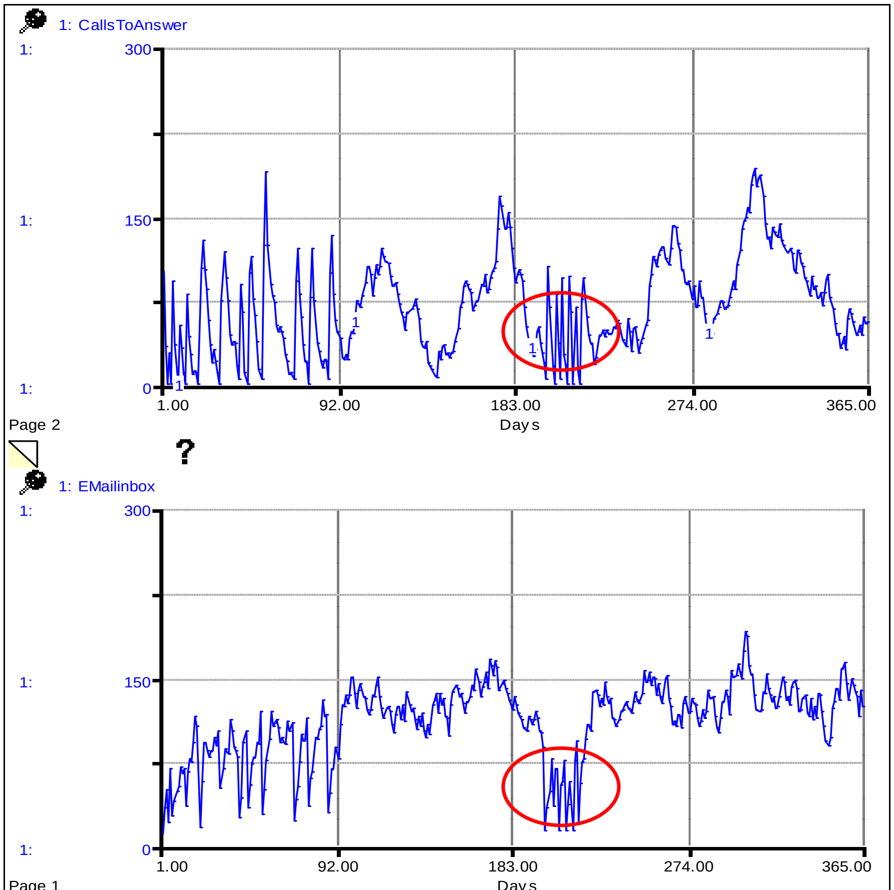


Exhibit 3: Technical support service model

Dynamic complexity of the model is also regulated through a series of variables representing several activities. *AverageCalls* and *AverageEmails* represent the amount of calls and emails that arrive each day. Both are statistically represented by Poisson Probability functions.

Scenario 1: Pilot Test

Scenario 1 served as a pilot test for the model, in order to validate if the output data from the model was effectively representing the firm´s reality. This scenario does not consider a periodical use of a Knowledge Base. Exhibit 4 shows the simulation outcomes for a 365 day period



WaitingCalls	69.09	WaitingEmail	110.38
CallsAnsweredPerDay	78.64	EmailRepliedPerDay	32.02

Exhibit 4: System behavior considering low stock of knowledge

As shown in Exhibit 4, the amount of calls to answer has a fluctuant behavior, with peaks near 150 calls per day. The situation with email inbox is similar with peaks over 150 emails per day. When *CallsToAnswer* reaches zero, attendants boost their email replying, visualized in Exhibit 3 between the 190th and 230th days of the simulation period, when the amount of emails to reply reduces drastically due to the near-zero level of *CallsToAnswer*.

This behavior can also be seen at different moments of the simulation in a lesser scale, sustaining the fact that when *CallsToAnswer* reach levels close to zero, the attendants have more time available to reply emails.

Exhibit 4 also shows that the average amount of non-attended calls – *WaitingCalls* - per day is 69,09, this means that on an average day, 69,09 calls will be in the waiting line. For emails the *WaitingEmail* average is 110,38.

In order to test and validate the model, the outputs of *CallsAnsweredPerDay* and *EmailRepliedPerDay* were confronted with actual data of the firm.

Variables	Outputs of Simulation	Actual Data	Divergence (%)
Calls answered per day	78,64	81,31	3,28
Emails replied per day	32,02	32,81	2,40

Table 1. Validity Test.

According to Table 1, the errors between actual data and simulation outputs are less than 4%, thus, making the model reliable for further experiments.

Scenario 2: Knowledge Base considered

Once the model was tested and that its reliability was confirmed, the Scenario 2 considers the use of a Knowledge Base as a service time reducing element.

Exhibit 5 shows the results of this scenario. In this Scenario, the Knowledge Base starts being used after the first 1000 calls answered and 1000 emails replied (approximately the first 90 days of the simulation).

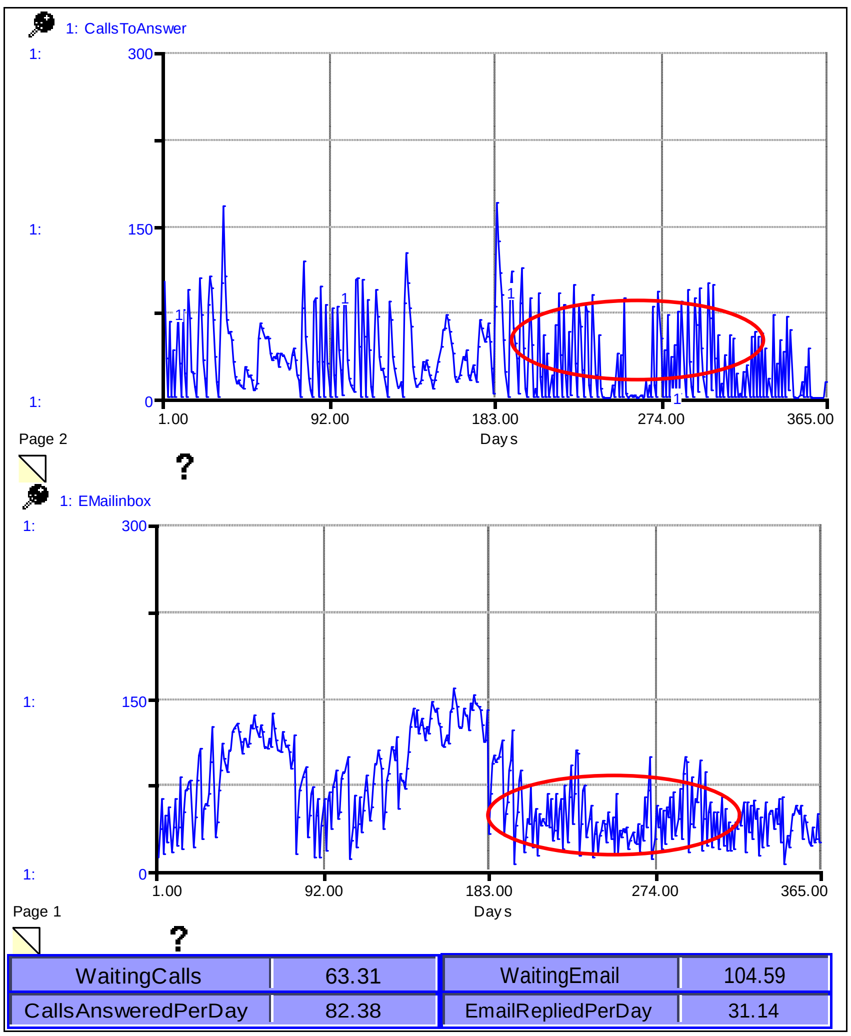


Exhibit 5: System behavior considering high stock of knowledge

As shown in Exhibit 5, the amount of *CallsToAnswer* is lesser than in Scenario 1. This is due to the use of a Knowledge Base, which allows to reuse the knowledge incorporated in the technical support. There is also a 120 days period approximately when the amount of emails to reply reduces significantly below the 150 emails limit, at the same time when *CallsToAnswer* reduces its backlog.

Exhibit 5 also shows that the average amount of non-attended calls – *WaitingCalls* - per day is 63,31, this means that on an average day, 63,31 calls will be in the waiting line. For emails the *WaitingEmail* average is 104,59.

Discussion

Table 2 illustrates the summary of the results in both simulations.

Key-Performance Indicators	Scenario 1	Scenario 2	%
Waiting Calls (Number of calls)	69,09	63,31	-8,36
Waiting Email (Number of emails)	110,38	104,59	-5,24
Calls answered per day	78,64	82.38	+4,75
Emails replied per day	32,02	31.14	-2,74

Table 2. Summary of the results.

The results have indicated that *KnowledgeBase* do have significant influence on the service quality in knowledge-intensive service systems.

As shown on Table 3, Scenario 2 presents reductions for both waiting calls and waiting emails, for the first one around 8% and for the latter around 5%.

This reduction can be explained by using McElroy´s KMCI Model, where the use of artifacts and codification tools able changes in service and process behavior, working as a feedback loop that reinforces the organizational learning process.

In other words, workers increase their service speed and are capable of answering more calls and replying more emails, by using a knowledge base as a stock of knowledge about past services.

Table 2 also presents the results for calls answered and emails replied. For the first one, there is an increase of calls answered of 5% approx., this increase means that technical operators are able to answer 4% more calls per day, once the Knowledge Base is implemented.

For emails replied, there is a reduction of 3% approx., although, this reduction implies on lesser emails answered, the percentage of difference can be understood as a indirect effect of the models random variability. This difference would represent numerically around one (1) email less answered per day.

Conclusions and Future Research

Flexibility in service operations and design-ability are the fundamental requirements of modern day service sectors. In today's customer driven market, these requirements are of paramount importance more than ever before.

This paper has tried to demonstrate the usefulness of simulation techniques, such as System Dynamics, in service system design. Specifically, it aimed to analyze the effects caused by knowledge reuse in a technical support service.

It concludes that knowledge management implementations should be analyzed earlier in the design phase, supported by simulation techniques for scenario-testing and evaluation. The System Dynamics model was developed using real data of a software-house. This data was used to create two different scenarios, showing the importance of knowledge management initiatives in knowledge-intensive activities.

Even though this paper culminates in the recommendation of using simulation techniques for service system design in the studied field, it calls for future extension of this research into the specific details of knowledge conversion, i.e. the SECI model of Nonaka and Takeuchi (1995) so as to facilitate the storage of knowledge in the *KnowledgeBase*; as well as processes such as organizational forgetting and un-learning that outflows the *KnowledgeBase* stock. There is also enough scope to add new variables into the model (e.g. organizational culture factors, motivation issues, demographic influences, etc.), which influence service system design.

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