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# SIMULATION FOR BUSINESS PROCESSES AND INFORMATION SYSTEMS DESIGN

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## ABSTRACT

Business Process (BP) literature promotes the value of business processes as essential gearwheels that help organizations to reach their goals. Similarly, many process design approaches claim that Information Technology (IT) is a major enabler of business process, a view also shared by the Information Systems (IS) community. Despite this, BP and IS approaches do not provide clear guidance on how to assess the benefits that a given IS design may bring to the BP prior the IS implementation. Nor is clear indication of which modeling techniques could be used to assess such relationship. This paper uses the insights gained during a UK funded research project, namely ASSESS-IT, that aimed to depict the dynamic relationships between BP and IT to propose an alternative framework to develop BP simulation models that depict the dynamic behavior of the relationships between BP and IS.

## 1 INTRODUCTION

Business Processes (BP) became the focus of continuous improvement efforts during the 1940's (Davenport and Stoddard 1994). Despite BP was studied throughout the years under various different disciplines it was not until the beginning of the 1990's when the process movement became stronger. Business Process Reengineering also named Process Redesign, or Process Innovation is today one of the most popular concepts in business management (Davenport 1993; Hammer and Champy 1993). The study of business processes, however, is not isolated and has always been related to Information Technology (IT). IT is considered one of the most important enablers of process change. For example, in one of the first articles about BPR, Davenport and Short (1990) argue that together, processes and information technology can be seen as a new industrial engineering that may revolutionize the way in which organizations operate.

Most of the advocators of the business process reengineering movement highlight the importance of the role that IT plays in the reengineering process. Many argue that IT should be seen as an enabler of organizational change rather than as a tool to implement business processes (Davenport 1993). Childe, Bennett and Maul (1994) for example, state that the initiative to move towards BPR in many cases originates from the IT departments. In one of the first empirical studies on IT-enabled BPR, Grover, Fielder and Teng (1994) claim that the success of IT to enable BPR lies in Information Systems (IS) strategy integration. They contend that the success of IT-enabled BPR efforts will succeed only if they are directed through a strong integration with strategy. This relationship, however, is not fully explored in most of the existing business process methodologies, or in the IT domain. This research assumes that the relationship between BP and IT can be seen as a three-layered structure, namely Business Process, Information Systems and Computer Networks (CN). Business processes usually rely on the support provided by the information systems to perform many of the activities. Similarly, the information systems that support these processes also depend on the underlying communications infrastructure, namely computer network

The relationship between BP and IT can be depicted as shown in Figure 1.

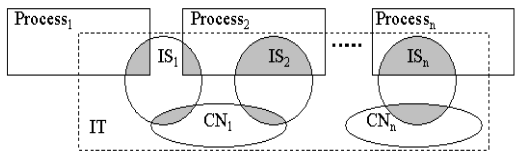


Figure 1 BP, IS And CN Relationships

The processes, which may be found in any organization, are represented in the diagram by the rectangles. The information systems that support these processes are depicted by the circles, and the ovals represent the computer network infrastructure that the information system operates on. It must be noted that organizations will have more than a single process running and that it is possible for an information system to support more than one process, and that more than one information system can run on a single computer network.

Figure 1 illustrates that the relationship between BP and IT can be seen as a three inter-related layers, BP, IS, and CN. Figure 1 suggests that this is a complex relationship and implies that changes in one domain may affect either or both of the other two domains. This is especially true of the information system layer, which connects both the process layer and the computer network layer.

This paper uses the insights gained from a UK funded research project, namely ASSESS-IT, that used Business Process Simulation and Computer Network Simulation techniques to model the dynamic behavior of the relationships between BP, IS and CN. This paper takes the findings from the project and uses the knowledge gained to propose a new framework that applies business process simulation techniques to depict the interactions between business processes and information systems, namely the BPISS framework.

The case study used to test the framework is not designed to be exhaustive but rather to show that the development of simulation models to capture the behavior of business process and information systems is possible, and that the results provide relevant information to asses the impact that IT may have on business processes. The case study also provides opportunity to discuss the advantages and limitations of the proposed framework.

## 2 THE ASSESS-IT CASE STUDY

The case study used for ASSESS-IT consists of two collaborating organizations in Greece. One company is a branch of a major multinational pharmaceuticals organization (we will refer to this company as Org-A), while the other is a small-sized regional distributor of Org-A's products (we will refer to this company as 'Org-B').

The case study was carried out within a single business unit, which deals with hospital consumables. The business unit does not produce products but imports them from other Org-A production sites across Europe. The goods are stored in a warehouse that operates as a central dispatch point for all products, which are then distributed to the company's customers via a network of collaborating distributors. One of these distributors is Org-B.

Org-B is a small company that has signed an agreement to act as Org-A's exclusive distributor of Medical unit products. The agreement states that Org-B's responsibilities include:

1. Receiving orders from Org-A customers.
2. Maintaining an adequate inventory of products that fulfill the orders.
3. Distributing the ordered products to customer premises.

Due to the nature of the products, Org-B, as the company in charge of delivering products, has to operate within rigorous deadlines. The agreement between the companies, stipulates that each order has to be fulfilled within 24 hours for products delivered within the city of Thessaloniki, or within 48 hours for the rest of northern Greece.

Org-A management has noted, however, that these targets are rarely met in practice. A brief analysis by the companies seemed to attribute the problems to some inefficiencies within the ordering system as well as difficulties being experienced by Org-B in maintaining their inventory at an optimal level. In addition to this the communication system between the two companies was also seen as slow and cumbersome. The effects that these inefficiencies caused were seen as a major source of customer dissatisfaction, so an in-depth analysis of the problem was commissioned. The main objectives of the ASSESS-IT study were:

1. To examine the existing business processes that were felt to be responsible for long lead times for order fulfillment.
2. To determine the sources of problems and propose alternative solutions.
3. To evaluate the potential of introducing appropriate IT to improve communication between the two companies.

In order to calculate the business effects of changing the underlying IT, the ASSESS-IT framework aimed to develop a computer network model, including IS design, identify the information that may be relevant to the BPS model and incorporate it in the latter. The framework is divided into two major phases. The first phase develops the Computer Network Simulation model. The second phase develops the Business Process Simulation Model and uses the outputs of the CNS model to reflect the impact of the IT in the BP. A complete description of the ASSESS-IT framework and analysis of the results can be found in Serrano (2002).

## 3 ASSESS-IT:LESSONS LEARNED

The results obtained from ASSESS-IT showed that the impact that the computer network infrastructure were heavily dependent on time. These results also demonstrated that due to current network technologies, the information systems that could suffer from changes to network architecture are those that depend on time. The type of systems that the ASSESS-IT approach aimed to address, however, do not fit within this category. The experiments showed that changes to the network infrastructure and to other parameters (network traffic) did not have a considerable effect on IS performance, and consequently, did not affect the BP performance. Similar results were found in the business process-modeling phase. The results obtained in this phase showed that using IT to improve business response time does not necessarily improve process performance and might have negative results. The experiments did not show a significant improvement on business process performance despite the fact that the time for those activities that used the new IS was dramatically reduced. A deeper analysis of this situation suggested that the problem was due to the fact the ASSESS-IT approach concentrated on depicting the way IT affects processing time, but not in the way IT affects process performance. Business process modeling experiments showed that time was not a parameter that could affect process performance (Eatock, Paul and Serrano 2002). The experiments showed, however, that there are other IS parameters that affect BP performance. For example, once it was detected that the backordering process was a major system bottleneck, it was proposed to use the EDI system to alleviate this problem. Therefore, the IS was designed, amongst other things, to reduce the number of backorders. This information, though, could not be reflected in the business process model because the BP model was designed to represent the percentage of backorders as a fixed number and not dynamically. Reducing the backorders percentage manually (from 30% to 5%) demonstrated that the reduction of backorders would reduce the overall processing time. This figure was directly related to the way the IS would handle the backordering process.

Two conclusions can be obtained from the ASSESSIT approach exercise. A) The computer network infrastructure does not affect the performance of information systems used to support organizational processes. Consequently, the overall business processes performance is not affected, in a significant way, by changes to the CN infrastructure. Therefore, the use of a computer network model is, in the context of the ASSESS-IT approach, unnecessary. B)The experimentation with different BP scenarios provided evidence that suggests that in order to portray the benefits that the use of an IS may bring to the business processes, it is necessary to obtain measurements of the way the IS behaves over time.

In order to provide a modeling approach that depicts the relationships and interactions between BP and IT, it is necessary to focus on the relationship between BP and IS alone. Furthermore, the insights gained from the experiments with different BP scenarios imply that the parameters that govern the relationship between business processes and information technology are not those that are related to time constraints but are instead those that are related to IS performance measurements. It was observed that time reduction on certain activities of the ordering process did not improve business process performance. On the other hand, IS performance measurements, such as the reduction of the number of backorders produced by the IS, improved the overall process performance. These facts lead us to think that a new BP/IT integrated approach was needed. Therefore, the new approach should focus on the relationship between BP and IS, and more importantly, should depict IS behavior measurements. This means, it is necessary to model IS performance. IS performance measurements are also known as information system's Non-Functional Requirements (NFR) (Sommerville 1997; Bennett, McRobb and Farmer 1999). Most IS modeling techniques, however, aim to depict functional requirements. Non-Functional Requirements, on the other hand, are not easy to represent in a measurable way, thus, a limited number of techniques and approaches can be found (Nuseibeh and Easterbrook 2000). The results rendered by the ASSESS-IT approach highlighted the need to portray the dynamic behavior of the IS as it evolves over time. The following section presents the rationale for a new hypothesis that uses the ASSESS-IT framework results as the base to propose a new approach that can be used to identify NFR that affect IS performance and to model the behavior of the IS and the BP as they evolve over time.

## 4 THE BPISS FRAMEWORK

This paper uses the experience gained from the ASSESS-IT project, and proposes an alternative approach to address the limitations found. The new framework, namely BPISS (Business Process and Information Systems Simulation), attempts to portray the behavior of both IS and BP using discrete-event simulation techniques. The major objective of the BPISS is to provide guidelines to develop a simulation model that provides stochastic measurements of the way business process and information system behave, thus assessing the impact that IS may have on BP. To achieve this objective, the BPISS framework is divided into sixteen tiers. The first tier can be considered as a simulation study on its own where the major aim is to develop a model of the way current business processes operate (as-is BP model). The results from ASSESS-IT showed that the development of as-is BPS models could help to identify possible process limitations and areas of improvement, including possible IT solutions. The BPS model derived from this tier will be used in subsequent tiers to a) identify process limitations, b) propose alternative BP and IT solutions, c) identify non-functional requirements, and d) validate the BPISS model. Tiers Two to Eight are the guidelines to develop an as-is BPISS model. The BPISS model considers the way the functionality of the IS supports business processes. Because this is an as-is model, the functionality of the current system should be portrayed. If the business processes are not supported by IT, the functionality of the manual system should be modeled instead. Tiers Nine to Twelve are the guidelines to develop the to-be BPISS model considering the functionality of the proposed IS solution together with the corresponding changes to the BP. Tiers Thirteen to Sixteen use (Banks et al. 2000) simulation steps (steps nine to twelve) to conclude the simulation study. The tiers in the BPISS framework are fully described in the following section.

### 4.1 Tier One:As-Is BPS Model Development

*Aim*. To develop an as-is BPS model. The BPS model derived from this tier will be used in subsequent tiers to a) identify process limitations, b) propose alternative BP and IT solutions, c) identify non-functional requirements, and d) validate the BPS /ISS model.

*Activities and Techniques*. The simulation steps proposed by Banks et al. (2000) will be used in this step to develop the as-is BPS model. The simulation study proposed in this tier though, stops in the validation step because subsequent tiers of the BPISS framework involve the activities proposed in the remaining steps of Banks et al. framework.

### 4.2 Tier Two: Identifying BP Limitations And Possible IS Solutions

*Aim*. The as-is BPS model developed in Tier One will be used in this tier to: One, identify current process limitations. The ASSESS-IT framework showed that the insertion of IT in poorly-designed processes does not improve process performance. Thus, process design problems need to be overcome, whenever possible, before proposing IT-based solutions. Two, identify those processes where performance can be improved by the insertion of IS. ASSESS-IT also found that the analysis of process design problems also helped to identify those processes that can benefit from the use of a new IS. In cases where the organization is already supported by an IS, this step will identify those processes where IS are currently used.

*Activities and Techniques*. To identify process limitations the performance measurements obtained from the BPS model should be assessed against organizational performance goals, which were previously captured in Tier One. In doing so, the modeler can identify those processes where performance measurements are not satisfactory. Experimentation, with different scenarios can be used to identify possible causes that produce low process performance, such as poor process design, inappropriate use of resources, and so on. Once the proposed scenarios are tested, and process-related problems are identified, the insertion of IS should be considered next. To do so, IS and BP analysts should coordinate efforts so the functionality of the new IS addresses the limitations found in Tier One. Therefore, this tier also aims to provide a general description of what the proposed IS system is expected to do, in other words the functionality of the IS. In doing so, BP and IS modelers will be able to assess which processes can be benefited from the insertion of the IS and the ways it may improve process performance.

It is argued that use cases can be used, among other things, to capture user requirements, to test the correctness of the system, and to coordinate IS analysis and design (Jacobson et al. 1992; Stevens and Pooley 2000). The BPISS framework proposes the use of UML techniques, specifically use cases, to capture the functionality of the IS and to validate the BPISS model. The authors, though, recognize that other IS techniques can be used to portray IS functionality and advocates that the techniques used in this step should be chosen considering the modelers' and organization's preferences.

### 4.3 Tier Three: Identify And Capture IS Non-Functional Requirements

*Aim*. Because the BPISS framework attempts to portray the way the functionality of the system will affect BP performance, this tier aims to identify and capture the expected performance of the information system. In Tier Two use case techniques were used to capture both, the functionality of the system and the way the system is expected to deliver that functionality (non-functional requirements). This tier aims to use the BPS model to identify other performance measurements that may have been overlooked in Tier Two.

*Activities and Techniques*. IS non-functional requirements are those that describe how well the system delivers the functional requirements, in other words, how the system should behave. Professionals and academics advocate that non-functional requirements and organizational objectives are strongly related, therefore, non-functional requirements should always be captured considering the organizational context. The BPISS attempts to depict a specific type of non-functional requirements, namely performance requirements. The BPISS framework will use the BPS model develop in Tier One to identify performance requirements. To achieve this aim, BP and IS modelers should analyze those processes and activities that were considered to be affected by the proposed IS, previously identified in Tier Two. A closer analysis of the behavior of such processes and activities can provide useful information to identify other IS performance requirements that could have been overlooked using current IS modeling techniques. The Use Case model developed in Tier Two should be complemented with the findings of this tier.

### 4.4 Tier Four: Describe Current IS Functionality

*Aim*. This tier aims to capture three major aspects of the current IS. One, to identify the overall workflow of the IS activities that are related to BP so this can be simulated in the as-is BPISS model. Two, to identify and understand how the data manipulated by the IS may affect BP entities, thus BP performance. Three, to identify the IS operations performed in during the process flow, so they can be represented in the BPISS model.

*Activities and Techniques*. Taking into account that UML techniques were used to capture user requirements, this tier advocates the use of three UML modeling techniques: Activity models to capture the system's flow and identify relationships between activities. Collaboration diagrams to identify the collaboration between IS components and the IS operations performed. Finally, class models will be used to identify those classes that are related to the business entities.

## 4.5 Tier Five: Map BP And IS Entities

In the ASSESS-IT framework two different types of entities were defined. The first type is named Record Entities (RE) which are those entities found at the business level. RE usually represent objects that contain information and are used in the BP model to represent process behavior. For example, in the case study used in the ASSESS-IT project, the record entities used in the BP model were orders, backorders, and partial orders. The second entity type defined in the ASSESS-IT framework is named Field Entities (FE). FE are the collection of entities that represent the information contained in a RE. The IS usually uses the information conveyed in these entities to perform part of its functionality. For example, in the case study mentioned earlier, the IS will use the information contained in the order, such as product type and number of items requested, to assess whether a backorder is required or not.

*Aim*. This tier aims to:

1. Identify all RE used in the business process level and map them to their corresponding FE.
2. Map the FE to the corresponding process/activity in the BP model.
3. Identify the operations performed during these activities and that affect RE or FE.

*Activities and Techniques*. In Tier Four of the BPISS framework a number of IS models that depict IS entities (classes or objects in UML) were produced. This tier will use those models to create a table, namely Record Entity/Field Entity Relationship (REFER), which relates the entities that are used in the BP model, their corresponding FE, the activities where FE are used to control the IS flow, and the operations performed when using these FE. The first step to build the REFER table is to identify RE and their corresponding FE. The class diagrams developed in Tier Four can be used to identify those classes that represent BP entities. Attributes of these classes represent the FE. Because not all of those attributes are used to control IS flow, the IS analyst should identify those attributes that are used to control flow and register them in the FE column. The activity diagrams developed in Tier Four will be used to identify which processes and/or activities use the FE identified before. The activities/processes are registered in the process/activity column. If an FE is used in more than one process/activity, this should be registered as a separate row. Finally, collaboration diagrams will be used to identify the IS operations that use or transform the FE in each of the activities. In doing so, each row of the REFER table provides information about a given FE, to which RE it is linked, in which activities it is involved, and which is the aim pursued by the IS when using the FE (IS operation). An example of a REFER table is shown in Table 1.

Table 1 A REFER Table Example

| Record Entity | Field Entity | Process/Activity | Operations |
|---|---|---|---|
| Order | product_id | check warehouse activity | To identify the product requested |
| | product_quantity | check warehouse activity | To check product_stock stock levels against product_stock |
| | Product_stock | check warehouse activity | To check product_stock stock levels against product_stock |

## 4.6 Tier Six: Develop The As-Is BPISS Model

*Aim*. This tier aims to develop the as-is BPISS model using the information collected in previous tiers, in particular, the information captured in the REFER table. Business process models usually do not include informational aspects of the organization. For example, to obtain performance measurements of a backordering process, the modeler needs to know, amongst other important information, the number of backorders that will be produced by the system. These figures are usually obtained during the data collection step. To develop the as-is BPISS model the modeler needs to identify the RE and FE that are related to business performance and the business rules, including informational aspects, that may affect them. Following the same example of a backorder, the modeler needs to identify the activity or activities where a backorder is produced and the business rules that produce a backorder.

*Activities and Techniques*. The BPISS framework considers the IS as a black box (see Figure 2). The relationship between BP and IS can be seen as relationships between input and output interfaces in each process and/or activity with the corresponding interfaces in the IS. For instance, the relationship between BP output-IS input interfaces is used to obtain information contained in BP entities (FEs) to perform the corresponding operations in the IS. Subsequently, the relationship between IS output-BP input interfaces is used to reflect the changes that the IS produces on the BP entities. It can be observed in Figure 2 that any input to the IS is reflected at any activity within all processes.

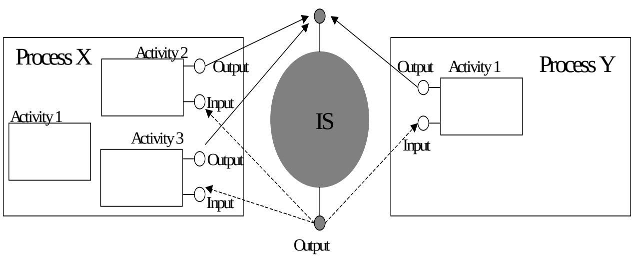


Figure 2 BP and IS Relationship

To develop the as-is BPISS model, this tier will modify the as-is BPS model developed in Tier One so it includes the information system behavior. In doing so, it is assured that the components used in the as-is BPS model, such as data distributions, resources, and entities are consistent in both models. The development of the as-is BPISS model is divided in the following steps:

*One.* Represent FE in the RE. FE should be represented in the BPISS model as attributes of RE. This information can be obtained from the REFER table. The modeler should also identify other FE that are not linked to a specific RE. These FE should be recognized in the REFER table as Models' FE and should be represented as Model's attributes in the BPISS model.

*Two.* Program the functionality of the system. The modeler needs to insert programming code that represent the business conditions that produce changes to FE and RE together with the consequences of these changes. Most of current BPS software provides the facility to add programming code to any activity and make changes to different model elements, including entities and attributes. Furthermore, the modeler can chose the simulation conditions when the code should be processed. For example, the code can be processed when an activity accepts an entity or when the latter is released from the activity. This adds the flexibility of choice to select the most suitable condition to run the code. To achieve this aim the modeler can use the information provided by the REFER tables, which indicate in which processes/activities the code should be inserted. In case that the information described in the REFER tables cannot provide enough details about the functionality of the system in a given activity, this information can be obtained analyzing the activity and collaboration diagrams developed in Tier Four.

### 4.7 Tier Seven: Verify The As-Is BPISS Model

*Aim.* This tier aims to ensure that the computerized representation of the model is correct.

*Activities and Techniques*. The BPISS model is, per se, a simulation model. Thus, existing techniques to verify simulation models apply to the BPISS model. Detailed information about verification techniques can be found in Banks et al. (2000) and Law and Kelton (2000).

### 4.8 Tier Eight: Validate The As-Is BPISS Model

*Aim.* This tier aims to ensure that the model is an accurate representation of the real system.

*Activities and Techniques.* Because the as-is BPISS model is based on the as-is BPS model developed in Tier One, and the latter has already been validated, this tier aims to validate the as-is BPISS model against the as-is BPS model. To validate the as-is BPISS model, performance measurements from the as-is BPISS model are compared against those from the as-is BPS model. Amendments to the BPISS model should be done until the results of the as-is BPISS model match, in the best possible way, the results from the as-is BPS model.

### 4.9 Tier Nine: Describe To-Be IS Functionality

*Aim.* The aim of this tier is to describe the functionality of the proposed IS so this can be included in the as-is BPISS model.

*Activities and Techniques.* This tier will use the same approach and modeling techniques as those used to describe the current IS functionality in Tier Four. Furthermore, the models developed for the current IS can be used as the basis to create the new IS models. Thus, a new set of activity, collaboration, and class diagrams will be derived from this tier.

### 4.10 Tier Ten: Map BP And IS Entities

*Aim*. This tier aims to update the REFER table obtained from Tier Five, so the new RE and FE that may be derived from the new IS are registered in the REFER table.

*Activities and Techniques.* Mapping BP and IS entities in this tier follows the same process as the one used to map these entities in the current model in Tier Five with the difference that this tier aims to map BP and IS entities of the proposed IS. BP entities are very unlikely to change, though the new IS may include new FE entities that need to be added to the REFER table. Therefore the same guidelines and modeling techniques used in Tier Five will be used in this tier to update the REFER table.

### 4.11 Tier Eleven: Develop The BPISS To-Be Model

*Aim.* This tier aims to program the behavior of the proposed IS in such a way that the model reflects any changes that the IS produces in the BP, specifically changes to FE and consequently their corresponding RE. The advantage of this model over an ordinary BPS model is that the BPISS model can assess the impact that the new IS may have on process performance. Furthermore, the modeler can also identify conflicts and tradeoffs between non-functional requirements and select the most suitable BP and IS scenario.

*Activities and Techniques.* The first step is to develop the to-be BPISS model is to add/remove any RE or FE that may have changed from the as-is model (see Tier Six- Step one). It is very unlikely that RE entities will change, however, the new functionality of the IS may have added other FE that need to be added or removed from the BPISS model. It is expected that some activities in the business processes will change due to the insertion of the new IS. Therefore, the second step in this tier is to identify those processes and activities that need to be changed or removed from the BPISS model. Once changes are made in the BP level, the final step is to program the functionality of the new IS. The same guidelines described in Tier Six-step two will be used to program the new IS functionality with the difference that the new REFER table obtained from Tier Ten will be used.

### 4.12 Tier Twelve: Verification?

*Aim*. This tier aims to ensure that the model is reflected accurately in its computerized representation.

*Activities and Techniques.* The BPISS model is, per se, a simulation model. Thus, existing techniques to verify simulation models apply to the BPISS model. The modeler, though, needs to take into account that the verification of the IS functionality needs to be assessed as well.

### 4.13 Tier Thirteen: Result And Analysis

*Aim*. The results provided by the BPISS model need to be analyzed in order to assess whether the proposed BP and IS design satisfies the organizational needs. An advantage of the BPISS model over traditional BPS models is that the results obtained from the former reflect the impact that the proposed IS has on the processes themselves. Another advantage is that the BPISS model can provide other stochastic information related to IS performance. Thus this tier aims to obtain information from the BPISS model to predict BP and IS performance and compare it against the organizational goals and the user requirements (non-functional requirements) identified in Tier Three.

*Activities and Techniques*. The BPISS model will provide two performance measurements, process and IS performance. Thus the analysis of these results should be performed by both BP and IS analyst. Depending on the results, the following tier indicates whether the proposed IS and BP need to be redesigned or if experimentation with other parameters or ranges of the existing ones, is considered necessary.

### 4.14 Tier Fourteen: More Runs?

*Aim*. The aims of this tier is twofold: One, to assess whether the redesign of IS and/or BP is needed; two to investigate the possibility of experimenting with different BP/IS scenarios.

*Activities and Techniques*. This tier analyses the results obtained from the BPISS model and compares them against the non-functional requirements identified in Tier Three assessing, in this way, whether the proposed BP and IS satisfy these requirements. If the results show that organizational goals and performance requirements are not met, the redesign of BP or IS functionality may be needed. If the redesign of BP is needed, the modeler should re-start the design from Tier Eleven. If changes to the IS functionality is required the tiers should start from Tier Nine.

It is very likely that changes to input parameters may cause unexpected variation on the output performance measurements. Thus, the relationship between input and output parameters should be carefully analyzed. The BPISS model is designed in a way that performance measurements of both BP and IS can be obtained. This can help to observe the impact that changes to IS input parameters may have on BP performance and vice versa. In this way, the experimentation with these parameters allows the modelers to optimize the model so the scenario that better suits the organizational needs can be identified.

### 4.15 Tiers Fifteen: Documentation And Sixteen: Reporting And Implementation

The major aim of the BPISS framework is to provide specific guidelines to create a simulation model that reflects both BP and IS performance. Therefore, it can be said that the contribution of the BPISS model ends after the experimentation tier is finished (Tier Fourteen). This research, though, recognizes that it is important to include the documentation and reporting, and implementation tiers in the BPISS framework so these are not excluded from the simulation study. Because these tiers do not change from their analogue steps proposed by Banks et al.'s (2000), this research will use the guidelines provided in the documentation and reporting, and implementation steps provided in Banks et al.

## 5 EXPERIMENTING WITH THE BPISS FRAMEWORK

The development process of the BPISS framework involves the design of several BP and IS models. Considering that this research does not attempt to provide new modeling techniques in these domains but to use the knowledge in these areas to support different steps of the BPISS framework, this paper omits the description of the development of BP and IS models and concentrates on the most relevant issues identified during the experimentation of the BPISS framework.

### 5.1 Identifying NFR

Two IS non-functional requirements related with performance measurements were identified for the proposed IS. The first and most important requirement was requested by Org-A and establishes that the overall delivery time, including backorders, should be 24 hours, for products delivered within the city of Thessaloniki, or within 48 hours for the rest of northern Greece. It was expected that the introduction of the new IS would reduce current delivery times so they fit the requirements previously mentioned. The second requirement was obtained during experimentation of the BPS model. It was detected that the backordering process was a major system bottleneck, and that delivery times depended on this process. The experimentation with the as-is BPS models showed that when reducing the back-orders percentage from 30% to 5%, the overall processing time was significantly reduced. Therefore, a performance requirement that was not identified before is related to the percentage of backorders produced by the IS. Therefore, the new IS should reduce backorders.

### 5.2 Analyzing BP And IS Performance

The results of the to-be BPISS model reported a significant reduction in the total lead times, in particular, backorder lead times. These reductions in lead-time, however, were still below the organizational targets. An interesting observation is that the percentage of backorders produced by the to-be BPISS model, which includes IS functionality, reported an increase of 9.6% contrary of what it was expected. A possible reason that may give rise to this situation may be related to the product stock levels. The minimum product stock level used in the model (10 products) produces a greater number of backorders. This event, though, does not affect backorder lead-time because the new system schedules delivery times in a more accurate manner than the manual system. The results obtained from the BPISS model showed that a possible way of reducing backorders and consequently lead times is to increment the minimum stock level for each product.

Experiments were conducted in order to determine the minimum stock levels for each product. Experiments were conducted that recorded stock levels and correlated these levels with the days that requests for a product produced a backorder. From the results of the experimentation it could be seen that if the minimum stock level was set at 100 products then backorders could be effectively reduced to just 5%. It was also discovered that increasing the minimum stock level over this margin did not reduced backorders beyond this level.

## 6 CONCLUSIONS AND FURTHER RESEARCH

This paper argues that despite the fact BP and IT interact in practice, existing BP and IS design approaches and modeling techniques aim to design organizational processes or information systems, but do not provide a clear guidance of how to address the relationships between them. Trying to address this problem, the ASSESS-IT framework proposed the use of BPS and CNS to coordinate the design of business process and IT simulation models and depict the effect that changes on any of these domains may have on the others.

The results derived from the ASSESS-IT framework suggest that the relationship between BP and IT can be described as the relationship between business processes and the information system that support those processes, and not as a three layered structured (BP, IS and CN) as it was initially thought in the ASSESS-IT framework. Furthermore, the results from the ASSESS-IT framework found that in order to depict the interactions between BP and IS it is necessary to portray IS non-functional requirements, in particular IS performance requirements. This paper used this knowledge to propose a new simulation framework, namely BPISS, to develop simulation models that depict business process and information systems performance.

The simulation results provided by the BPISS model shows that it is possible to obtain performance measurements of the IS and depict the way the insertion of IS affects BP performance. For example, the model provided quantifiable metrics of the IS that cannot be obtained with traditional BP approaches, such as the number of backorders that the IS produces over a given period of time given a particular organizational context. These measurements helped to investigate the way IS may affect process performance. For example, new backordering delivery lead times that considered the effects that the IS has on the backordering process were obtained.

Another outcome of the BPISS framework is that it rendered evidence that confirms that IS static modeling techniques cannot always predict the way the IS behaves in practice. For example, based on the IS description provided by static models, it was thought that the IS would significantly reduce the number of backorders. After running the BPISS simulation model, it was shown that this was not the case. The experiment showed that depicting the behavior of the IS and the effects that the latter would have on the processes is feasible, however, this was not and easy task. Despite the simplicity of the example used the development of the model proved to be complex. It is thought that the higher the complexity of the IS the harder the construction of the simulation model. Hence, there is the need to test the BPISS framework with more complex IS. Regardless of these drawbacks, the results of the experiment showed that the new IS would improve the performance of the processes. Furthermore, It was noticed that the performance of the process did not depend only on the IS behavior but also on accurate changes to the business process themselves. This shows that business processes and the information systems are closely correlated and further research is needed to analyze this relationship in more detail. Finally, one of the major reasons of the complexity of this new approach was due to the fact that the discrete-event simulation tool used in our example was designed to model and simulate business process and offered limited capabilities to model and simulate information systems. Further research in this area is also needed in order to identify simulation tools that offer better capabilities to model the elements required to simulate IS or to propose the development of such tools.

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