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Highlights

- A novel method for implementing ITIL is proposed.
- The method is based on business process management and simulation modelling.
- An application case for the Incident Management process implementation is introduced.
- The method is evaluated from the process stakeholders perspective.

Met4ITIL: A Process Management and Simulation-based Method for Implementing ITIL

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Abstract

A key requirement for service providers is to define, manage and deliver Information Technology (IT) services to effectively support business goals and customer needs. Several process reference models for the IT service management (ITSM) have emerged, being Information Technology Infrastructure Library (ITIL) the reference model accepted as de facto standard for ITSM. This paper introduces a novel method for implementing ITIL which is based on business process management lifecycle and simulation modeling. An application of the method to implement the incident management process in a Spanish company is also presented. The method has been reviewed by ITIL experts and evaluated from the process stakeholders' perspective using a questionnaire. The answers provided to the questionnaire show the usefulness of the method to address the critical success factors and to support the application of adequate process management practices.

Keywords: ITSM, ITIL, IT service incident management, ITIL implementation, simulation modeling.

1. Introduction

Since the use of information management technologies has significantly increased over the last years, companies are demanding more efficient technological services and solutions. Thus, IT service providers need to focus more on service quality and the relationships with their customers than in technology and their internal organization [1][2].

IT Service Management (ITSM) is considered a sub-discipline of the Service Science [3] that can be defined as "*a set of processes that cooperate to ensure the quality of live IT services, according to the levels of service agreed to by the customer*"[4]. Conger at al. [5] add that ITSM "*focuses on defining, managing and delivering IT services to support business goals and customer needs, usually in IT operations*". In order to provide guidance to manage IT services with effectiveness, several ITSM-related standards and process models have emerged [6][7][8], such as ISO/IEC 20000 [9][10][11], CMMI-SVC (Capability Maturity Model Integrated for Services) [12][13], and ITIL (Information Technology Infrastructure Library) [14]. The implementation of ITSM models allows the improvement of IT service quality and customer satisfaction, and the reduction of the service provision cost [15][16]. Thus, implementing an ITSM reference model has become one of the main priorities for IT companies to assure their continuity and maximize the return of investment and business opportunities [17].

A well-defined ITSM framework results in a better monitoring of processes so that companies can reach higher maturity levels. Higher maturity enables a global understanding and a better vision of processes. When the productivity and efficiency of process activities are improved, the organization can develop, maintain and deliver high quality services, meet business objectives and obtain a higher customer satisfaction. To help IT companies improve their maturity level, several models for the assessment and improvement of ITSM processes have been developed, such as TIPA for ITIL [18][19], ISO/IEC 15504-8 [20] and CMMI-SVC [12][13]. These models define a process improvement approach that provide basic elements to establish process improvement goals, set a point of reference for assessing current processes, and support the process performance improvement [17].

ITIL has been accepted in the industry as the de *facto* standard for ITSM [17][21] and is adopted by organizations worldwide**.** It provides the basis for quality ITSM through documented and well-established processes that cover all the service lifecycle [22][23]. In recent years, a growing number of organizations are implementing ITIL in an attempt to improve their ITSM processes and provide significant benefits [24][25]. Given the popularity of ITIL, there are many published research papers in the field of ITIL implementation. Most of them are focused on studying the benefits of ITIL implementation in real-world organizations [26] and the critical success factors (CSF) for a successful implementation (CSFs) [26][27]. Since ITIL is a process-oriented reference model, one of the factors that most influence on the ITIL implementation success is the adequate management of processes [28][29]. Using an appropriate ITIL implementation method and a suitable process to train stakeholders are other important factors that influence on ITIL success [28].

ITIL contains a set of best practices but it does not provide a step-by-step guideline that details how to conduct the implementation of an ITSM framework in companies [30]. Besides, in research literature there is very few works focus on methods for implementing ITIL. Given the importance of having a method that aids managers through the implementation [28], we have conducted a research work in this field.

The contributions of this paper are twofold. The first contribution is a method for implementing ITIL that is based on process management and simulation modeling. The method helps to address the CSFs and to apply process management practices for implementing the appropriate processes. The method proposes the use of simulation modeling since this technique has been proved beneficial for process management in different business areas [31][32][33][34][35].

To illustrate the applicability and utility of the method proposed, the second contribution of this paper is an application case that shows the first results of how the method has helped implement the incident management process in a Spanish company.

The rest of the paper is structured as follows. Next section presents a study of the published research works related to our proposal. Section 3 introduces the research methodology used to develop the proposed method. Section 4 describes the method and Section 5 presents the application case. Section 6 and 7 include the findings of the evaluation of the method from the process stakeholders' perspective and the improvements needed, respectively. Finally, Section 8 contains our conclusions and further works.

2. ITIL implementation in organizations: related works

This section explores the research literature related to ITIL implementation projects. To analyze and classify the information about this type of projects in the research literature, a set of key topics was identified. These key topics and the reasons for their selection follow.

a) *Critical success factors*. Organizations that implement ITIL successfully obtain important benefits, such as an effective ITSM, IT alignment to business goal, and decrease of IT costs, among others [26]. Thus, it is fundamental that IT managers know the most critical factors influencing the ITIL success [26][27][28].
b) *Methods for ITIL implementation*. ITIL contains a set of best practices for the implementation of an ITSM framework but it does not provide a detailed procedure that aids IT managers through the implementation process [30]. The use of a well-designed method is one of the most influential aspects in the ITIL implementation success [28].
c) *Process implementation sequence*. ITIL framework does not suggest an implementation order for their processes. This decision constitutes the first challenge that an organization must overcome when starting an ITIL implementation [28] [36].
d) *Process management practices*. ITIL is a process-oriented ITSM framework focused on the assessment and continual improvement of processes [37][18]. So, integrating process management practices in ITIL implementation projects allows organizations to improve service quality and customer satisfaction [17].

In addition, the use of simulation modeling in ITIL processes has also been analyzed, since simulation has been widely used in different business areas to support process management tasks such as process design, process assessment and process improvement [31][38][39].

In order to find the relevant works that provide information about the key topics of ITIL implementation projects described above and the use of simulation modeling in them, two different literature reviews have been made. Even though performing a systematic review of the literature is without the scope of this work, the works related to our proposal have been formally searched and analyzed following a procedure inspired by [40]. The main steps of the followed procedure are:

a) Design the search strings for the relevant topics of the search.
b) Select the digital databases to perform the automatic searches. The searches were restricted to tittle, abstract and keywords.
c) Select the relevant works. The paper selection process was performed in the following two phases:
    a. *Phase 1*. Study the title and abstract of the retrieved papers to evaluate their suitability. The title and abstract of each paper were reviewed against the inclusion and exclusion criteria. Papers clearly irrelevant were excluded.
    b. *Phase 2.* The papers selected during the phase 1 were further reviewed. The conclusions or even the full text were read to select the most relevant papers that contain information about

the addressed topics. We also reviewed some works referenced in the papers selected in this phase that we considered interesting for the purpose of our study.

The following subsections describe the main findings of each literature review.

2.1. Main topics regarding ITIL implementation projects

In order to obtain the information available in the research literature regarding the main four topics identified in Section 2, we searched for the findings of systematic literature reviews performed in the area of ITIL implementation. The automatic searches were performed in the following databases: Scopus, Web of Science, IEEE Xplore, ACM, and SpringerLink. The searches were conducted using the search string (("literature review" OR "systematic approach" OR "systematic review") AND (ITIL OR ITSM OR "IT service management")). This search string was adapted to each individual database. The searches were restricted to tittle, abstract and keywords. Table 1 shows the inclusion/exclusion criteria applied.

Table 1
Inclusion/Exclusion criteria

Inclusion criteria	• Publications that present systematic reviews focused on ITIL implementation. • Papers that examine critical factors for the ITIL success. • Papers that study the role of process management in ITIL implementation projects. • Publications that study methods for implementing ITIL. • Papers that analyze how to determine an adequate process implementation sequence.
Exclusion criteria	• The publication abstract is available but not the full text. • Papers not written in English. • Chapters of books.

Table 2 classifies the relevant papers according to the main topic they address.

Table 2
Topics and reviewed papers

Topic	Topic description and reviewed papers
Critical success factors	Studying critical factors for the ITIL implementation success. [16] [21][29][41][42][43][44]
Process management practices	Examining the use of process management practices in ITIL implementation projects. [16][21][29]
Methods for implementing ITIL	Analyzing methods for implementing ITIL. [21][45][46][47][48]
Process implementation sequence	Determining and adequate process implementation sequence. [16][36][49]

The main findings per topic are discussed in detail below.

a) Critical success factors

The authors of the literature review introduced in [41], Ahmad and Shamsudin, use a technique for multivariable decision-making called Analytical Hierarchy Process to classify the CSFs as follows: top management support, change management and organizational culture, monitoring and evaluation, communication and cooperation, project management and governance, training and competence of involved stakeholders, process implementation, and applied technology. The hierarchy of CSFs proposed in this work was tested through an interview and a survey of fifteen experts from a financial institution in the United Arab Emirates.

Another literature review that examines CSFs is presented in [21]. In this work, Iden and Eikebrokk propose an ITIL success model, which is composed of the following ten factors: top management support, a project champion, staff's expertise, broad involvement, continual information and organizational culture, willingness to change, external consultant, support tools, and firm size. In [29], the same authors demonstrate empirically that there is a positive relationship between ITIL implementation progress and the following factors: senior management involvement, group efficacy, project management capability, software quality, and organizational resources.

The study presented in [16] adds that lack of funds for developing ITIL projects as an important challenge to consider. Finally, the adoption of ITSM models in small and medium-sized enterprises is studied in [42], [43] and [44]. On the one hand, in [42] training employees for improving their skills and selecting the adequate support tools are considered as important factors. On the other hand, the studies presented in [43] and [44] conclude that there is few research about ITIL implementation in the context of small companies. The complexity, cost and risk of adopting ITIL are found to be the reasons for this lack of implementation of ITIL in small companies.

Though all the factors above indicated are important for the ITIL implementation success, Table 3 summarizes the factors most frequently mentioned in the reviewed papers.

Table 3
Critical success factors

Factor	Description
Organization commitment	• To provide support and sufficient resources, to involve key employees, to promote organizational culture change, etc.
Project management	• To plan the project, and to comply with budget and time limits.
Implementation sequence	• To identify and prioritize adequately the processes to implement.
Stakeholder efficacy	• To improve the knowledge and skills of process stakeholders.
Support tool quality	• To dispose of adequate support tools that help managers implement and improve processes.
Monitoring and evaluation	• To measure and evaluate systematically the process performance and results.
Cost and time	• To reduce the cost and time of implementation.

b) Process management practices

The literature reviews examined focus was mainly on studying CSFs, progress, outcomes, benefits and consequences of ITIL implementation. However, they do not include papers that address the integration of process management practices in ITIL implementation projects. Iden and Eikebrokk consider that this is an important study area [21], and they have conducted a research study in this field [29]. They have demonstrated empirically that there is a strong positive relationship between the ITIL implementation progress and the use of business process management practices. The study was conducted through a survey whose indicators are the following: process is well standardized and documented, process has an effective ownership, process performance objectives are set, process performance metrics are systematically monitored, and process is continuously improved. The survey indicators were based on process management models introduced in the literature [21][29] and were validated by ITIL experts. Marrone and Kolbe also highlight the importance of applying business process management practices in ITIL implementation projects [16].

c) Methods for ITIL implementation

The method for implementing ITIL is one of the topics addressed in the literature review introduced in [21]. The results obtained conclude that very few published papers provide methods or theoretical frameworks for the ITIL implementation. Nabiollahi et al. [45] use Enterprise Architecture to define an integrated framework for identifying and addressing requirements and issues of IT service architectures. The framework presented in [46] is an ITIL evaluation framework based on the benefits of implementing ITIL. Finally, in [47] and [48] methods for implementing and improving ITIL processes are introduced. The method that Gallup and Dattero propose in [47] is based on a Dynamic Network Analysis (DNA) and its five steps are the following: 1) define the process, 2) define the roles, 3) build a DNA model of the process, 4) analyze the DNA model, and 5) suggest improvements of the process. In [48], Jin and Ray introduce a business-oriented methodology for an effective service delivery based on ITIL best practices. The methodology stages are the following: 1) defining design attributes, 2) agreeing performance agreements, 3) generating and evaluating concepts, 4) developing detailed design, 5) implementing design, 6) measuring performance, 7) assessing user satisfaction, and 8) improving performance.

d) Process implementation sequence

ITIL is a set of comprehensive publications providing descriptive guidance on the ITSM processes, functions, roles and responsibilities. However, ITIL framework does not suggest a process implementation sequence and organizations need to decide an implementation order for their processes when starting an ITIL implementation project. Lema et al. have conducted a literature review [36] to study the criteria used to select the process implementation sequence and the processes that are implemented first. The findings show that business needs, “quick wins”, strengthen service support, customer services, and demands prioritization are the criteria most suggested by experts. Besides, the process most suggested as the first process to be implemented is incident management, and request fulfillment and service level management are the second and the third most suggested process respectively. Likewise, in [49] Valiente et al. highlight that incident management is one of the first processes to adopt because it is highly visible to the business and it is hence easier to prove its value. Marrone and Kolbe [16] claim that the incident management process is adopted by 95% of organizations.

2.2. Simulation modeling in the context of ITIL processes

The second literature review was conducted to study the use of simulation modeling in the context of ITIL processes. We have studied in more detail the papers that present simulation models developed in the field of the incident management process, because that is the process considered in the application case developed in this work (see section 5). As stated before, the intent of this review is not to provide an exhaustive study but rather to offer an overview of the applicability and usefulness of simulation modeling techniques in this field.

The automatic searches were performed in various digital libraries and citation databases of peer-reviewed papers, such as Scopus, Web of Science, IEEE Xplorer, ACM, and SpringerLink. The search string was (simulation AND (ITIL OR ITSM OR “IT service management” OR “IT support” OR “IT service support” OR “Service Desk” OR “Help Desk” OR “service incident” OT “IT incident”)). Initially, the title and abstract of the retrieved papers were examined to determine if the papers fulfilled the inclusion and exclusion criteria showed in Table 4. The selected works were further reviewed to study the simulation model purpose.

Table 4
Inclusion/Exclusion criteria

Inclusion criteria	• Papers that present simulation models developed in the context of ITIL processes. • Papers that introduce simulation models that help managers conduct process management tasks.
Exclusion criteria	• The publication abstract is available but not the full text. • Papers not written in English. • Chapters of books.

The results of this review show that there are many published papers that describe different simulation models developed in the context of ITIL processes, such as: Strategic Management [50], Incident Management [51], Change Management [52], Financial Management for IT Services [53], Service Level Management [54], Capacity Management [55], Service Continuity Management [56], and Security Management [57], among many others. The purpose of the simulation models depicted in the reviewed papers is to help IT managers conduct diverse process management tasks, such as to design adequate service management strategies, evaluate process performance metrics, define service level objectives and evaluate its compliance, and determine the optimal process configuration.

The works describing simulation models particularly developed for the incident management process and their purpose are collected in Table 5. It can be concluded that the main purpose of these simulation models is to help analyze the process key performance indicators (KPIs) and the service level agreement (SLA) compliance under different process configurations. Though the KPIs and the SLA parameters considered in these works are not always the same, the most frequently considered can be categorized as follows: a) *process KPIs*: number of solved incidents, average time of incident resolution, utilization and efficiency of support level/support group agents and incident routing effectiveness; b) *SLA parameters*: maximum incident resolution time and percentage of incidents resolved within the target resolution time**.**

Table 5
Works describing simulation models in the context of the incident management process

Work	Purpose
[58][59]	• Study the process KPIs by varying the Service Desk configuration.
[60][61][62][63]	• Examine the process KPIs and the SLA compliance with different configurations of both the IT organization support levels and the incident management strategies (incident assignment to support level and incident routing policies).
[51][53][64][65][66][67] [68]	• Predict the behaviour of more complex IT support organizations which are structured in several levels of support groups which are specialized in concrete incident categories. Several additional incident management strategies (e.g. support group reorganization and incident prioritization policies) and process KPIs (e.g. incident routing effectiveness and support group efficiency) have been considered in these works.

2.3 Literature review findings

This subsection summarizes the main findings of the analysis of the related literature for each of the intended topics.

The first topic addressed was the critical factors for a successful ITIL implementation. The findings highlight the importance of the following factors: a) organization commitment, b) having a method that drive IT managers through the ITIL implementation, c) planning the ITIL implementation project and managing processes adequately, d) determining an appropriate process implementation sequence, e) developing and deploying adequate process support tools, and f) training process stakeholders.

The second topic focused on studying the use of process management practices in ITIL implementation projects. The results reveal the importance of applying process management practices in ITIL implementation projects. Moreover, they indicate that there exists a strong positive relationship between the use of process management practices and the ITIL implementation progress.

The third topic focused on examining methods for implementing ITIL. The results show that a small number of papers have studied this topic. The methods proposed in the works examined allow IT managers to address concrete ITIL implementation topics, such as to define an adequate IT service architecture, evaluate ITIL implementation benefits, or deliver effective services, among others. However, evidences of papers that propose ITIL implementation methods have not been found. Likewise, there is no evidence of a systematic use of implementation methods in real-world ITIL implementation projects.

The fourth topic studied how to determine an adequate process implementation sequence. The findings indicate the most used criteria are “quick wins”, most strengthen service support, customer services, and demands prioritization. They also show that incident management process is one of the first processes adopted by companies.

Finally, the last topic was the use of simulation modeling in the field of ITIL processes. It is observed that simulation modeling has been widely used to conduct diverse management tasks in the context of numerous ITIL processes. These techniques help IT managers design adequate process management policies, evaluate process KPIs and SLA compliance considering alternative process configurations, and determine optimal process configurations.

3. Research methodology

One of the findings of the literature review conducted in the previous section emphasizes the importance of having a method to guide IT managers through the ITIL implementation process. Likewise, the positive relationship between the use of process management practices and the ITIL implementation success is also highlighted in the works analyzed. However, no evidence has been found of papers introducing methods for implementing ITIL that help apply process management practices for implementing the appropriate processes.

In this paper, we propose a novel method for implementing ITIL. The method has been developed using the research methodology shown in Figure 1. This methodology is based on the "*action design research*" methodology for conducting design science research in information systems [69]. The methodology "*action design research*" is a research methodology in the information systems discipline in which new knowledge is produced by the construction and evaluation of "*artifacts*". An "*artifact"* is broadly defined as *"software, composite systems of software, users and use processes, and information systems-related organizational methodologies and interventions*" [69]. This methodology differs from "*traditional design research*" by requiring on-organizational-site artifact implementation and evaluation so that the artifact emerges from both designer/researcher vision and interaction of the artifact and its designers with the organizational environment. In our case, the artifact developed is a method for implementing ITIL.

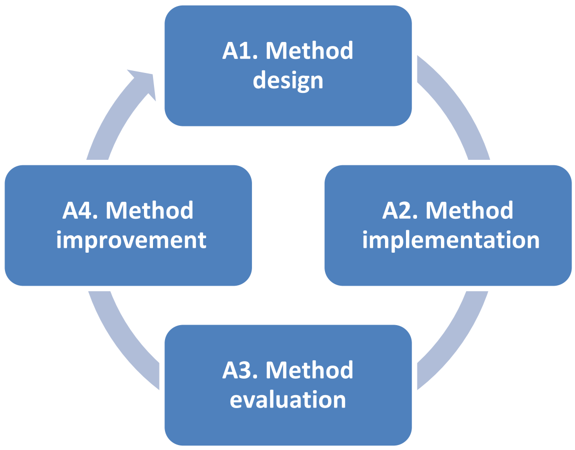

Figure 1. Research methodology

The activities of the research methodology used to develop the method proposed in this work are the following:

1. *A1. Method design*: to define the activities of a method for implementing ITIL. The method proposed in this work is based on business process management lifecycle (process identification, process discovery, process analysis, process redesign, process implementation, and process monitoring and controlling) and simulation modeling.
2. *A2. Method implementation*: to apply the method for implementing ITIL processes in real-world companies. This work presents an application case of the method for implementing the incident management process in a Spanish company.
3. *A3. Method evaluation*: to evaluate the method quality. The method proposed has been evaluated from the perspective of the incident management process stakeholders.
4. *A4. Method improvement*: to study what changes could be done to the method to solve the issues identified in the method evaluation.

Sections 4 to 7 describe in detail the different results of these activities. It is noteworthy that in order to check the feasibility of this proposal, the results of activities A1, A3 and A4 have been discussed with two ITIL experts. Both experts work for IT companies specialized in ITIL and offering consulting services about ITIL implementation and training to obtain ITIL certifications.

4. Research activity 1. Method design

Figure 2 presents Met4ITIL, a method proposed for implementing ITIL. The method is based on the business process management (BPM) lifecycle [70] and proposes the use of simulation modeling to help IT managers conduct process management activities. Thus, the method combines process management and simulation modeling techniques into an approach for a successful ITIL implementation.

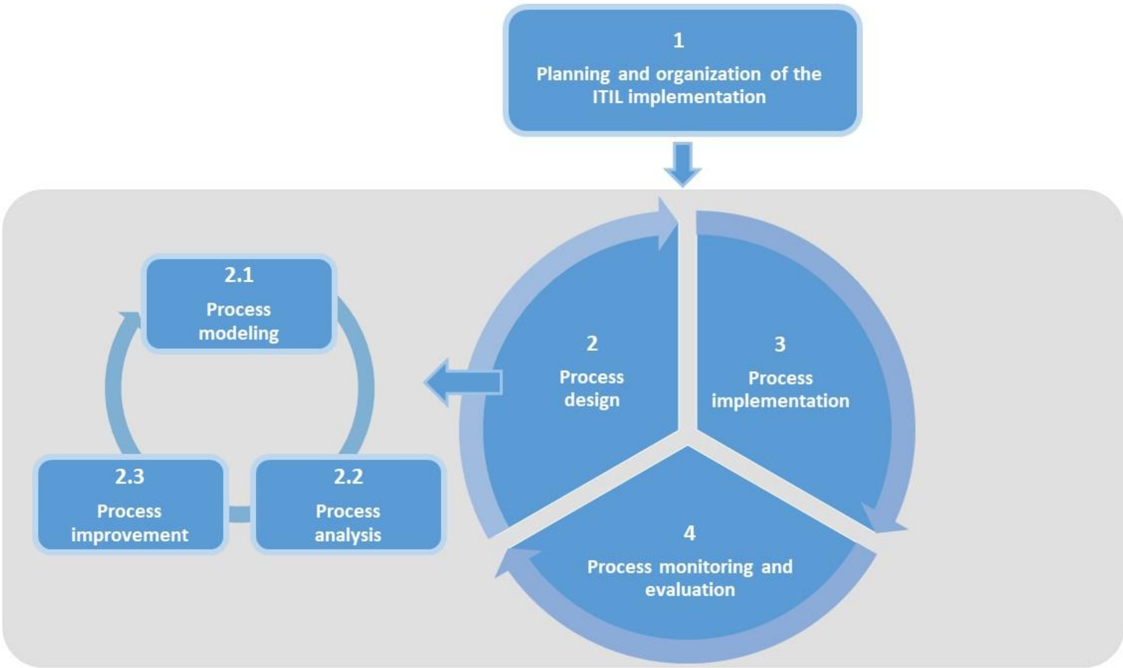

Figure 2. Method proposed for implementing ITIL (*Met4ITIL*)

The activities of Met4ITIL have been defined adapting the BPM lifecycle to the particular characteristics present in ITIL implementation projects and taking into account the process management principles [71][72][73][74][75][76][77]:

1. *Process awareness*: a process should be identified, named and documented. Besides, the process stakeholders should possess the necessary knowledge and skills for an appropriate process implementation.
2. *Process ownership*: a process should have an owner who is responsible for designing the process correctly and ensuring the compliance of the process performance targets.
3. *Process measurement*: a process should have concrete performance and results objectives, and it should be systematically measured. A fundamental aspect of any process-oriented company is the evaluation of the process performance for the compliance of its strategic and operational goals.
4. *Process improvement*: process performance and results should be constantly evaluated. Changes for improving the process should be conducted when necessary.

These process management principles have been also considered in ITSM-related standards and process assessment models, such as ITIL [14], ISO/IEC 20000 [9][10][11], CMMI-SVC [12][13], ISO/IEC 15504-8 [20], and TIPA for ITL [18][19].

Figure 2 shows that the activity lifecycle proposed in Met4ITIL is a continuous cycle comprising the following activities: a) planning and organization of the ITIL implementation, b) process design, c) process implementation, and d) process monitoring and evaluation. Table 6 provides an overall view of the methods activities, the stakeholders, and the RAICI role of the stakeholders.

Table 6
Met4ITIL activities

Activity	Description	Stakeholder
1. Planning and organization of the ITIL implementation	• Identifying and prioritizing processes to implement • Performing planning and organizational tasks	• ITIL practitioners (consulted, informed) • IT managers (responsible, accountable) • Process owner (responsible)
2. Process design	• Designing processes to implement based on ITIL description and organization characteristics	• ITIL practitioners (consulted, informed) • IT managers (consulted, informed) • Process owner (accountable, consulted) • Process agents (consulted) • Simulation model developer (responsible)
3. Process implementation	• Automating processes • Training process stakeholders	• ITIL practitioners (consulted, informed) • IT managers (consulted, informed) • Process owner (accountable, consulted) • Process agents (consulted, informed) • Support tool technicians (responsible)
4. Process monitoring and evaluation	• Collecting actual process metrics • Evaluating the process	• ITIL practitioners (consulted, informed) • IT managers (consulted, informed) • Process owner (responsible, accountable)

A very important contribution of Met4ITIL is that it proposes the use of simulation modeling to support the process design and the continual process improvement. A process simulation model helps IT managers perform these activities because it allows the evaluation of the process performance considering alternative process configurations. Besides, it enables IT managers to evaluate the effects of corrective actions before their implementation in a cost-effective way without incurring in the time or risk of experimenting with the real process.

Below, the Met4ITIL activities are described.

Activity 1. Planning and organization of the ITIL implementation

In this activity, a feasibility study is conducted to identify and prioritize the ITIL processes to be implemented in the organization. The most adequate process implementation sequence is also defined.

Besides, this activity includes other planning and organization tasks such as the following: a) set the business goals and exceptions; b) determine the process owner, c) provide the necessary resources and support for a successful implementation; and d) establish the budget and time limits.

Below, the activities for implementing a concrete ITIL process namely process design, process implementation, and process monitoring and evaluation are described (see Figure 2):

Activity 2. Process design

No two organizations are the same in the way they operate or how they decide to implement ITIL processes in terms of functions and organizational structure. The purpose of this activity is to design the process considering both the ITIL process description and the organization particular characteristics. Standards or models for ITIL process assessment and improvement, such as TIPA for ITIL [18][19] can also be used as a useful source of information in the process design activity, especially if the organization is interested in adopting a process assessment standard.

To help the process owner design the process, we propose to build a process simulation model and perform model simulations. We consider that this is appropriate for the following reasons [38]:

a) A process simulation model allows managers to look into the process with more detail since the model structure represents the process control flow (activity chain, events and decisions performed as part of the process).
b) Conducting model simulations enables managers to study the process behavior and its performance over time considering the different scenarios that may occur.
c) Simulation model experimentation allows managers to examine the results of different decisions without incurring the cost, time and risk of experimenting with the real process.
d) A process simulation model is easy to communicate and to change because it is developed with visual modeling tools.

Figure 3 shows the relationships between the simulation modeling activities (*process simulation model development* and *simulation model experimentation*) and the design activity tasks (*process modeling*, *process analysis* and *process improvement*).

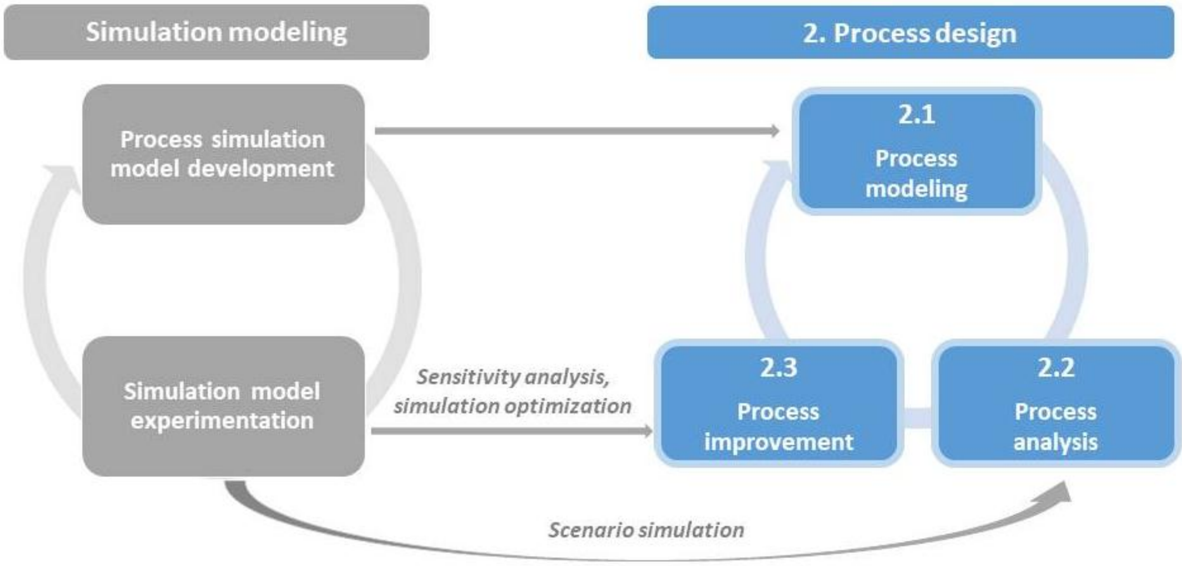

Figure 3. Relationships between process design and simulation modeling

The tasks of the activity called Process design are described in the following sections.

Task 2.1. Process modeling

The process-modeling task consists on performing the following two subtasks:

1) Describe the process that will be implemented in the organization: scope and purpose, objectives, activity sequence, management policies, resources, configuration parameters, and output variables (process behavior, process results, and process KPIs). This subtask will be conducted taking into account the particular characteristics of the company and the ITIL recommendations for the target process.

2) Developing a process simulation model using a methodology for building valid and credible simulation models [78]. The methodology activities are the following:

   a) *Model conceptualization*: according to Kellner's proposal [38] for describing simulation models, the model conceptualization is described in terms of its scope and purpose, input parameters, result variables and process abstraction.
   b) *Model formalization*: defining the model using a formal specification language. The language depends on the simulation model approach used for model building. Normally, these formalisms are abstracted through a graphical notation and equations.

c) *Model implementation*: implementing the model using a tool that supports the simulation approach.
d) *Model validation*: checking that the model is correct and consistent, and the structure and behavior of the process is represented faithfully.

Task 2.2. Process analysis

The purpose of this task is to evaluate the process performance and determine if the process obtains the desired results. Moreover, this task conducts the identification and evaluation of process issues and chances for the process improvement.

Conducting scenario simulations with the process simulation model developed in previous task will help IT managers analyze the behavior, results and performance of the process (simulation model output variables) considering different process configurations. Simulation scenarios will be configured varying the values of the simulation model input parameters that represent the process configuration.

Task 2.3. Process improvement

This task consists on studying what process changes are needed to solve the issues identified in the previous task and to improve the process performance.

Conducting sensitivity analyses and simulation optimization experiments will help IT managers carry out this task. On the one hand, sensitivity analyses will allow IT managers to study the effect of changes in the process configuration parameters over the process outputs. This technique also enables the identification of the most influential process configuration parameters that most largely affect the process results. Likewise, sensitivity analyses allow determining the probable value range of the process outputs when there are uncertainties in the process configuration. On the other hand, simulation optimization experiments will help IT managers determine the values that the process configuration parameters need to take to meet an established optimization objective. The optimization objective will be defined by maximizing or minimizing the values of one or several process results variables.

If model simulation results indicate that it is necessary to perform changes for improving the process, the simulation model will be modified to represent those changes. Figure 3 shows that process design tasks will be repeated continuously until the process performance is adequate and the process reaches the objectives established. Then, the designed process will be implemented in the organization.

Activity 3. Process implementation

The process implementation activity involves process automatization and process training tasks. Process automatization consists on developing and deploying adequate IT systems or tools to support the process. Process training focuses on improving the stakeholders' knowledge and their skills to implement the process properly. Training activities are necessary to ensure that roles and responsibilities are clearly understood, and the process participants follow the procedures defined.

The process simulation model built in the previous task will be very useful for training the process stakeholders. Conducting model simulations will allow participants to know the process and predict the process results under the different scenarios that may occur [38].

Activity 4. Process monitoring and evaluation

This activity involves process monitoring and process evaluation tasks. The purpose of process monitoring is to collect and analyze systematically the metrics and results of the processes implemented in the organization. The actual process data will be evaluated to determine the process performance and detect deviations with respect to the process objectives established. The data collected in this activity will be also used to validate the process simulation model with real process data.

Process evaluation consists on assessing the ITIL process maturity using a process assessment model, such as TIPA for ITIL [18][19]. TIPA for ITIL combines the process assessment standard ISO/IEC 15504 with the ITSM best practices described in ITIL, and defines a framework and requirements for process assessment and process improvement. Process maturity is measured by analyzing the way the process is performed and managed. Determining process maturity measures to what extent the process is performed, managed, established, predictable or optimizing (6-level process maturity scale). Specific process improvements can be identified from the assessment results.

If deviations with respect to the process targets or possible process improvements are detected, improvement actions will be undertaken. Figure 2 shows that Met4ITIL supports the loop of activities that provides the design, implementation, evaluation and improvement of processes. This activity cycle will be repeated on a continuous basis to support the continual process improvement.

5. Research activity 2. Method implementation

This section presents an application case of Met4ITIL that has been carried out in the context of a Spanish public company. The company provides a wide range of services related to the technical inspection of vehicles and the metrological control of measuring equipment. For confidential reasons, we will refer to this company as ServIn. The following subsections describe the results of performing each one of the method activities (see Figure 2).

5.1 Activity 1. Planning and organization of the ITIL implementation

First, ServIn decided to implement the Incident Management, Request Fulfillment, Change Management, and Service Level Management processes. In this work, we focus on the implementation of the Incident Management process. The process owner is in charge of designing the process, defining the process objectives, and providing the necessary resources and support for an adequate process implementation. Moreover, the process owner is responsible for meeting the budget and time limits established.

In the following sections, the activities for implementing the Incident Management process are described. We focus mainly on the process design activity to illustrate the usefulness and applicability of simulation modeling to perform this activity.

5.2 Activity 2. Incident management process design

The purpose of this activity is to design the incident management process based on both the ITIL process description and the idiosyncrasy of ServIn.

IT support organizations are structured in various levels of support groups. These groups work in shifts. The agents of each support group are specialized according to different categories of incidents and they are the ones to perform the necessary tasks to resolve the incidents of the category they are specialized in. Figure 4 shows the ITIL incident management process [79]. The process starts when a customer detects an incident and notifies it to ServIn. In response, an available agent of the Service Desk (first support level) is assigned to the incident and performs the following tasks: i) opens a new incident, and records and classifies the incident, and ii) determines the incident severity and priority. Then, based on the incident data (severity, priority and category) the incident is allocated to an idle agent of a support group specialized in the incident category (the support group and the agent will be determined according to the support group allocation policy adopted by the company). If the agent assigned cannot resolve the incident within the maximum resolution time established or the maximum waiting time in the support group incoming queue is exceeded, the incident is reassigned to a different support group, usually scaling the incident to a support group of a higher level with more skilled agents in that category of incident. If the customer is satisfied with the solution, the incident is closed. Otherwise, the incident is reassigned to a higher level support group for its correct resolution.

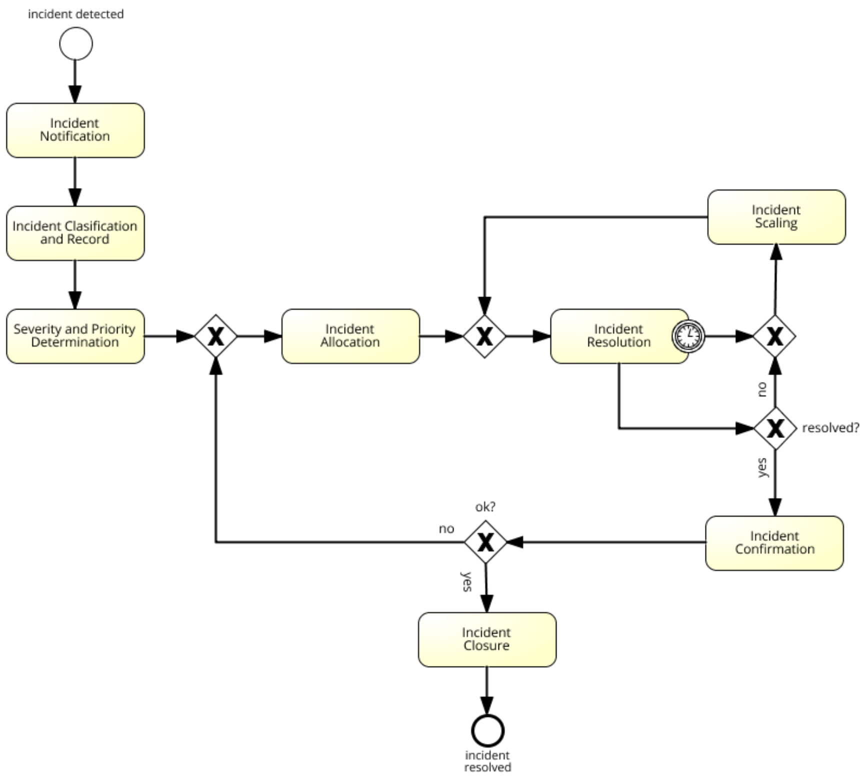

Figure 4. ITIL incident management process (BPMN notation)

The objectives of the incident management process are indicated in the service level agreements (SLA) that the organization agrees with its clients. The process performance and the degree of SLA compliance depend mainly on the configuration of both the support groups and the incident management policies adopted by the company. Accordingly, the process owner has to decide how to configure them to optimize the process performance and to meet the established objectives. Simulation modeling helps process owner make this decision because these techniques allow her to examine the process performance and the SLA compliance considering alternative process configurations.

The following section describes the tasks conducted to design the incident management process that will be implemented in ServIn.

5.2.1. Task 2.1. Process modeling

This section summarizes the activities of the Law's methodology [78] carried out to build the process simulation model.

5.2.1.1. Model conceptualization

According to Kellner´s proposal for describing simulation models [38], the conceptualization of a simulation model is described in terms of its scope and proposal, input parameters, result variables, and process abstraction.

a) Model scope and proposal

The proposal of the simulation model for the incident management process is to allow the examination of the process indicators and the degree of SLA compliance under different process configurations. The model also allows the study of the penalty that ServIn would have to assume for not meeting SLA targets. Moreover, the model enables finding both the process parameters that most influence the process outputs, and the configuration that either complies with the SLA objectives or even optimizes the process results.

b) Input parameters

The input parameters of the simulation model represent the process configuration options. These parameters are the following: a) incident received rate (*IncRate*), b) SLA parameters (Table 7), c) support groups (Table 8), and d) incident management policies (Table 9). These parameters enable the definition of alternative process configurations through the user interface of the simulation model.

Table 7
SLA parameters

Input parameter	Description
∀ client type *i*, $i \in$ {*Gold, Non-Gold*}, and ∀ incident priority *j*, $j \in$ [*P1..P4*]	
• $IncMResTime_{ij}$	• Maximum resolution time for incidents with priority *j* of *i* type clients.
• $PerIncMResTime_{ij}$	• Percentage of incidents with priority *j* of *i* type clients that must be resolved within the time specified in the parameter $IncMResTime_{ij}$.
• $Penalty_{ij}$	• Penalty for not meeting the value of the parameter $PerIncResTime_{ij}$.

(P: priority)

Table 8
Support group parameters

Input parameter	Description
Support group structure:	
• $ServiceDeskAgents_{ij}$	• Number of agents of the support group *i* of the *Service Desk* assigned to the work shift *j*, $i \in$ {*analysts, operators*}, $j \in$ {*first, second, third*}.
• $SGAgent_{ij}$	• Number of agents in support group *i* of level *j*, $i \in$ [*SG1..SG15*], $j \in$ [*L1..L2*].
• $SGShiftWork_{ij}$	• Shift assigned to support group *i* of level *j*, $i \in$ [*SG1..SG15*], $j \in$ [*L1..L2*].
• $SGCategory_{ij}$	• Incident category *i* in which the support group *j* is specialized, $i \in$ [*C1..C4*], $j \in$ [*SG1..SG15*].
Service times: Estimations of the completion times for each process activity (minimum, average and maximum time). The simulation model uses these estimations to calculate the activity duration using a triangular probability distribution.	
• *MinTimeAP, MedTimeAP, MaxTimeAP*	• Estimations of the times for the incident analysis and prioritization activity.
• $AService_{ij}$, $OService_{ij}$, $L1Service_{ij}$, $L2Service_{ij}$	• Estimations of the times required by the support groups of the different levels to solve incidents of the category *i* with priority *j*, $i \in$ [*C1..C4*], $j \in$ [*P1..P4*].
Support group efficiency:	
• *AEfficiency, OEfficiency, L1Efficiency*	• *Percentage of incidents that the support groups of the different levels can resolve without scaling (support group efficiency).*

(SG: support group, L: support level, C: category, P: priority)

Table 9
Incident management policy parameters

Input parameter	Description
Incident severity policy:	
• *SeverityPolicy*	• Severity policy selected to be applied.
• $TSeverityPolicy_{ijk}$	• Severity of an incident with urgency *i* and impact *j* applying the severity policy *k*, $i \in$ [*U1..U3*], $j \in$ [*I1..I3*], $k \in$ [*S1..S2*].
Incident priority policy:	
• *PriorityPolicy*	• Priority policy selected to be applied.
• $TPriorityPolicyy_{ijk}$	• Priority of an incident with urgency *i* and impact *j* applying the priority policy *k*, $i \in$ [*S1..S4*], $j \in$ {*Gold, Non-Gold*}, $k \in$ [*S1..S2*].
Support group allocation policy:	
• *L1AllocationPolicy, L2AllocationPolicy*	• Policy selected to be applied to determine which *Level 1* support group and *Level 2* support group the incident is allocated to.
• $AllocationPolicy_{ij}$	• Function that determines the *Level j* support group to which the incident is allocated applying the support group allocation policy *i*, $i \in$ [*S1..S4*], $j \in$ [*L1..L2*].

Incident scaling policy:	
• *ScalationOperation$_{ij}$, ScalationAnalyst$_{ij}$, ScalationLevel1$_{ij}$*	• Percentage of time, measured over *IncResTime$_{ij}$*, that determines that an incident with priority *i* of a client of the category *j* must be scaled from the operators of the Service Desk to the analysts of the Service Desk *(ScalationOperator),* from de analysts of the Service Desk to the support level 1 *(ScalationAnalyst),* or from de support level 1 to support level 2 *(ScalationLevel1), i* ∈ [*P1..P4*], *j* ∈ {*Gold, Non-Gold*}.

(U: urgency, I: impact, S: severity, L: support level, P: priority)

c) Result variables

The model result variables represent the process KPIs, the degree of SLA compliance and the penalty for not meeting SLA targets (Table 10). The values of these variables show the values that the process indicators would obtain with the process configuration set by the values given to the input parameters.

Table 10
Model result variables

Result variable	Description
Indicators of process behavior	
• *NIncRecCat$_i$, PIncRecCat$_i$*	• Number and percentage of incidents of *i* type clients received, *i* ∈ {*Gold, Non-Gold*}.
• *NIncSolCat$_i$,PIncSolCat$_i$*	• Number and percentage of incidents of *i* type clients resolved, *i* ∈ {*Gold, Non-Gold*}.
• *NIncRecPr$_i$, PIncRecPr$_i$,*	• Number and percentage of incidents with priority *i* received, *i* ∈ [*P1..P4*].
• *NIncSolPrj, PIncSolPrj*	• Number and percentage of incidents with priority *i* resolved, *i* ∈ [*P1..P4*].
• *NIncRecCatPr$_{ij}$, PIncRecCatPr$_{ij}$,*	• Number and percentage of incidents with priority *j* of *i* type clients received, *i* ∈ {*Gold, Non-Gold*}, *j* ∈ [*P1..P4*].
• *NIncSolCatPr$_{ij}$, PIncSolCatPr$_{ij}$*	• Number and percentage of incidents with priority *j* of *i* type clients *i* resolved, *i* ∈ {*Gold, Non-Gold*}, *j* ∈ [*P1..P4*].
Indicators of process results	
• *PIncSolIRT*	• Average percentage of incidents resolved within the agreed time limits.
• *TotPenalization*	• Total penalty for not meeting SLA targets.
• *NIncSolIRTCat$_i$, PIncSolIRTCat$_i$*	• Number and percentage of incidents of *i* type clients resolved within the agreed time limits, *i* ∈ {*Gold, Non-Gold*}.
• *PenaltyCat$_i$*	• Penalty for not meeting SLA targets of the *i* type clients, *i* ∈ {*Gold, Non-Gold*}.
• *PIncSolIRTCl$_i$*	• Average percentage of incidents of the client *i* resolved within the agreed time limits, *i* ∈ [1..*num. of clients*].
• *PenaltyCl$_i$*	• Penalty for not meeting SLA of the client *i*, *i* ∈ [1..*num. of clients*].
Indicators of process performance	
• *SGQueue$_i$*	• Queue size of the support group *i*, *i* ∈ [*SG1..SG15*].
• *SGAgent$_i$*,	• Number of idle agents of the support group *i*, *i* ∈ [*SG1..SG15*].
• *SGUse$_i$*	• Average use level of the support group *i*, *i* ∈ [*SG1..SG15*].

(P: priority, SG: support group)

d) Process abstraction

The conceptual model of this process simulation model represents the behavior of both the process activities and the incident management policies adopted in the organization. These activities are described as follows:

1. The process begins when a client detects that an incident has occurred and notifies it to ServIn.
2. The information system records the incident and allocates it to an idle agent of the active support group of analysts of the Service Desk. The agent performs an initial analysis and determines the severity and priority of the incident. Finally, the agent records these values in the information system.
3. According to both the client type (Gold, Non-Gold) and the incident priority, the information system allocates the incident to either an active support group of the Service Desk, the support level 1 or the support level 2. If the incident is allocated to the support level 1 or the support level 2, the information system follows the support group allocation policy selected to decide the support group and the agent to which the incident is allocated.
4. The agent assigned to the incident performs the resolution tasks. The following situations may occur: a) the agent resolves the incident, b) the agent cannot resolve the incident, or c) the incident exceeds the maximum waiting time because there are no agents available at that moment.
5. If the situation b) or c) of the previous step occurs, the information system applies the active incident scaling and support group allocation policies to determine the support level, the support group and the agent to which the incident is scaled. Then, the process returns to the step 4.
6. The process ends when the incident is resolved and the client confirms that the incident has been resolved satisfactorily. In this case, the incident is closed. Otherwise, the information system reallocates the incident to a higher level support group for its correct resolution.

5.2.1.2. Model formalization and implementation

Given that the main objective of the simulation model is to represent a process, the simulation paradigm chosen for model building is discrete event simulation [80]. The model has been built with AnyLogic TM V.6 [81], a multiparadigm simulation environment that is based on an object-oriented design to support the modular, incremental and hierarchical development of simulation models. It provides the Enterprise Library that includes a collection of objects to define business process or workflows, and their resources. Besides, AnyLogic disposes of pre-designed experiments, Monte Carlo, sensitivity analysis and parameter variation, that help analysts find out how randomness and parameter change affect the process behavior. Simulation optimization enables analysts to find better solutions for their business challenges based on their constraints and requirements [81].

Table 11 presents the type and quantity of the Enterprise Library components that have been used to model the resources and the activities of the process. Table 12 shows the general components of the

Enterprise Library that have been used to model the input parameters, the output variables and the process functions. These components show the structural complexity of the simulation model.

Table 11
Enterprise Library Components (model activities and resources)

Component	Quantity	Model element
Entity	1	Entities generated or processed in a discrete simulation model in AnyLogic.
IncidentRequest	1	Incident that participates in the process (*Entity* specialization).
Source	1	Activities: *Incident Notification*, and *Incident Classification and Record*. This component generates the incidents.
Service	16	Activities: *Severity and Priority Determination*, and *Incident Resolution*. These activities consume time and resources.
ResourcePool	20	Number of agents of the support groups (each component is connected to the associated object *Service* that models the support group).
SelectOutput	2	Route incidents through the process flow according to the result of a probabilistic condition evaluation.
Enter and Exit	50	Activities: *Incident Allocation* and *Incident Scaling*.
Sink	1	Activity: *Incident Closure* (end of the process).

Table 12
Enterprise Library components (input parameters, output variables and functions)

Component	Quantity	Model element
Parameter	77	Input parameter (32 are multidimensional).
Output Variable	11	Output variable (8 are of the type *plain* and 3 are of the type *collection*).
Function	60	Specific process function or function that facilitates reutilization logic. It can be invoked dynamically by the objects of the Enterprise Library.

5.2.1.3. Model validation

The simulation model has been validated according to the validation scheme proposed by Sterman [80] and Barlas [82]. Table 13 shows tests conducted and the techniques used for the validation of the simulation model.

Satisfactory results were obtained for all tests performed. However, more tests need to be done to fully validate the simulation outputs. These tests need ServIn to totally complete the implementation of the incident management process and to collect the process outputs by monitoring its performance. The additional tests that make use of these monitored data are: a) *results validation test* [78] which consists of comparing the simulation model output data with the comparable output data collected from the actual process, and b*) behavior validation test* [80][82] which consists of evaluating how the model reproduces the main behavior patterns exhibited by the real process.

Table 13
Simulation model validation tests

Test	Description	Technique used
Computerized model verification	**Assess model implementation is error-free**	
Dimensional consistency	• Variables dimensions are consistent and the units are correct.	Model compilation/AnyLogic™
Syntax validation	• Behavior-governing model equations are free of syntax errors.	Model compilation/AnyLogic™
Semantic validation	• Behavior-governing model equations are free of semantic errors.	Model compilation/AnyLogic™
Conceptual model validation	**Evaluate the model structure**	
Structure confirmation	• Model equations correspond with the real process relationships.	ITIL process study, literature review and face validity *(1)*
Parameter confirmation	• Evaluating model parameters against the process knowledge.	ITIL process study, literature review and face validity *(1)*
Extreme conditions	• Assessing model behavior under extreme conditions.	Model simulations, literature review and face validity *(1)*
Behavior sensitive	• Determining the process parameters to which the model is highly sensitive.	Model simulations, literature review and face validity *(1)*

(1) Face validity: interviews, inspections and/or opinions of the process stakeholders

5.2.2 Task 2.2. Process analysis

To examine the process indicators and the SLA compliance, simulation experiments were conducted with AnyLogic™ considering an initial process configuration. The configuration of the simulation scenario and its results are shown below.

5.2.2.1 Configuration of the simulation scenario

The simulation scenario was configured through the model input parameters as follows:

a) *SLA parameters*

Table 14 shows the values of the SLA parameters for each incident priority and customer type (Gold and Non-Gold).

Table 14
SLA parameters

Priority	*IncMResTime* (hours)		*PerIncMResTime*		*Penalty*	
	Gold	Non-Gold	Gold	Non-Gold	Gold	Non-Gold
1	3	6	95%	90%	4%	3%
2	5	10	90%	85%	4%	3%
3	12	24	85%	80%	3%	2%
4	24	48	80%	75%	3%	2%

(See SLA parameters in Table 7)Table 7*Organization structure parameters*

ServIn is composed of three support levels (Service Desk or support level 0, support level 1 and support level 2). These support groups are configured as Table 15 shows. Each support group: a) has a particular number of agents (*Num*), b) is specialized in particular incident categories (*Category*), and

c) works on a specific shift (*Shift 1*: 8:00 AM to 04:00 PM, *2*: 04:00 PM to 00:00 AM, and *3*: 00:00 AM h to 08:00 AM). The support group efficiency is equal to 70%.

Table 15
Support group structure configuration

Service Desk			Support Level 1				Support Level 2			
SG	Shift	Num	SG	Shift	Num	Category	SG	Shift	Num	Category
AnalystsFirstShift	1	3	*SG1*	1	3	1	*SG11*	1	3	1,2
AnalystsSecondShift	2	3	*SG2*	2	3	1	*SG12*	2	3	1,2
AnalystsThirdShift	3	2	*SG3*	3	2	1,2	*SG13*	3	2	1,2,3,4
OperatorsFirstShift	1	3	*SG4*	1	3	2	*SG14*	1	3	3,4
OperatorsSecondShift	2	3	*SG5*	2	3	2	*SG15*	2	3	3,4
OperatorsThirdShift	3	2	*SG6*	3	2	3,4				
			SG7	1	3	1,3				
			SG8	2	3	1,3				
			SG9	1	3	1,4				
			SG10	2	3	2,4				

(See support group configuration parameters in Table 8) (SG: support group, Num: number of agents)

b) Incident management policy parameters

Incident management policies allow the determination of the incident severity and priority, the support group assigned to the incident and the support level to which the incident is scaled.

Table 16 and Table 17 show the two policies for incident severity management considered. With these policies, the incident severity (how critical the service interruption is for the organization) is determined based on how quickly the client needs a resolution (incident urgency) and how many users are affected (incident impact). Incident severity (S_i) is measured within a range of four levels, whereas incident urgency (U_i) and incident impact (I_i) are measured within a range of three levels. The severity policy considered in this simulation scenario was severity policy 1 shown in Table 16.

Table 16
Severity policy 1

	I1	I2	I3
U1	S1	S2	S3
U2	S2	S3	S4
U3	S3	S4	S4

Table 17
Severity policy 2

	I1	I2	I3
U1	S1	S1	S2
U2	S2	S3	S4
U3	S3	S4	S4

(See severity policy configuration parameters in Table 9) (U: urgency, I: impact, S: severity)

Table 18 and Table 19 show the two policies for incident prioritization considered. These policies help determine the incident resolution priority based on the incident severity and the customer type (Gold and Non-Gold). The incident priority (Pi) and incident severity (Si) are measured within a range of four levels. The priority policy considered in the simulation scenario was priority policy 1 described in Table 18.

Table 18
Priority policy 1

	S1	S2	S3	S4
Gold	P1	P1	P3	P3
Non-Gold	P2	P2	P4	P4

Table 19
Priority policy 2

Category	S1	S2	S3	S4
Gold	P1	P1	P3	P4
Non-Gold	P1	P2	P3	P4

(See priority policy configuration parameters in Table 9) (S: severity, P: priority)

To determine the support group to which the incident is allocated, the following four policies have been considered:

a) *P1*: the incident is allocated to an active support group that has idle agents. If several support groups have idle agents, the incident is allocated to the support group with the smallest number of pending incidents.
b) *P2, P3 and P4*: the incident is allocated to an active support group specialized in the incident category that has idle agents. If several of the specialized support groups have available agents, the incident is allocated as follows: a) *P2*: to the support group with the smallest number of incidents in its queue; b) *P3*: to the support group with the shortest average resolution time, normally because its agents are more skilled to solve the incidents of that category; and c) *P4*: to any of the specialized support groups. These support group allocation policies take into account the specialization and skills of the support group agents.

The simulation model allows to study the effects of adopting any of the support group allocation policies indicated above. In the scenario simulated, the policy for incident allocation that has been considered is P3.

Finally, the incident scaling policy determines the support level to which the incident is allocated if one of the following situations occurs: a) the maximum waiting time to assign an idle agent to the incident is exceeded; or b) the agent assigned cannot resolve the incident within the maximum resolution time established (70% in the simulation scenario). With the scaling policy considered in the simulation scenario, the incidents are scaled to a higher-level support group, with more skilled agents to solve incidents. The scaling policy is as follows: i) from the analysts of the Service Desk to the operators of the Service Desk; ii) from the operators of the Service Desk to the support level 1; and iii) from the support level 1 to the support level 2. In this scenario, the percentage of time (measured over the maximum resolution time) that determines when an incident must be scaled is equal to 70%.

5.2.2.2 Simulation runs

The objective of this experiment is to analyze the behavior, performance and results of the process with the initial process configuration. Since the number of model output variables is very high, in this work we focus on the following: percentage of incidents resolved (*PIncSolPr*), SLA compliance, and performance of the support groups (*SGQueue*, *SGAgent*, *SGUse*).

Simulation results indicate that the percentage of incidents resolved is different for each incident priority: a) around 11% for incidents of priority 1, 2 or 4; and b) around 43% for incidents of priority 3. On the other hand, Table 20 shows that the average degree of SLA parameters non-compliance is high (*IncMResTime*: 52.5%, *PerIncMResTime*: 5.5%), and higher for Gold customers (*IncMResTime*: 91% , *PerIncMResTime*: 9%) than for Non-Gold customers (*IncMResTime*: 14%, *PerIncMResTime*: 2%).

Table 20
SLA non-compliance

Client Type	SLA parameters	
	IncMResTime (hours)	*PerIncMResTime*
Gold	91%	9%
Non-Gold	14%	2%
Average percentage	52.5%	5.5%

(See SLA parameters in Table 7)

The performance of support groups during the simulation period can be also examined. For instance, at a given time during the simulation, the shortest average resolution time of level 1 support group is around 1.5 (SG3, SG6, SG7 and SG9), and the longest is around 4.6 (SG1). Figure 5 and Figure 6 represent the values of the variables that measure the queue size and the busy agent number of level 1 support groups at that simulation time. It is observed that the performance of the support groups of this level is not optimal. While some support groups have a high average use, keep all its agents busy and hold many incidents pending, others have no incidents in its queue, present a low workload and keep many agents idle.

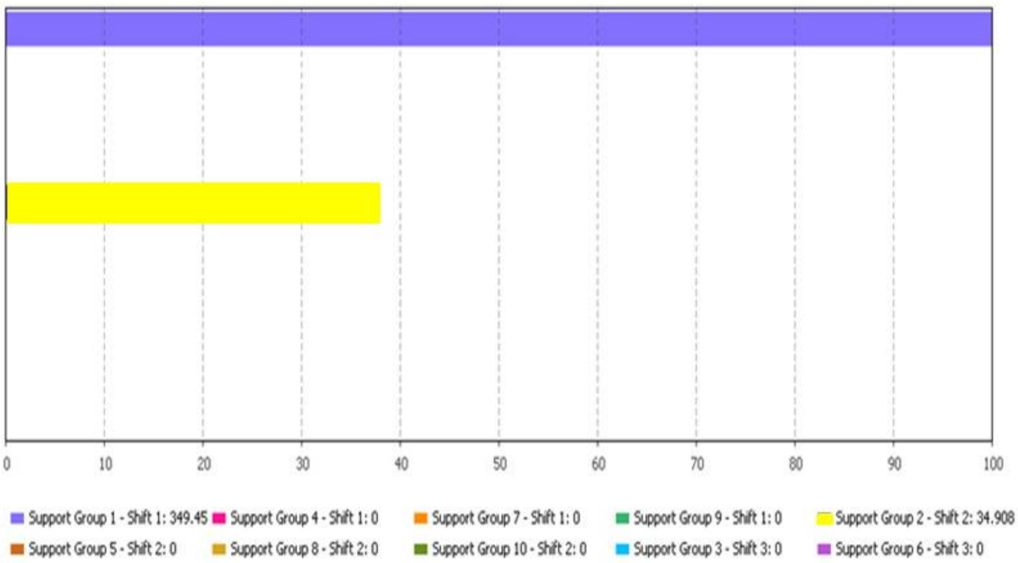

Figure 5. Queue size of the level 1 support groups

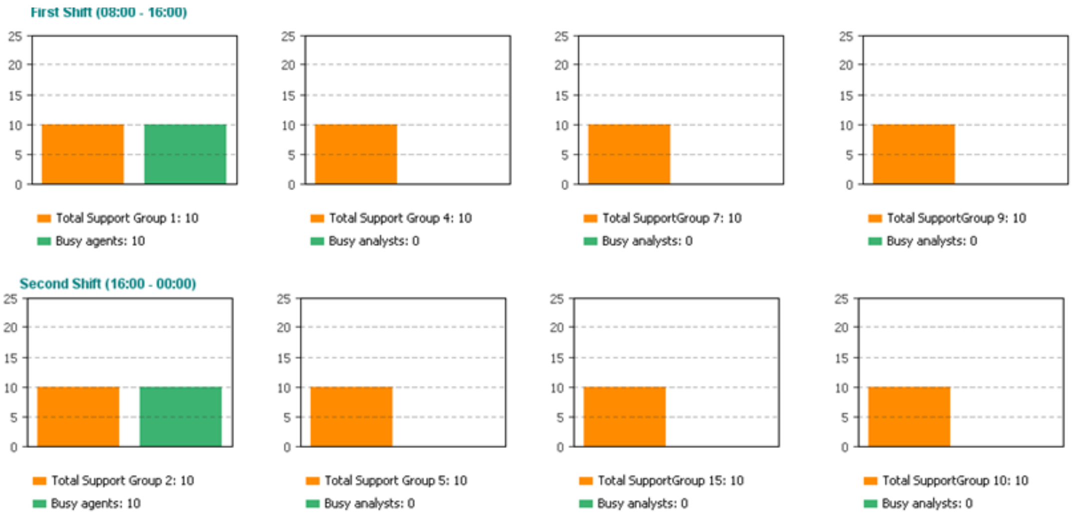

Figure 6. Busy operators of the level 1 support groups

5.2.3. Task 2.3. Process improvement

This section introduces several sensitivity analyses and simulation optimization experiments conducted with AnyLogic™. The purpose of these experiments was to determine what changes could be made in the initial process configuration to improve the process performance and meet the objectives established in SLAs.

5.2.3.1 Sensitivity analyses

Sensitivity analyses were conducted to determine: a) the process parameters that most influence on the process results, and b) what changes could be made on the process configuration to improve the process performance.

The first sensitivity analysis was configured varying the values of the following model input parameters: a) Service Desk configuration (see Table 21); b) incident severity and incident priority policies selected (see Table 22). Table 23 shows the values achieved by the variable that measures the average percentage of incidents resolved within the agreed times in the different simulation scenarios. They indicate that the best result is obtained varying the initial process configuration as follows: a) two agents in each support group of Service Desk, b) incident severity policy number 2, and c) incident priority policy number 2. With this process configuration, the average percentage of incidents resolved within the maximum resolution time established in the SLA is equal to 81.84 %. This percentage is 29.34 % higher than the percentage obtained with the initial process configuration (52.5 %). It is observed that the simulation model is highly sensitive to changes in the configuration of the Service Desk and the incident severity and incident priority policies adopted.

Table 21
Service Desk configuration (same in the four scenarios)

Analysts Shift 1	Analysts Shift 2	Analysts Shift 3	Operators Shift 1	Operators Shift 2	Operators Shift 3
[1-4]	[1-4]	2	[1-4]	[1-4]	2

Table 22
Severity and priority policy configuration

Scenario	Severity Policy	Priority Policy
1	Policy 1	Policy 1
2	Policy 1	Policy 2
3	Policy 2	Policy 1
4	Policy 2	Policy 2

Table 23
Sensitivity analysis results

Scenario	*PIncSolIRT*
1	64.61%
2	79.68%
3	68.71%
4	81.84%

(*PIncSolIRT:* average percentage of incidents resolved within the maximum resolution time)

Another sensitivity analysis was configured varying the values of the incident scaling policy configuration parameters (see Table 24). Figure 7 shows the output variable that measures the average percentage of incidents resolved within the maximum resolution time. It is observed that the range of values obtained for this variable during the simulation period is between 79% and 83.1%. The highest value of this variable (83.1 %) is only 2.84 % higher that the value obtained with the initial process configuration (80.26 %). Thus, the simulation model is much less sensitive to changes in the configuration of the incident scaling policy.

Table 24
Scaling policy configuration

Parameter	**Range**	**Distribution**
ScalationAnalysis, ScalationOperation, ScalationLevel1	[20%-95%]	Uniform continuous

(See incident scaling policy configuration parameters in Table 9)

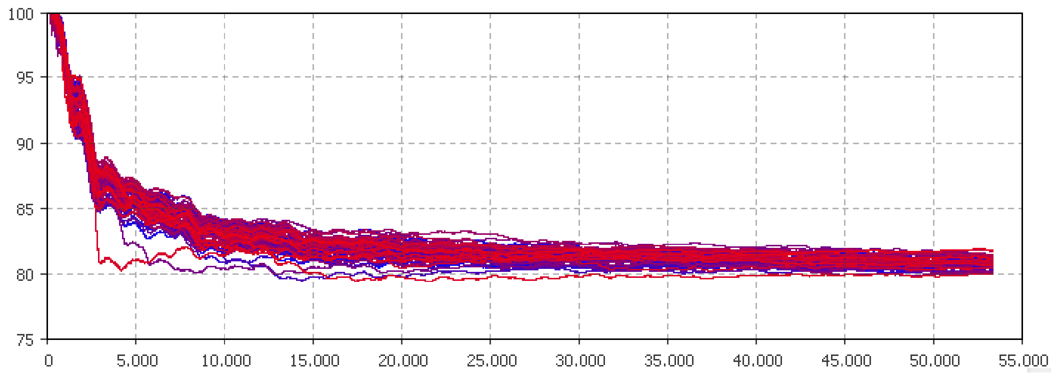

Figure 7. Average percentage of incidents resolved within the maximum resolution time

5.2.3.2. Simulation optimization

Simulation optimization experiments were conducted using the metaheuristic techniques of the AnyLogic^{TM} optimization engine OptQuest® [83]. The purpose of these experiments is to determine what changes could be made in the initial process configuration to optimize the process results and meet the agreed SLAs.

The purpose of the first optimization experiment was to determine the support group configurations and the values of the scaling parameters that maximize the percentage of incidents that the process can resolve without exceeding the maximum response time agreed (value of the SLA parameter *IncMResTime*). The column "*Range*" of Table 25 shows the restrictions to limit the maximum number of support group agents and the values of the scaling parameters set in this experiment. In the optimal process configuration obtained in the scenario simulated, the personnel configuration parameters and the scaling policy parameters reach the values shown in the column "*Result*" of Table 24. With this process configuration, the maximum percentage of incidents that can be resolved within the agreed times is equal to 85.1 % (value of the result variable *PIncSolIRT*). This value is 32.6 % greater than the value that this output variable obtained with the initial process configuration (52.5 %).

Table 25
Optimization experiment 1 configuration and results

Service Desk configuration			**Level 1 configuration**			**Level 2 configuration**		
Parameter	Range	Result	Parameter	Range	Result	Parameter	Range	Result
AnalystsFirstShift	[1-5]	5	*SG1*	[1-5]	5	*SG11*	[1-5]	5
AnalystsSecondShift	[1-5]	5	*SG2*	[1-5]	3	*SG12*	[1-5]	5
AnalystsThirdShift	2	2	*SG3*	2	2	*SG13*	2	2
OperatorsFirstShift	[1-5]	1	*SG4*	[1-5]	1	*SG14*	[1-5]	1
OperatorsSecondShift	[1-5]	1	*SG5*	[1-5]	1	*SG15*	[1-5]	4
OperatorsThirdShift	2	2	*SG6*	2	2			
Incident Scaling Policy configuration			*SG7*	[1-5]	5			
Parameter	Range	Result	*SG8*	[1-5]	1			
ScalationAnalysis	[20%-95%]	28%	*SG9*	[1-5]	1			
ScalationOperation	[20%-95%]	73%	*SG10*	[1-5]	1			
ScalationLevel1	[20%-95%]	47%						

(See support group configuration parameters in Table 8 and incident scaling policy configuration parameters in Table 9)
(SG: support group)

The second optimization experiment allows the determination of the process configuration that meets the following optimization objectives: 1) the percentage of incidents solved without exceeding the resolution times agreed (value of the SLA parameter IncMResTime) must be greater than or equal to 96% of the incidents received; and 2) the difference between the minimum percentage of incidents that must be resolved within the agreed times (value of the SLA parameter PerIncMResTime) and the percentage of incidents that the process resolves within the agreed times must be minimized.

The simulation scenario was configured varying the initial process configuration of support groups and the scaling policy as the column "Range" of Table 26 shows. In the optimal process configuration that meets the optimization objective, these parameters reach the values shown in the column "Result" of Table 26. This process configuration allows the resolution of 98.1 % of the incidents received within the agreed times (value of the result variable *PIncSolIRT*). This percentage is 45.6 % greater than the percentage obtained with the initial process configuration (52.5 %).

Table 26
Optimization experiment 2 configuration and results

Service Desk configuration		
Parameter	Range	Result
AnalystsFirstShift	[1-15]	12
AnalystsSecondShif	[1-15]	14
AnalystsThirdShift	[1-15]	2
OperatorsFirstShift	[1-15]	14
OperatorsSecondShift	[1-15]	11
Operator sThirdShift	[1-15]	2

Incident Scaling Policy configuration		
Parameter	Range	Result
ScalationAnalysis	[20%-95%]	28%
ScalationOperation	[20%-95%]	73%
ScalationLevel1	[20%-95%]	47%

Level 1 configuration		
Parameter	Range	Result
SG1	[1-15]	13
SG2	[1-15]	14
SG3	[1-15]	2
SG4	[1-15]	9
SG5	[1-15]	7
SG6	[1-15]	2
SG7	[1-15]	11
SG8	[1-15]	6
SG9	[1-15]	4
SG10	[1-15]	5

Level 2 configuration		
Parameter	Range	Result
SG11	[1-15]	9
SG12	[1-15]	7
SG13	[1-15]	2
SG14	[1-15]	12
SG15	[1-15]	8

(See support group configuration parameters in Table 8 and incident scaling policy configuration parameters in Table 9)
(SG: support group)

The simulation experiments introduced in this work show that the simulation model of the incident management process is a very useful tool that helps the process owner conduct the following tasks: a) to examine the process performance and results considering different process configurations, b) to identify the process parameters that most influence the process results, and c) to determine the best process configuration that meets the established process objectives.

5.3 Activity 3. Incident management process implementation

This activity includes the training of the process stakeholders. The stakeholders of the incident management process have improved their knowledge and skills conducting model simulations with alternative process configurations.

The second task of this activity consists on developing and deploying a tool to support the incident management process designed in the previous activity. According to the planning for the ITIL implementation project, next year ServIn will develop and deploy with EasyVista [84] an incident management tool to support the process already designed. EasyVista is a service management platform that enables companies to deliver engaging services and manage their technology.

5.4 Activity 4. Incident management process monitoring and evaluation

Once implemented, the incident management process in ServIn, the process will be monitored to collect the actual process outcomes and KPIs. The data obtained will be used to complete the simulation model validation (see section 5.2.1.3) by performing the *results validation* [78] and *behavior validation tests* [80][82].

If the actual process KPIs values indicate that the process performance is not suitable, it will be necessary to make changes in the process to improve the process performance and meet the SLAs established. The process simulation model is a very useful tool to perform this task because it allows managers predict the effects that those changes would have on the process performance before their real implementation.

Models or standards for ITIL process assessment and improvement, such as TIPA for ITIL [18[19], can be used to evaluate the process maturity and determine possible improvement actions, especially if Servin decides to adopt a process assessment model.

6. Research activity 3. Method evaluation

Due to a lack of a commonly accepted definition of the quality of ITIL implementation [21]**,** we define a quality implementation method as the one that contributes positively to address the critical factors for a successful ITIL implementation and facilitates the application of process management practices. This section presents the evaluation of the Met4ITIL quality according to this definition. The evaluation has been conducted based on the perceptions of the stakeholders of the incident management process through questionnaires after the application of the method. We consider this approach is appropriate because both questionnaires are used to measure variables that cannot be directly observed and the success of ITIL adoption is usually measured from the process's stakeholders perspective [36][21][29].

For the purpose of this work, the questionnaire consists of 14 fixed items grouped into two categories: "critical success factors" and "process management" (see Table 27). The items in the category "critical success factors" allow the study of the method's usefulness to address the CSFs. These items are based on the CSFs identified in the literature review conducted in Section 2 (see Table 3). The items of the category "process management" enable the study of the method's usefulness to apply the process management practices. These items are partially based on Eikebrokk and Iden's proposal [29]. An item to measure the simulation modeling usefulness to design and improve the processes has been also included in this category. The item response format is based on a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). Each item also includes a text field where participants can further explain their answers. Different process stakeholders involved in the process implementation took part into the evaluation (see Table 6). More precisely, the participants were: 2 IT managers, the incident management process owner, 3 service desk agents, 3 level 1 support agents, and 3 level 2 support agents (totaling 12 participants).

Table 27
Evaluation questionnaire items

Item	Name	Question
Critical success factors		
1	Organization commitment	Do you think the method promotes the organization commitment with the process implementation?
2	Project management	How useful is the method for planning and managing the ITIL implementation project?
3	Implementation sequence	Is the method efficient for defining the process implementation sequence?
4	Stakeholders efficacy	How much do you think the method contributes to your process learning and improve your skills?
5	Support tool quality	Does the method include the developing and deploying of a process support tool?
6	Monitoring and evaluation	Does the method allow the monitoring and evaluation of the process?
7	Cost and time	Do you think the method helps reduce the cost and time of the process implementation?
Process management practices		
8	Process definition	In your opinion, is the process well-defined and documented?
9	ITIL recommendations	Do you think the process design complies with ITIL recommendations?
10	Process owner	Does the process have an owner assigned?
11	KPIs/Objectives definition	How much do you think the method contributes to define the KPIs and objectives of the process?
12	KPIs measurement	How efficient is the method for measuring the values of the process KPIs?
13	Continual process improvement	In your opinion, does the method support the continual process improvement?
14	Simulation modeling usefulness	Does simulation modeling help design and improve the process?

Below, we analyze the aggregated values of the answers to the questionnaire items provided by the participants in order to identify the most positive and negative aspects of *Met4ITIL*.

a) Critical success factors

In general, the critical success factors items have been evaluated positively. Figure 8 shows a radial diagram with the aggregated ratings obtained by these items. The item “cost and time” obtained the highest value, showing the participants’ agreement on their perception that the use of Met4ITIL might reduce the cost and time of the process implementation. This cost and time reduction is supported by the conduction of model simulations that enable the analysis of process changes in a cost and time effective manner. The items “organization commitment”, “stakeholder efficacy” and “monitoring and evaluation” were also very positively rated. According to the participants’ answers, the item “organization commitment” was highly rated because the Met4ITIL favored a cultural change, a high commitment to provide the necessary support and resources, and a high participation of the stakeholders. The item “stakeholder efficacy” obtained a high value because participants consider that their process knowledge and skills improved significantly by learning ITIL process and conducting process model simulations. The value of the item "monitoring and evaluation" was very favorable because the last method activity emphasizes on the importance of the systematic collection and evaluation of the process KPIs. The items "implementation sequence" and "support tool quality" received also a high rate because Met4ITIL includes tasks to identifying and prioritizing the processes to implement (task of the activity "planning and organization of the ITIL implementation") and process automation (task of the activity "process implementation "). Though the stakeholders valued these items positively, they highlighted that the method does not include recommendations to conduct these tasks. The item "project management" was the worst rated because the tasks for managing the ITIL implementation tasks are not included.

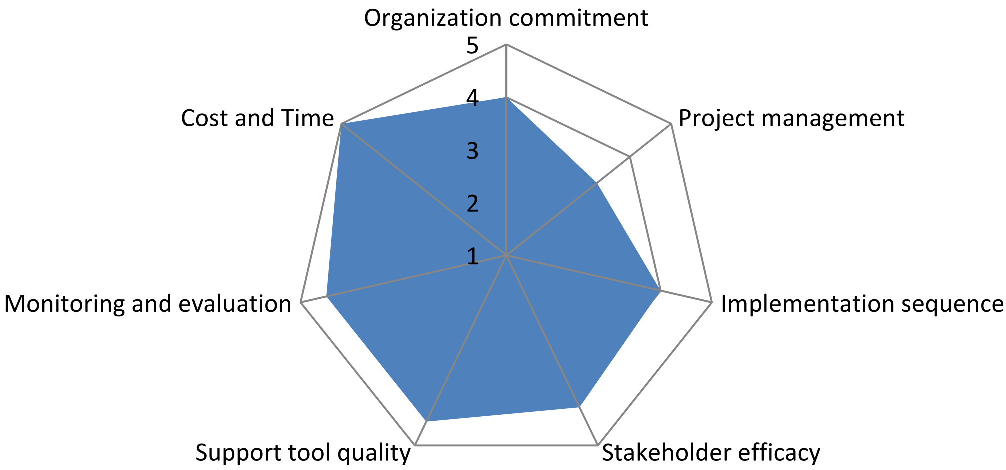

Figure 8. Radial diagram of critical success factors items

b) Process management practices

Figure 9 shows a radial diagram with the aggregated ratings of the answers provided for the process management items. Most of these items were highly rated. The items "process definition" and "ITIL recommendations" obtained the highest value meaning that Met4ITIL is perceived as well defined and in accordance with the ITIL process description and recommendations. The item "KPIs/Objectives definition" received also the highest possible value because the activity "process design" includes the definition of the KPIs and objectives of the process. The item "process owner" was favorably rated because the first activity, "planning and organization of the ITIL implementation", includes a task to assign an owner to the process. The item "KPIs measurement" obtained a positive value because Met4ITIL includes the activity "process monitoring", whose purpose is to collect and analyze systematically the KPIs and results of the process. The stakeholders did not assign the maximum value to this item because the process has not been implemented yet and the actual KPIs cannot be measured. The item "continual process improvement" did not obtain the highest value for a similar reason. As the process has not been implemented yet, improvement actions have not been carried out. The participants highlighted that the continuous activity cycle that method proposes will facilitate the continual process improvement. Finally, the item "simulation modeling usefulness" was very highly rated because the simulation model helped design the process and improve the participants' process knowledge. The IT managers and the process owner expressed that the participation of a simulation modeling expert with sufficient knowledge about the process is required in order to build a reliable process simulation model.

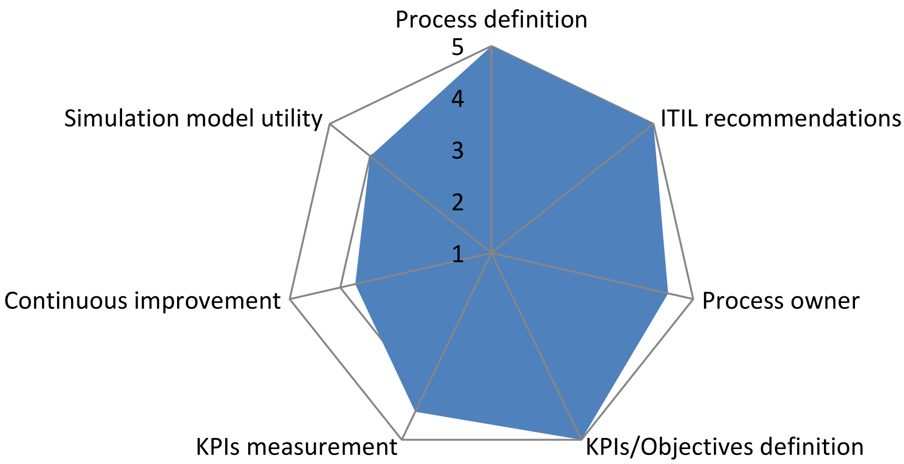

Figure 9. Radial diagram of process management items

7. Research activity 4. Method improvement

The answers provided to the questionnaire reveal the participants' agreement on the usefulness of Met4ITIL for the ITIL implementation. The participants opine that the method guides them through the implementation process and helps them both to address the main CSFs and to apply the process management practices. Besides, they highlight the usefulness and applicability of simulation modeling for process design and improvement.

Though most of the items were fairly well rated, some of them were not positively rated for the following reasons:

a) The actual status of the incident management process implementation. Currently, the process is in the design phase. For this reason, some activities, such as "process automation" and "process monitoring and evaluation", have not been conducted yet. However, the participants rated favorably the topics related with these activities, such as "monitoring and evaluation" and "KPIs measurement", since Met4ITIL enables to collect and analyze systematically the process KPIs and results. Besides, the continuous activity cycle that the method proposes will facilitate the continual process improvement.

b) The lack of detail in the description of some Met4ITIL activities. The participants noticed that it would be necessary to describe further how to conduct the following activities: a) planning and organization the ITIL implementation, b) determining the process implementation sequence, and c) developing and deploying a process support tool.

8. Conclusions and further works

The work presented in this paper focuses on ITIL implementation. The results of the conducted research literature study show that the research works in this field focus on either examining the critical factors for a successful ITIL implementation or present particular study cases of ITIL implementation in real-world companies. However, despite the importance of having methods to guide managers through the ITIL implementation [30][43] and the benefits of applying process management practices in ITIL projects [29], these topics have scarcely been studied together in the research literature.

In this paper, we have introduced Met4ITIL, a novel method for implementing ITIL, it has been developed adapting the business process management lifecycle [70] to the particular characteristics of ITIL implementation projects. The method proposes the use of simulation modeling to help managers design the processes and make decisions for the continual process improvement. To illustrate the usefulness and applicability of Met4ITIL, an application case to help a company start the implementation of the incident management process has been described. Since the company has not finished the complete implementation of the process yet, in this work, we report on the application of the first activities, especially on the process design activity and the usefulness of simulation modeling to conduct this activity. The process simulation model developed to help managers design the process and some of the conducted simulation experiments have been introduced. These experiments show that the process simulation model helps managers to look into the process with more detail and study the process performance over time varying the values of the process configuration parameters (SLA, support groups and incident management policies). Besides, sensitivity analyses and optimization experiments enable managers to determine the process parameters that most influence the process results and to decide what changes to perform on the process configuration to optimize the process results and meet the established objectives. The experiment results show that the initial considered process configuration was not the adequate on maximizing the process efficiency. In this case, the process performance could be improved by changing both the configuration of the support groups, and the incident severity and priority policies.

It is important to notice that even though in this paper we have applied Met4ITIL to help a company implement the incident management process, the method is suitable to help companies implement any of the ITIL processes. In each company and for each process, the activity for process design will rely on the building of a simulation model for the intended process to be implemented. These simulation models will necessarily represent the behavior and the particular idiosyncrasy of each company, such as the policies they are interested in analyzing, their internal structure, the different roles and skills of their personnel, etc.

Our proposal is the result of a six-month work in which several researchers have analyzed the available research literature in the field of ITIL implementation projects and designed Met4ITIL to help organizations implement ITIL processes. Met4ITIL has been reviewed by two ITIL experts and evaluated from the perspective of the incident management process stakeholders through a questionnaire. The answers provided to the questionnaire reveal that the participants agree that the

Met4ITIL is a valuable guide for the ITIL implementation. They consider that the method helps focus on the critical success factors that were selected from the literature review and apply process management practices. Additionally, the method evaluation has helped us also identify some weaknesses that need to be improved. For instance, the participants expressed that Met4ITIL should provide further detail regarding some activities, such as how to plan and organize an ITIL project, how to determine the process implementation sequence and how to deploy the process support tools.

Although this work has a particular focus on ITIL and its models for assessment and improvement, Met4ITIL itself is completely independent of any ITSM standard and helps as a guidance to implement any process model regardless the standard followed in a particular company. In order to apply Met4ITIL for a different ITSM-standard implementation, the process models recommended by that particular ITSM standard would be the ones used as a reference for the activities suggested in this method.

Finally, even though Met4ITIL has received very positive feedback from the participants in its application, there are some recommendations for improvement that need to be done. Our further works in this area are the following:

- Finish the implementation and automation of the incident management process in the company. Once the implementation of the incident management process in ServIn is finished, the validation of the process simulation model with actual monitored process data will be performed. Besides, the method will be applied for the continual process improvement within the company.
- Enhance Met4ITIL with the improvements suggested by the participants in its evaluation. More precisely, the improvements requested adding further detail regarding some particular activities, such as how to plan and organize an ITIL project, how to determine the process implementation sequence and how to deploy the process support tools.
- To apply Met4ITIL for implementing other ITIL processes in ServIn and other organizations of similar or different characteristics. The evaluation of next method implementations will allow the continual method improvement.

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References

[1] X. Tang, Y. Todo, A study of service desk setup in implementing IT service management in enterprises. *Technology and Investment* 4 (2013), 190-196.

[2] A.L. Mesquida, A. Mas, Integrating IT service management requirements into the organizational management system, Computer Standards & Interfaces 7 (2015) 80-91.

[3] H. Zhang, C-P. Wej, P.Y.K. Chau, Service science in information systems research, Decision Support Systems 53(4) (2012) 770-771. doi:10.1016/j.dss.2012.05.010.

[4] C.M. Young, An introduction to IT service management, Gartner (2014).

[5] S. Conger, M.A. Winniford, L. Erickson-Harris, Service management in operations, in: Proceedings of the 14th America Conference on Information Systems (362) (2008), <http://aisel.aisnet.org/amcis2008/362>.

[6] M.Mora, M.Raisinghani, R.V.O'Connor, J.M. Gomez, O.Gelman. An extensive review of IT service design in seven international ITSM processes frameworks: Part I, International Journal of Information Technologies and Systems Approach, 7(2) (2014), 8-107.

[7] M.Mora, J.M. Gomez, R.V.O'Connor, M.Raisinghani, O.Gelman. An extensive review of IT service design in seven international ITSM processes frameworks: Part II, International Journal of Information Technologies and Systems Approach, 7(2) (2015), 8-107.

[8] M.Mora, R.V.O'Connor, M.Raisinghani, J. Macias-Luévano, O.Gelman. An IT service engineering and management framework (ITS-EMF), International Journal of Service Science, Management, Engineering and Technology, 2(2) (2011).

[9] ISO/IEC (2011). ISO/IEC 20000-1:2011. Information technology – Service management – Part 1: Service management systems requirements.

[10] ISO/IEC (2012) ISO/IEC 20000-2:2012. Information technology – Service management – Part 2: Guidance on the application of service management systems.

[11] ISO/IEC (2010) ISO/IEC TR 20000-4:2010. Information technology – Service management – Part 4: Process reference model.

[12] CMMI Institute, Capability Maturity Model Integration for Services (CMMI-SVC) v1.3, 2010: CMMI Institute, http://www.sei.cmu.edu/reports/10tr034.pdf, (online: accessed 12-December-2017).

[13] CMMI Institute, <http://cmmiinstitute.com/cmmi-models>, (online: accessed 12-December-2017).

[14] OGC, Information Technology Infraestructure Library, 2011 (ITIL®): Office of Government Commerce, <http://www.itil.org.uk/>, (online: accessed 12-December-2017).

[15] M. Marrone, L.M. Kolbe, Uncovering ITIL claims: IT executive's perception on benefits and Business-IT alignment, International Systems and E-business Management 9(3) (2011) 363-380. doi:10.1007/s10257-010-0131-7.

[16] M. Marrone, L.M. Kolbe, Impact of IT service management frameworks on the IT organization. An empirical study on benefits, challenges and processes, Business & Information System Engineering 3(1) (2011) 5-18. doi:10.1007/s12599-010-0141-5.

[17] A.L. Mesquida, A. Mas, E. Amengual, J.A. Calvo-Manzano, IT service management process improvement based on ISO/IEC 15504: a systematic review, Information and Software Technology 54 (2012), 239-247. doi:10.1016/j.infsof.2011.11.002.

[18] TIPA for ITIL, http://www.tipaonline.org (online: accessed 12-December-2017).

[19] B.Barafot, A. Rousseau, E. Dubois, How to design an innovative framework for process improvement? The TIPA for ITIL case, in: Proceedings of European Conference on Software Process Improvement (2014), pp.48-59.

[20] ISO/IEC (2012b) ISO/IEC TS 15504-8:2012. Information technology – Process assessment – Part 8: An exemplar process assessment model for IT service management.

[21] J. Iden, T.R. Eikebrokk, Implementing IT Service Management: A systematic literature review. International Journal of Information Management 33 (2013) 512-523. doi:10.1016/j.ijinfomgt.2013.01.004.

[22] A. Fayoumi, P. Loucopoulos, Conceptual modelling for the design of intelligent and emergent information systems. Expert Systems with Applications 59 (2016), 174-194. doi:10.1016/j.eswa.2016.04.019.

[23] M. Arcilla, J.A.Calvo-Manzano, T. San Feliu, Building an IT service catalog in a small Company as the main input for the IT financial management, Computer Standards & Interfaces 36(2013) 42-53.

[24] A. Cater-Steel, W.G.Tan, M. Toleman, itSMF Australia 2009 Conference: Summary report of ITSM standards and frameworks survey. Technical Report (2009).

[25] A. Cater-Steel, M. Toleman, W.G.Tan, Transforming IT Service Management – the ITIL impact, in: Proceedings of Australasian Conference on Information Systems (2006).

[26] A. Cater-Steel, W.G.Tan, Implementation of IT Infrastructure Library (ITIL) in Australia: Progress and success factors, in: Proceedings of IT Governance International Conference (2005).

[27] A. Cater-Steel, W.G.Tan, itSMF Australia 2005 conference: Summary of ITIL adoption survey responses. Technical Report (2005).

[28] C.Pollard, A.Cater-Steel, Justifications, strategies and critical success factors in successful ITIL implementations in U.S. and Australian companies: An exploratory study. Information Systems Management 26(2)(2009), 164-175.

[29] T.R., Eikebrokk, J. Iden, Strategising IT service management through ITIL implementation: model and empirical test, Total Quality Management & Business Excellence. 28(3-4) (2015), 238-265. doi:10.1080/14783363.2015.1075872.

[30] Lucio-Nieto, R. Colomo-Palacios, P. Soto-Acosta, S. Popa, A. Amescua-Seco, Implementing an IT service information management framework: The case of COTEMAR. International Journal of Information Management 32 (2012) 589-594.

[31] K.H., Han, J.G. Kang, M. Song, Two-stage process analysis using the process-based performance measurement framework and business process simulation. Expert Systems with Applications 36(3) (2009), 7080-7086. doi: 10.1016/j.eswa.2008.08.035.

[32] M. Perkusich, G. Soares, H. Almeida, A. Perkusich, A procedure to detect problems of processes in software development projects using Bayesian networks, Expert Systems with Applications 42(1) (2015) 437-450. doi: 10.1016/j.eswa.2014.08.015

[33] J. Saldivar, C. Vairetti, C. Rodriguez, F. Daniel, F. Casati, R. Alarcón, Analysis and improvement of business process models using spreadsheets, Information Systems 57 (2016) 1-19. doi:10.1016/j.is.2015.10.012.

[34] R. Mans, H. Reijers, D. Wismeijer, M. van Genuchten, A process-oriented methodology for evaluating the impact of IT: A proposal and an application in healthcare, Information Systems 38 (2013) 1097-1115. doi:10.1016/j.is.2013.06.005.

[35] A. Rozinat, R.S. Mans, M. Song, W.M.P. van der Aalst, Discovering simulation models, Information Systems 34(3) (2009) 305-327. doi:10.1016/j.is.2008.09.002.

[36] L. Lema, J.A. Calvo-Manzano, R. Colomo-Palacios, M. Arcilla, ITIL in small to medium-sized enterprises software companies: towards an implementation sequence, Journal of Software: Evolution and Process 27 (2015), 528-538.

[37] OGC (2011). ITIL® Continual Service Improvement, 2011: Office of Government Commerce.

[38] M.I. Kellner, R.J. Madachy, D.M. Raffo, Software Process Simulation Modelling: Why? What? How? The Journal of Systems and Software 46 (2/3) (1999) 91-105. doi.10.1016/S0164-1212(99)00003-5.

[39] L. Lättila, P. Hilletofth, B. Lin, Hybrid simulation models – When, Why, How? Expert Systems with Applications 37 (2010) 7969-7975.

[40] B. Kitchenham, Charters, S, Guidelines for performing systematic literature reviews in software engineering. Keele University and Durhanm University Joint Report.

[41] N. Ahmad, Z.M. Shamsudin, Systematic approach to successful implementation of ITIL, in: Proceedings of the 2013 International Conference on Information Technology and Quantitative Management (2013), pp. 237-244.

[42] P. Schmidtbauer, K. Sandkuhl, D. Stamer, The industrial practice of ITIL implementation in medium-sized enterprises, in: Proceedings of Business Information Systems Workshops, Lecture Notes in Business Information Processing (2013), pp. 124-135.

[43] N.J. Cruz-Hinojosa, J.A. Gutiérrez-de-Mesa, Literature review of the situation research faces in the application of ITIL in small and medium enterprises. Computer Standard & Interfaces 48 (2016), 124-138.

[44] K. Melendez, A. Davila, M. Pessoa, Information technology service management models applied to medium and small organizations: A systematic literature review. Computer Standards & Interfaces 47 (2016) 120-127.

[45] A. Nabiollahi, R.A. Alias, S. Sahibuddin, Involvement of service knowledge management system in integration of ITIL V3 and enterprise architecture, American Journal of Economics & Business Administration 3(1) (2011) 165-170.

[46] B. McNaughton, P. Ray, L. Lewis, Designing an evaluation framework for IT service management. Information & Management 47(4) (2010) 219-225. doi:10.1016/j.im.2010.02.003.

[47] S.D. Galup, R. Dattero, A five-step method to tune your ITSM process. Information Systems Management, 27(2) (2010), 156-167.

[48] K. Jin, P. Ray, Business-oriented development methodology for IT service management, in: Proceedings of the 41 st Annual Hawaii International Conference on System Sciences (2008) doi:10.1109/HICSS.2008.85.

[49] M.C. Valiente, E. García-Barriocanal, M.A. Sicilia, Applying ontology-based models for supporting integrated software development and IT service management processes, IEEE Transactions and Systems. 42(1) (2012) 61-74. doi: 10.1109/TSMCC.2011.2132717.

[50] E. Orta, M. Ruiz, M. Toro, Analyzing strategic business rules through simulation modelling, in: Proceedings of the IFIP Conference on E-Business, E-Services and E-Society (2009), pp. 357-368.

[51] C. Bartolini, C. Stefanelli, M. Tortonesi, SYMIAN: Analysis and performance improvement of the IT incident management process, IEEE Transactions on Network and Service Management 7(3) (2010), 132-144. doi:10.1109/TNSM.2010.1009.I9P0321.

[52] A.P. Moore, R.S. Antao, Improving management of information technology: System dynamics analysis of IT controls in context, in: Proceedings of the 24th International Conference of the System Dynamics Society (2006).

[53] Y. Lee, L. An, S. Bagchi, D. Connors, S. Kapoor, K. Katirciouglu, J. Xu, Discrete event simulation modelling of resource planning and service order execution for service business, in: Proceedings of the 2007 Winter Simulation Conference (2007), pp. 2227-2233.

[54] O. Hühn, C. Markl, M. Bichler, On the predictive performance of queueing network models for large-scale distributed transaction processing systems, Information Technology and Management (2009), 10 (2-3), 135-149.

[55] E. Orta, M. Ruiz, M. Toro, A system dynamics approach to web service capacity management, in: Proceedings of the European Conference on Web Services (2009), pp. 109-117.

[56] L. Wang, A. Sahai, J. Pruyne, A model-based simulation approach to error analysis of IT services, in: Proceedings of the 10th IFIP/IEEE International Symposium on Integrated Network Management (2007), pp. 805-808.

[57] I.J. Martinez-Moyano, E. Rich, S. Conrad, D.F. Andersen, T.R. Stewart, A behavioral theory of insider-threat risks: A system dynamics approach, Transactions on Modeling and Computer Simulation 18 (2) (2008).

[58] P. Thannimalai, M. Kadhum, J.F. Feng Chin, Theoretical approach with simulation models on full cross training and workforce working schedule to increase IT Help Desk efficiency, Procedia-Social and Behavioral Sciences 129 (2014) 236-243.

[59] J.H., Lee, Y.S. Han, C.H. Kim, IT service management case based simulation analysis & design: Systems dynamics approach, in: Proceedings of International Conference on Convergence Information Technology (2007), pp. 1559-1566. doi:10.1109/ICCIT.2007.325.

[60] Y. Diao, A. Heching, Workload management in dynamic IT service delivery organizations, in: Proceedings of the International Workshop on Distributed Systems: Operations and Management, LNCS-5841 (2009), pp. 123-137. doi: 10.1007/978-3-642-04989-7_10.

[61] G. Fenner, A. Lima, N. de Souza, A. Moura, R. Andrade, A system dynamics model for managing Service Desk capacity, in: Proceedings of International Symposium on Integrated Network Management (2015), pp. 1424-1427. doi:10.1109/INM.2015.7140506.

[62] C. Cao, Z. Zhan, Incident management process for the cloud computing environments, in: Proceedings of the IEEE International Conference on Cloud Computing and Intelligence Systems (2011), pp. 225-229. doi: 10.1109/CCIS.2011.6045064.

[63] Y. Li, T-H. Li, A method of effort estimation for incident tickets in IT services, in: Proceedings of the International Conference on Service Operations and Logistics, and Informatics (2013), pp. 311-316. doi:10.1109/SOLI.2013.6611432.

[64] P.M. Deshpande, D. Garg, N. Rama Suri, Auction based models for ticket allocation problem in IT service delivery industry, in: Proceedings of the International Conference on Services Computing (vol. 1) (2008), pp. 111-118. doi: 10.1109/SCC.2008.83.

[65] X. Li, Z. Zhan, S. Guo, L. Zhang, IT incident assign algorithm based on the difference between support groups, in: Proceedings of International Conference on Advanced Intelligence and Awarenss Internet (2010). doi: 10.1049/cp.2010.0778.

[66] C. Bartolini, C. Stefanelli, M. Tortonesi, Business-impact analysis and simulation of critical incidents in IT service management, in: Proceeding of the International Conference on Symposium on Integrated Network Management (2009), pp. 9-16. ISBN: 978-1-424, pp.183-4-3486-2.

[67] G.K. Kundu, B.M. Manogar, J. Bairi, Incident management process capability: A simulation study, in: Proceedings of the International Conference on Recent Trends in Computing, Communication and Information Technologies (2011), pp. 243-255. doi: 10.1007/978-3-642-29216-3_27.

[68] A. Kieninger, F. Berghoff, H. Fromm, G. Satzger, G. Simulation-based quantification of business impacts caused by service incidents, in: Proceedings of the International Conference on Industrial Engineering and Service Science (2013), pp. 170-185. doi:10.1007/978-3-642-36356-6_13.

[69] M. Sein, O. Henfridsson, S. Purao, M. Rossi, R. Lindgren, Action Design Research, MIS Quarterly 35(1) (2011) 35-56.

[70] M. Dumas, M. La Rosa, J. Mendling, H.A. Reijers. Fundamentals of Business Process Management, Springer-Verlag (2013). ISBN 978-3-642-33142-8.

[71] J. Iden, Investigating process management in firms with quality systems: A multi-case study, Business Process Management 18(1) (2012), 104-121. doi:10.1108/14637151211215037.

[72] J. Becker, M. Krugeder, M. Rosemann, Process Management: A Guide for the Design of Business Processess, 2nd ed. Springer, Berlín, 2007.

[73] T.R. Gulledge, S.A. Sommer, Business process management: public sector implications, *Business Process Management Journal* 8(4) (2002), 364-376.

[74] M. Hammer, S. Stanton, How process enterprises really work, Harward Business Review (1999), pp. 108-118.

[75] P. Küng, C. Hagen, The fruits of business process management: An experience report from a Swiss bank. Business Process Management Journal 13(4) (2007) 477-487

[76] J.P. Pritchard, C. Armistead, Business process management – lessons from European business. Business Process Management Journal 5(1) (1999) 10-32.

[77] W.M.P. Van der Aalst, A.H.M. ter Hofstede, M. Weske, Business process management: a survey, in: Proceedings of the 2003 International Conference of Business Process Management (2003) pp. 1-12.

[78] A.V. Law, How to build valid and credible simulation models, in: Proceedings of the 2009 Winter Simulation Conference (2009), pp. 24-33.

[79] OGC (2011). ITIL® Service Operation, 2011: Office of Government Commerce.

[80] J.D. Sterman, Business Dynamics. Systems Thinking and Modelling for a Complex World, McGraw-Hill (2000).

[81] AnyLogic, <http://www.anylogic.com>, (online: accessed 12-December-2017).

[82] Y. Barlas, Formal aspects of model validity and validation in system dynamics, Systems Dynamics Review, John Wiley & Sons 12(3) (1996), 183-210.

[83] OpTek Systems, Inc. OptQuest® (2017), <http:// www.opttek.com/>, (online: accessed 02-August-2017).

[84] Easyvista, <http://www.easyvista.com>, (online: accessed 12-December-2017).