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Table of contents

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Editorial

It is our great pleasure to bring you the first number of the third volume of IJISPM - International Journal of Information Systems and Project Management. The mission of the IJISPM is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

In this issue readers will find important contributions on business process improvement, Health Information Technology acceptance, and on Building Information Modeling.

The first article, “Business process improvement by means of Big Data based Decision Support Systems: a case study on Call Centers”, is authored by Alejandro Vera-Baquero, Ricardo Colomo-Palacios, Owen Molloy and Mahmoud Elbattah. Big Data is a rapidly evolving and maturing field which places significant data storage and processing power at our disposal. To take advantage of this power, organizations need to create new means of collecting and processing large volumes of data at high speed. Meanwhile, as companies and organizations, such as health services, realize the importance and value of "joined-up thinking" across supply chains and healthcare pathways, for example, this creates a demand for a new type of approach to Business Activity Monitoring and Management. This new approach requires Big Data solutions to cope with the volume and speed of transactions across global supply chains. The article describes a methodology and framework to leverage Big Data and Analytics to deliver a Decision Support framework to support Business Process Improvement, using near real-time process analytics in a decision-support environment. The system supports the capture and analysis of hierarchical process data, allowing analysis to take place at different organizational and process levels. Individual business units can perform their own process monitoring. An event-correlation mechanism is built into the system, allowing the monitoring of individual process instances or paths.

As Abd Rahman Ahlan and Barroon Isma'eel Ahmad state in the second article, “An overview of patient acceptance of Health Information Technology in developing countries: a review and conceptual model”, the potential to improve the quality, efficiency, outcomes, patient safety, and reduce cost of healthcare by Health Information Technology (HIT) has been established by researchers. But unfortunately HIT systems are not properly utilized or are not widely available. This problem is even more glaring in developing countries. The article presents a review of some available HIT systems in order to assess the level of their presence and the technology used in developing them. Works related to acceptance of HIT systems were also reviewed so as to study the gaps in this area and propose a solution in order to fill the gaps identified. The problems discovered from the review include lack of availability of these systems especially in developing countries, low rate of HIT systems acceptance and insufficient works on patient acceptance of HIT systems. Studying the factors that affect the acceptance of HIT systems by patients and considering the factors while developing the systems will play a significant role in getting over the aforementioned limitations. The authors propose a conceptual model of HIT acceptance in developing countries based on Technology Acceptance Model (TAM).

Romain Morlhon, Robert Pellerin and Mario Bourgault, in their article “Defining Building Information Modeling implementation activities based on capability maturity evaluation: a theoretical model”, develop an assistance model for Building Information Modeling (BIM) implementation. BIM has become a widely accepted tool to overcome the many hurdles that currently face the Architecture, Engineering and Construction industries. However, implementing such a system is always complex and the recent introduction of BIM does not allow organizations to build their experience on acknowledged standards and procedures. Moreover, data on implementation projects is still disseminated and fragmentary. The solutions that are proposed by the authors will help develop BIM that is better integrated and better used, and take into account the different maturity levels of each organization. Based on Critical Success Factors, concrete activities that help in implementation are identified and can be undertaken according to the previous maturity evaluation of an organization. The result of the research consists of a structured model linking maturity, success factors

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and actions, which operates on the following principle: once an organization has assessed its BIM maturity, it can identify various weaknesses and find relevant answers in the success factors and the associated actions.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like to express our gratitude to all the authors who submitted their work, for their insightful visions and valuable contributions.

We hope that you, the readers, find the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

The Editor-in-Chief,

João Varajão

University of Minho

Portugal

João Varajão is currently professor of information systems and project management at the *University of Minho*. He is also a researcher of the *Centro Algoritmi* at the *University of Minho*. Born and raised in Portugal, he attended the *University of Minho*, earning his Undergraduate (1995), Masters (1997) and Doctorate (2003) degrees in Technologies and Information Systems. In 2012, he received his Habilitation degree from the *University of Trás-os-Montes e Alto Douro*. His current main research interests are in Information Systems Management and Information Systems Project Management. Before joining academia, he worked as an IT/IS consultant, project manager, information systems analyst and software developer, for private companies and public institutions. He has supervised more than 50 Masters and Doctoral dissertations in the Information Systems field. He has published over 250 works, including refereed publications, authored books, edited books, as well as book chapters and communications at international conferences. He serves as editor-in-chief, associate editor and member of the editorial board for international journals and has served in numerous committees of international conferences and workshops. He is co-founder of CENTERIS – Conference on ENTERprise Information Systems and of ProjMAN – International Conference on Project MANagement.

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Business process improvement by means of Big Data based Decision Support Systems: a case study on Call Centers

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Business process improvement by means of Big Data based Decision Support Systems: a case study on Call Centers

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Abstract:
Big Data is a rapidly evolving and maturing field which places significant data storage and processing power at our disposal. To take advantage of this power, we need to create new means of collecting and processing large volumes of data at high speed. Meanwhile, as companies and organizations, such as health services, realize the importance and value of "joined-up thinking" across supply chains and healthcare pathways, for example, this creates a demand for a new type of approach to Business Activity Monitoring and Management. This new approach requires Big Data solutions to cope with the volume and speed of transactions across global supply chains. In this paper we describe a methodology and framework to leverage Big Data and Analytics to deliver a Decision Support framework to support Business Process Improvement, using near real-time process analytics in a decision-support environment. The system supports the capture and analysis of hierarchical process data, allowing analysis to take place at different organizational and process levels. Individual business units can perform their own process monitoring. An event-correlation mechanism is built into the system, allowing the monitoring of individual process instances or paths.

Keywords:
business process improvement; Big Data; Decision Support Systems; processes.

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1. Introduction

The Internet era has led to the production of increasing amounts of digital data [1]. Big Data (BD) is an emerging phenomenon [2] which has drawn huge attention from researchers in information sciences, as well as policy and decision makers in governments and enterprises [3]. There are several definitions for the term, however, the predominant one seems to be that BD relates to datasets that have become too large to handle with the traditional or given computing environment [4]. It is fair to say that the Information Technology (IT) world has been facing BD challenges for over four decades, but the definition of "big" has been changing from megabytes in the 1970s to the petabyte range today [5]. Within this phenomenon, [6] points out that BD can be seen as two different issues: big throughput and big analytics; the former includes the problems associated with storing and manipulating large amounts of data and the latter those concerned with transforming this data into knowledge. Focusing on the analytics, BD analytics is a workflow that distills Terabytes of low-value data down to, in some cases, a single bit of high-value data with the goal to see the big picture from the minutiae [7]. This new discipline requires new approaches to obtain insights from highly detailed, contextualized, and rich contents that may require complex math operations, such as machine learning or clustering [2]. This diversity of tools and techniques for BD–driven analytics systems makes the process nontrivial. In the analytics of these kind of systems several artificial intelligence technologies play a crucial role [8]–[10].

On the other hand, LaValle et al. [11] report that top-performing organizations 'make decisions based on rigorous analysis at more than double the rate of lower performing organizations' and that in such organizations analytic insight is being used to 'guide both future strategies and day-to-day operations'. In sum, literature reported significant interest in the potential of 'big data' and 'analytics' to transform the competitive landscape and to improve organizational performance [12]. Examples of the use of big data can be found in several sectors, including government [13], academia [14], medicine [15], climate science [16] and agriculture [17].

One of the main tools employed in organizations are Decision Support Systems (DSS). DSS are computer technology solutions that can be used to support complex decision making and problem solving [18]. Real-time, low latency monitoring and analysis of business events for decision making is key, but difficult to achieve [19]. The difficulties are intensified by those processes and supply chains which entail dealing with the integration of enterprise execution data across organizational boundaries. Such processes usually flow across heterogeneous systems such as business process execution language (BPEL) engines, Customer Relationship Management (CRM) systems, and Supply Chain Management (SCM) systems. The heterogeneity of these supporting systems makes the collection, integration and analysis of high volume business event data extremely difficult [20]. The new possibilities of storing and analyzing big data are changing the DSS landscape, including, for instance, decision support social networks [21].

Previous work by the authors [19] presented a big-data based DSS that provides visibility and overall business performance information on distributed processes. This DSS tool enables business users to access performance analytics data efficiently in a timely fashion, availing of performance measurements on an acceptable response time basis. This paper presents and extends a methodology presented also in [22] aimed to help users to deploy DSS tools in big data environments. In a nutshell, the aim of this method is to assist business users in sustaining a comprehensive process improvement program by means of a DSS built on Big Data. The remainder of this paper is structured as follows. Section 2 presents the five steps of the process to guide DSS implementation in Big Data environments for business process analytics. Section 3 presents a case study that depicts the application of the process in a real scenario. Finally, section 4 concludes the paper and outlines potential research directions.

2. Description of the process

The Business Processes Improvement (BPI) arena incorporates a plethora of methods and approaches. In spite of this fertility, BPI seems to be art rather than science [23]. To avoid getting lost in the "improvement black box" it would be useful to have directions and rules that support the act of process improvement [24]. The effort presented in this paper is not a method for BPI. This is a method to deploy DSS in big data environments to be applied with the final aim of BPI.

Thus, the methodology presented in this paper consists of five phases (Fig. 1). The first phase identifies business process models that we aim to monitor and improve. The second phase studies and defines the physical elements of the operational systems and prepares the analytical environment for collecting enterprise performance data. This phase will identify the steps that must be undertaken within the operational environment in order to gather and collect performance information. The third phase involves the implementation of listeners for capturing and collecting both structural and behavioral information from operational systems. The fourth phase monitors the execution of processes, and establishes quality control measures in order to identify critical paths and incompliant situations. And the fifth phase leverages the outcomes obtained from the previous step to reveal deficiencies in the process that was defined in the first phase. The deficiencies found determines those processes that are susceptible to be improved. Once the improvement measures have been undertaken, the lifecycle starts over again on a continuous refinement basis.

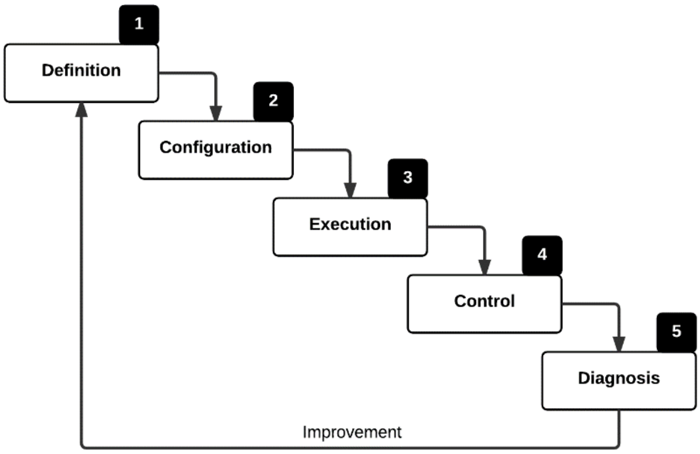

Fig. 1. A methodology for business process improvement

2.1 PHASE 1. Definition

In this phase, the identification of the distributed business process model along the large and complex supply chains are performed. Thus, the definition consists in discovering and defining the process that is aimed to be improved. Likewise, the purpose of this phase is not only to identify and represent the business process that has a significant value for the organization, but also to have clear insight into the strategic management of the enterprise and a good understanding of the business goals being pursued. This will help the analyst to identifying the critical processes or activities that must be monitored. For identification of the process models, authors use a method based on the tabular application development (TAD) methodology widely described in the work of Damij et al. [25]. Several steps are included in this phase, depicted as follows.

2.1.1 Identification of scope and boundaries

This step consists in identifying the scope and boundaries of the global business process, and defining the global business process itself. In large and complex supply chains, there are a considerable number of business entities that are involved in the business process, such as Manufacturing, Sales, Stock, Logistic, Accounting, etc. The determination of these participants is crucial for establishing the boundaries of sub-processes and discovering key interactions between enterprises (cross-functional) or departments (inter-departmental), hereinafter business nodes.

The Fig. 2 illustrates a cross-functional business process that flows across six organizations, namely business nodes. The demand and delivery lines depict the global business process that must be identified in this step along with the business nodes involved.

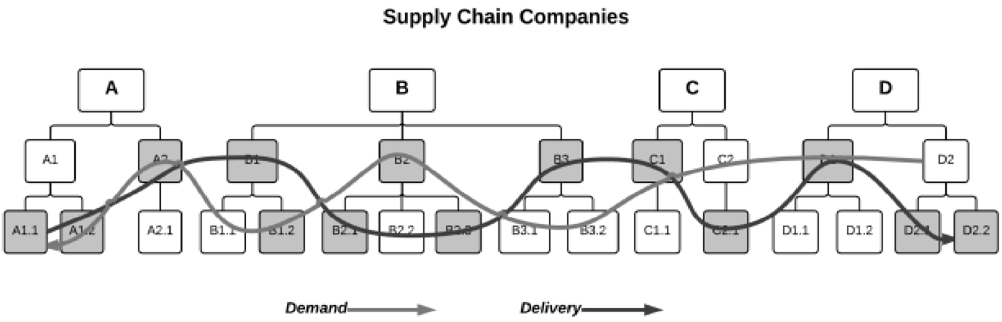

Fig. 2. Cross-functional business process

2.1.2 Definition of sub-processes, activities and sub-activities

In this step we have to iterate over each organizational node that has been identified in the previous step. For each organizational node previously defined, the aim is to discover sub-processes, activities and sub-activities (see Fig. 3) associated with the global process identified in the previous step.

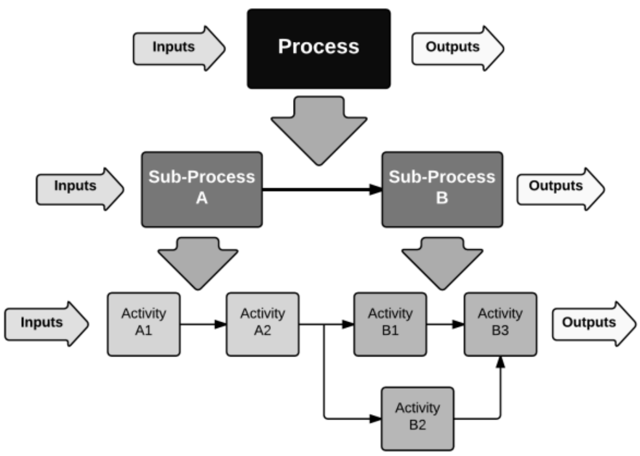

Fig. 3. Sample process hierarchy [14]

As stated, this BPI methodology is sustained by the big-data based DSS system discussed in [19]. This IT solution presents capabilities to monitor and query the structural and behavioral properties of business processes. Hence, it is required to gather properties relevant to the structure of the processes and activities. Similarly, it is imperative to focus on the input, outputs and payloads of processes and activities, as this information will be essential at further stages for establishing the link between inter-related processes.

2.1.3 Determination of level of detail within business processes

According to [20], as depicted in Fig. 3, “a process may itself be composed of a number of different sub-processes or activities which in turn may be decomposed into a set of smaller related tasks” [10]. There is no globally accepted limit on the number of levels, and depending on the nature of the business process and the specific requirements on process improvement endeavors, it may be necessary to monitor both high level and low level processes. The actual number of levels must be identified in this step.

The greater the number of nested levels, the more cumbersome is the deployment of the DSS, and the more complex is the monitoring and analysis of the performance information. Consequently, it is important to determine the trade-off between the deployment costs, and the final value of such data. If the performance information of an activity or sub-activities at a given level is neither crucial nor relevant, then it might be better to leave them out of the analysis. Additionally, each business node may have its own level of detail per process or activity. Every BASU (Business Analytics Service Unit) can perform the analysis of their own processes in isolation [19].

2.1.4 Development of model tables

The last step in this first phase is to model the business process in a tabular form. This methodology follows a business process model representation using tables because they are useful for representing the sequence of events clearly, are easy to manage for business users [25], and simplify the deployment of the DSS system in further stages.

In this step it is needed to create a table per business node (a very simplified representation of the business process model), where each table is organized as follows: the first column defines the global business process definition of the business node. Consequently, this process is a sub-process of the cross-organizational process defined in the first step. The second column presents the activities grouped by processes; the third column represents the nested level of the activity by making a reference to the parent activity. The fourth and last column lists a set of properties in the form of key value pairs.

2.2 PHASE 2. Configuration

During the configuration phase we prepare the analytical environment to receive structural event data from the operational systems that will feed the DSS for later analysis. Hence, this step is crucial for the overall success of the performance analysis, and equally important in the successful implementation of the DSS. During the configuration phase, software boundaries and inter-departmental processes within business nodes are identified. Likewise, the selection of the event data format, and the determination of instance correlation data are also undertaken. Finally, software listeners, along with a selection metrics and their threshold values, are established and implemented. Phase 2 consists of the steps outlined in next sections.

2.2.1 Business nodes provisioning and software boundaries identification

In this step the system must provision a BASU component [19] per business node identified in the Definition phase. The number of nodes may vary depending on three main factors: 1) the nature of the business process that it is intended to analyze; 2) the performance of the DSS; and 3) security issues due to the data sharing between the BASU unit and the GBAS (Global Business Analytic Service) component.

The DSS described in previous works [19] allows individual companies in a supply chain to own and manage their data. Provided data sharing was not an issue, or if a single secure data store was acceptable to all process owners, we can provide one BASU unit per business node. Otherwise, it is possible to breakdown a business node into smaller business units, and provision a unique BASU component per unit. This solution is also valid for performance reasons. Subsequently, and as part of the business nodes provisioning step, it is necessary to load the process model tables into each corresponding BASU unit.

Once we have provisioned all business nodes, we must identify the software boundaries within each business node. This will give us an insight into the software requirements on source systems when implementing the listener in a further step. Furthermore, these software boundaries are normally linked to inter-departmental sub-processes. Therefore, the use of the model tables developed in the Define phase are very useful to discover technological requirements for those processes that flow across heterogeneous systems.

2.2.2 *Selection of event data format*

The event format data that will feed the system must be established in this step. The selection of the right format will tackle the problems of integration described in [26]. According to [27], the most popular and accepted formats for process mining are XES, MXML and BPAF. The final selection of the format will depend on the business analyst and whether he or she considers it useful or not to maintain interoperability of the event logs with other process mining tools and techniques besides the DSS.

Within the DSS context, the legacy listener software may emit the event information to different endpoints depending on the message format provided. At this time, the platform presented in [19] supports a variety of widely adopted formats for representing event logs such as XES, MXML [27], [28] or even extended BPAF [28]. Every BASU unit transforms and correlates its own events by querying the event repository for previous instances. The DSS event correlation algorithm uses the event data specified in the message format, and consequently this correlation data is key for the accuracy and quality of the performance data.

2.2.3 *Event correlation data determination*

The goal of this step is the determination of which part of the message payload will be used to correlate instances. The term *instance correlation* refers to the unique identification of an event for a particular process instance or activity during execution. For instance, for an order process, the order number may be used to match the start and end of the event sequence in the timeline. Event correlation is on the critical path, and must be executed in a timely manner. Without the ability to correlate events, it is not possible to generate metrics or Key Performance Indicators (KPI) per process instance or activity [29]. Moreover, if the correlation data is not chosen in a correct way, established metrics would be incorrect, leading to a poor accuracy and loss of quality on analytical data. In this phase it is needed to look into the business process model table and identify the relationships among processes. The common properties along the business process will reveal good candidates for using their values as correlation data. Table 1 presents the identification of correlation properties.

Table 1 - Correlation properties identification on the model table

Process	Activity	Activity Parent	Properties
1#P_1	1#A_1		**$Prop_1$**
	2#A_2	A_1	**$Prop_1$**,$Prop_2$,$Prop_3$
	3#A_3	A_1	**$Prop_1$**,$Prop_2$
2#P_2	4#A_4		**$Prop_1$**
	5#A_5	A_4	**$Prop_1$**,$Prop_4$

2.2.4 *Listeners implementation*

In this step the software needed to collect event execution data of instances is developed. Taking into account that it must deal with the format selected in step 2, the event data must contain at least the mandatory entries stated in Table 2.

Table 2 - Event structure data.

Field	Description	Optional
EventId	Unique identifier for the event per business node.	
Source	BASU unit.	
ProcessDefinitionId	Definition of the process identified in model table.	
ProcesName	Name of the process.	X
ActivityDefinitionId	Definition of the activity identified in model table.	X
ActivityName	Name of the activity.	X
ActivityParent	Parent of the current sub-activity.	X
StateTransition*	State transition for the current event. This is highly dependent of the message format.	
Correlation[]	Set of key/value pairs used for correlation.	
Payload[]	Set of key/value pairs that represent the structural properties of the process or activity.	X

2.2.5 Selection of metrics and KPIs

KPIs are indispensable to build a concrete understanding of what needs to be monitored and analyzed. Within a Business Activity Monitoring (BAM) context, the construction of metrics and KPIs is intended to be performed with minimum latency, and this can be a data-intensive process in big data based DSS systems with BAM capabilities, as indicated in [19]. Hence, the metrics and KPIs must be selected carefully.

Once the metrics are triggered in the DSS, we may establish thresholds per process or activity. This decision depends whether there already exists or not in the DSS historical information where the expected execution time of a process or instance could be calculated or inferred. In such cases, the thresholds might be set in the BAM component to generate alerts, and hence detect non-compliant situations automatically. The structural metrics that the DSS is currently able to calculate are:

- **Running cases**: number of instances executed for a given process or activity;
- **Successful cases**: number of instances for a given process or activity that completed their execution successfully;
- **Failed cases**: number of instances for a given process or activity that finalized their execution with a failure state;
- **Aborted cases**: number of instances for a given process or activity that did not complete their execution.

Apart from structural metrics, the process also defines some behavioral metrics inspired by the works of [30]:

- **Turnaround**: Computes the gross execution time of a process instance or activity;
- **Wait time**: Measures the elapsed time between the entrance of a process or activity in the system and the assignment of the process or activity to a user prior to the start of its execution;
- **Change-over time**: Evaluates the elapsed time between the assignment of the process or activity to a user and the start of the execution of the process or activity;
- **Processing time**: Measures the net execution time of a process instance or activity;
- **Suspend time**: Gauges the time an execution of a process or activity is suspended.

Similarly, the methodology presented in this paper incorporates the performance dimension that is defined as a quality factor in the works of Heidari and Loucopoulos [31]. The following two measures refer to the performance dimension, and they are adapted to this methodology as KPIs that can be inferred from the metrics defined above.

CYCLE-TIME

Time is a universal and commonly used measure of performance. It is defined as the total time needed by a process or activity instance to transform a set of inputs into defined outputs [31], i.e. the total amount of time elapsed until task completion. This KPI is automatically derived from the "Turnaround" metrics defined in [30], and it is provided by the DSS.

$$T(a) = DD(a) + PD(a)$$

a = Activity.

T(a) = Cycle Time duration of an activity.

DD(a) = Delay Duration of an activity.

PD(a) = Process Duration of an activity (processing time).

$$DD(a) = CH(a) + WT(a) + ST(a)$$

DD(a) = Delay Duration of an activity.

CH(a) = Change over time of a process or activity.

WT(a) = Waiting time of a process or activity.

ST(a) = Suspended time of a process or activity.

$$OF : Min T(a)$$

OF = Objective Function.

TIME EFFICIENCY

This KPI is derived from the *Time Efficiency* quality factor defined in QEF. Activity *Time Efficiency* measures "how an activity execution is successful in avoiding wasted time". This KPI is the "mean of Time Efficiency in different instances of an activity execution". Formulae for *Time Efficiency* KPI calculation are defined as follows:

$$ET(a) = \frac{PT(a)}{T(a)} x\, 100$$

a = Process or activity.

ET(a) = Time of Efficiency of a process or activity.

T(a) = Cycle time duration of a process or activity.

PT(a) = Planned Time duration of an activity. This is a big data based function that is inferred by the historical registry of the DSS.

$$OF : E(a) \geq 100$$

OF = Objective Function.

2.3 PHASE 3. Execution

During this phase the operational systems are executed making the listeners and the overall DSS fully operational. During the execution phase, the overall infrastructure is monitored including matching of defined patterns of events and real data along with expected metrics.

The next phase is only reached once the trial-execution phase is completed successfully.

2.4 PHASE 4. Control

Outcomes of the overall implementation are analyzed by business users during this phase. Fig. 4 illustrates the different dimensions on which the analysis can be focused in this phase.

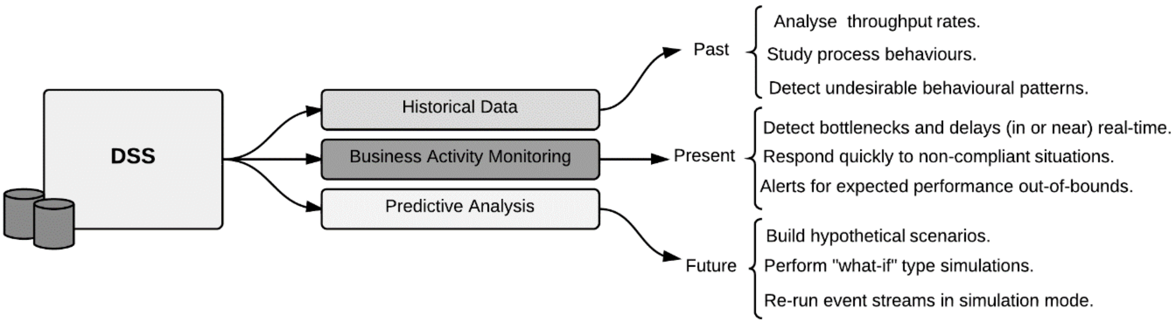

Fig. 4. Business process analytics on different dimensions

Effectively, the system processes the analytical data from three different perspectives [28]:

1) Historical Analysis: the analysis of the event logs to provide business users with a powerful understanding of what has happened in the past;
2) Business Activity Monitoring: monitoring and evaluation of what is happening at present;
3) Predictive Analysis: this will give analysts the ability to predict the behavior of process instances in the future.

2.5 PHASE 5. Diagnosis

Inspired by [32], the purpose of this phase is to evaluate the improvement results and ensure whether the operation performance of the problematic processes have achieved desired results. According to [33], the improvement phase is considered to be the most creative phase during a BPM project, so personnel working in this phase must be creative and competent to extract meaningful information from results.

Thus personnel may exploit the DSS capabilities such as visualization to identify hot-spots, or re-run event streams in simulation mode in order to perform root cause analysis, among others. Once the weaknesses are found, they must be eliminated from the operational systems. In such a case, the business process is re-designed and re-deployed in the operational environment, and the improvement lifecycle starts over again on a continuous refinement basis.

3. Case Study

We present a case study intended to test the methodology proposed by using a big data based DSS described in [19]. The case study is focused on the improvement of the service delivery process for call centers to enhance productivity while maintaining effective customer relationships. Call centers play an essential role in the strategic operations of organizations as it directly impacts on customer loyalty and their experiences greatly influence in their decision to stay or leave that organization [34]. The provision of effective customer service is crucial for corporations in running a competitive business environment.

In our approach we model a hypothetical large-scale international company with presence in multiple countries. This fictitious enterprise provides worldwide customer service assistance. Their call centers are spread around the globe assisting customers from different regions and in multiple languages (see Fig. 7). Every call flows through one or many call centers routing inbound calls towards the most suitable free agent to attend the request with the aim of providing the customer with the best service value. The flow of the incoming calls is modelled and represented as the target business process that we aim to monitor, analyze and improve.

Before proceeding with the description of the business process, we must first give a brief overview of how call centers internally work. Typically, a call center (see Fig. 5) is comprised of the following main components: a PABX (Private Automatic Branch Exchange); an IVR (Interactive Voice Response); multiple queue channels (normally grouped by categories); an ACD (Automatic Call Distributor); and a number of agents that handle the incoming calls. Every agent normally has a workstation that is connected to a specific-purpose enterprise information system. Usually, these systems are customer relationship management systems (CRM) or hybrid systems that complement each other to fulfil the customer demands. The PABX is the entry point to the call center and supports IVR and ACD functionality. A number of extensions are connected to a PABX, and every extension is attached to the ACD. The ACD switch is responsible for dispatching an incoming call over a certain line by selecting an extension with a free agent. An incoming call is first routed to an IVR once it succeeded to establish a communication with the trunk line in the PABX. The IVR provides standard message recording which drives the caller through a menu to select the most appropriate category to the customer. Finally, the ACD dispatches the call to the most suitable free agent. Alternatively, if the call center workload is unbalanced, inbound calls may be forwarded to another call center according to the customer requested services and needs [35].

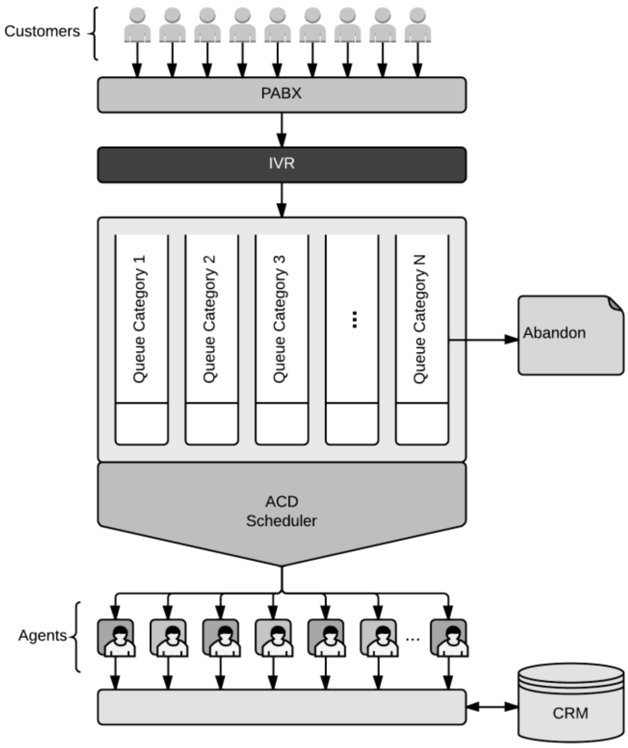

Fig. 5. Call center overview (adapted from [35]).

Based on the aforementioned assumptions, the objective business process aimed to be improved is illustrated in BPMN notation in Fig 6.

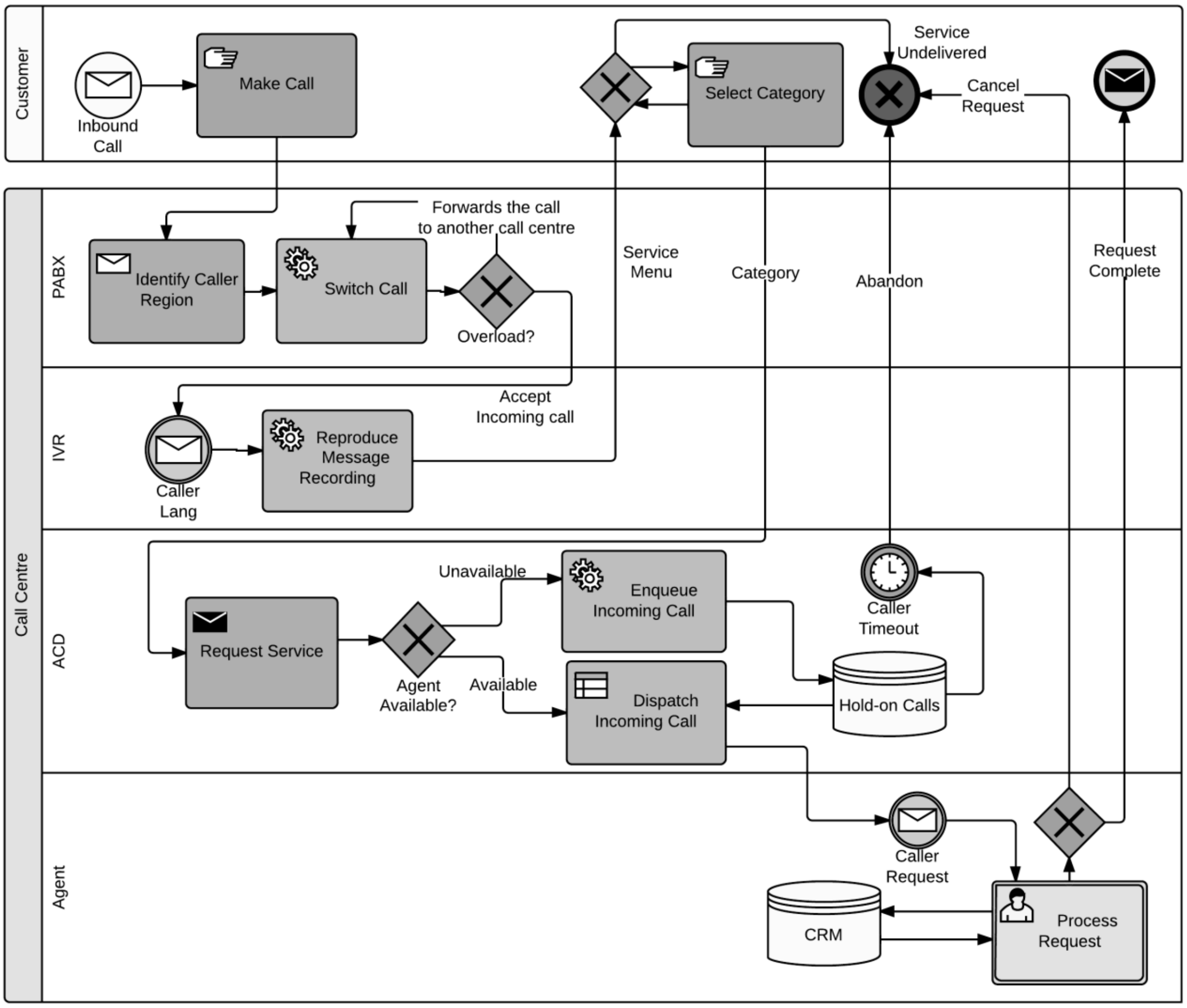

Fig. 6. Business process in BPMN notation

The improvement of the business process can drastically impact on the overall performance level of a call center. Of course, it is important not to drive the wrong type of behavior by rewarding agents for closing calls too quickly, and perhaps not dealing correctly with the customer query or problem. Notwithstanding, normal process throughput is basically measured in terms of waiting time of calls, the rates of abandons, and the productivity of the agents based on the number of calls handled and their duration. These measures will give analysts an insight into critical factors that will directly affect business process performance such as routing policies, queues distribution, overloads, abandonments, retrials, etc.

[35] outlines the following benchmarks for a well-run call center: 1) the agent underutilization level never goes up above the 5% of their total workload capacity; 2) the rate of call handling is approximately one thousand calls per hour over one hundred agents; 3) by average, a half of incoming calls are answered immediately; and 4) the abandon rate for calls on standby waiting for service ranges between a negligible 1 and 2 per cent. These high levels of service quality are very hard to accomplish for a call center, even for the most productive ones. This case study aims to achieve a global visibility of call center performance that will lay the ground for gaining an insight into the improvement of the overall quality of customer service.

The estimated volume of call arrivals is expected to be huge, whereby the number of events generated by the call center will grow considerably over time. In order to achieve a timely monitoring and analysis of call center performance, the big data based DSS system introduced in [19] has been leveraged and applied in conjunction with the proposed methodology. The implementation methodology is rolled out in the following sections.

3.1 PHASE 1. Definition

3.1.1 Identification of scope and boundaries

In this phase we identify 18 business nodes that correspond to the different call centers that are spread around the globe. The call centers are outlined in the following table. Whereas the volume of event data tends to be huge over time, the analysis will be broken down into several distinct locations. The reason for splitting the data analysis process through many locations is twofold: 1) *performance reasons*: the vast amount of event data produced by an individual call center is easier to manage when it is stored and analyzed in isolation; and 2) *managerial reasons*: the improvement process is greatly simplified as it allows business users to perform data analysis locally on individual call centers. This enables analysts to drill down into greater level of details within the scope of a particular call center rather than dealing with a broader view of the entire business service. This is more efficient and manageable to detect and identify exceptional issues that affect the performance of other call centers. Thereby, each call center will manage its own data locally, and the data interaction between call centers will be shared among them (see Fig. 7).

Table 3 - Call center identification

Call Center ID	Location	Call Center ID	Location
CC01	USA (East)	CC10	Spain
CC02	USA (West)	CC11	Norway
CC03	Canada	CC12	Algeria
CC04	Ireland	CC13	Ukraine
CC05	Mexico	CC14	Russia
CC06	Venezuela	CC15	India
CC07	Brazil	CC16	China
CC08	Argentina	CC17	Japan
CC09	South Africa	CC18	Australia

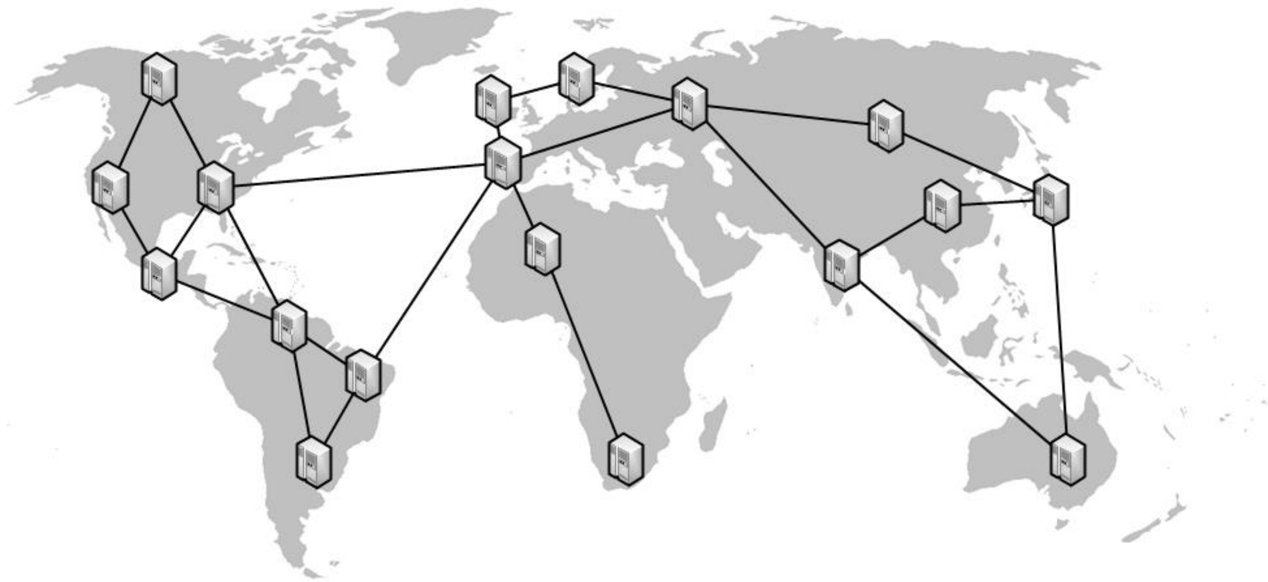

Fig. 7. Call center locations

3.1.2 Definition of sub-processes, activities and sub-activities

In this case study we aim to analyze the performance of the service delivery process of call centers. For this purpose, we define a global process that represents the service request that may flow through diverse call centers in different locations to cater the customer demand. Consequently, we define a sub-process as an incoming customer call that is processed within a particular call center. The activities and sub-activities of incoming calls correspond to the tasks and sub-tasks defined in the business process depicted in Fig. 6.

3.1.3 Determination of level of detail within business processes

The process performance improvement is intended to be performed on every call center, and this entails the monitoring and analysis of a wide range of information such as routing policies, queues distribution, overloads, abandonments, etc. Therefore, the data gathering and analysis must include the activity level of those tasks specified in the business process (see Fig. 6).

3.1.4 Development of model tables

For constructing the model table we have identified the activities (tasks) of the target process and determined their relevance for inclusion in the analysis. Table 4 outlines the process model developed and highlights those activities that are discarded. These tasks are rejected mainly because either they are irrelevant or supply useless information for decision making.

Table 4 - Call-center process model

Process	Activity	Activity Parent	Properties
Incoming.Call	Region.Identification*		CallID
	Swicth.Call		CallID, Country
	Message.Recording.Reporduction		CallID, Country , Category
	Request.Service		CallID, Country , Category
	Enqueue.Call		CallID, Country , Category
	Dispatch.Call		CallID, Country , Category, AgentID
	Process.Request		CallID, Country , Category, AgentID, CustomerID

**The "Region.Identification" activity is eliminated from the analysis because it does not affect the overall business process performance. This operation is attained by the call-center software and it is assumed it performs very quickly.*

3.2 PHASE 2. Configuration

3.2.1 Business nodes provisioning and software boundaries identification

We deployed 18 BASU nodes in a test environment for evaluating the approach. Once every business node is provisioned, the process model developed in the previous phase is loaded in every node. The BASU units deployed are outlined in Table 3. In a real case, this phase is crucial to identify the specific software requirements of every call center along with their internal information systems such as CRM, ERP, etc. The interaction among those systems gains special relevance in this step since the integration and data sharing between both will be essential when designing and implementing the listeners in a later stage. For instance, we must identify how the CallID is represented, stored and linked in the CRM system for a specific customer request. Whilst shared attributes like CallID, and CustomerID are part of the event payload, these are sourced from different systems, so this should be taken into account when implementing the listeners. In this study case, the event generation is performed using a simulation tool, and thus the analysis of the software boundaries is waived in this step.

3.2.2 Selection of event data format

We selected exBPAF as the event format since we do not require integration with other process mining tools. Furthermore, exBPAF does not require format conversion on the DSS since it already deals with BPAF internally.

3.2.3 Event correlation data determination

This phase is critical to recreate successfully the inbound customer calls across call centers. For the purpose of this case study, and assuming that the call-center software is able to generate a unique ID per call across nodes, the correlation data to be used is the identification number that is managed by call centers to identify incoming calls (CallID). This information will uniquely identify the process instance along the sequence of events.

3.2.4 Listeners implementation

For the implementation of the listeners we leveraged a simulation tool that generates the sequence of events according to a specific distribution function. The call duration time, volume of incoming calls, peak times, rate of abandons, and other relevant features used for diagnosis have been configured as input in the simulation engine (see PHASE 3. Execution). The aim of these specific settings is to demonstrate that the expected outputs on the DSS are those configured on the simulation side. Namely, the DSS is able to detect and identify any exceptional situation originating from the simulation. Next is a sample event generated by the listener.

```
<ns2:Event EventID="0e2c1d29-e6ea-4405-bd54-9648999d0326" ServerID="BASU-CC04"
ProcessDefinitionID="IC" ProcessName="Incoming.Call" ActivityDefinitionID="PR"
ActivityName="Process.Request" Timestamp="2014-06-25T09:14:53.190+01:00"
xmlns:ns2="http://www.uc3m.es/softlab/basu/event">
    <EventDetails PreviousState="Open.NotRunning.Ready" CurrentState="Open.Running.InProgress"/>
    <Correlation>
      <CorrelationData>
        <CorrelationElement key="CallID" value="a7256c96-83ee-467e-bb84-135b35bbba31"/>
      </CorrelationData>
    </Correlation>
    <Payload key="Country" value="Ireland [IE]"/>
    <Payload key="Category" value="Help Desk"/>
    <Payload key="AgentID" value="27AC0491"/>
    <Payload key="CustomerID" value="19408284761"/>
</ns2:Event>
```


3.2.5 Selection of metrics and KPIs

The set of metrics and KPIs selected for the purpose of this case study are specified below. The DSS-standard metrics are outlined in the Table 5 for representing behavioral measures, and Table 6 for the structural ones.

Table 5 - DSS-Standard behavioral measures.

DSS-Standard Measure	Description
Throughput time	Total amount of time for a call to process.
Change-Over time	Time elapsed since a call is assigned to an agent until the agent caters the customer request.
Processing time	Effective amount of time for an agent to process the request.
Waiting time	Time elapsed for a call in on-hold state waiting for a free agent to cater the call.
Suspended time	Total suspension time of a call by an agent while processing the request.

Table 6 - DSS-Standard structural measures.

DSS-Standard Measure	Description
Running cases	Number of incoming calls processed.
Successful cases	Number of incoming calls that were processed successfully.
Failed cases	Number of incoming calls that were processed unsuccessfully (did not fulfil the customer demand).
Aborted cases	Number of incoming calls that abandoned the queue.

The KPI's outlined above are deduced by querying and filtering the event data gathered from the listeners. The details of how this calculation is performed are out of scope in this paper. Regarding to the KPI selection, and only for illustration purposes, we have selected the following behavioral and structural KPI's for measuring and identifying non-compliant situations (in or near) real-time.

<u>*Behavioral KPIs*</u>

Congestion: This KPI uses the waiting time measure and sets a threshold value for those time intervals that are susceptible to experience some congestion at peak times. This measure gives an insight into the workload of agents and the need to allocate resources during certain periods of time. This threshold value is agreed at design time during the simulation stage. When the threshold is reached, an alert is fired on the DSS.

Agent efficiency: This KPI measures the agent efficiency by computing the total amount of time that it takes the agent to process the customer request and the effective time used to handle the call.

$$AE(a) = Th(p_a) / Pt(P_a)$$

AE(a) = Efficiency rate of agent "a".

$Th(p_a)$ = Throughput time of instances handled by agent "a" on "Process.Request" activity.

$Pt(p_a)$ = Processing time of instances handled by agent "a" on "Process.Request" activity.

<u>*Structural KPIs*</u>

Abandon rate: This KPI computes the average rate of abandons per category. This enables the system to detect bottlenecks or inefficiencies on a determined queue or category. This is calculated by obtaining the aborted instances of the "Enqueue.Call" activity per every running instance of the "Request.Service" activity.

$$AR(c) = \frac{\forall_i \in \text{"}EnqueueCall\text{"}: \left(AC(i) : i_c = c\right)}{\forall_j \in \text{"Request.}Service\text{"}: \left(RC(j) : j_c = c\right)}$$

AR(c) = Abandon rate KPI for the category "c".

AC(i) = Number of aborted cases for instances of process "Process.Request" under the category "c".

RC(j) = Number of running cases for instances of process "Process.Request" under the category "c".

Productivity: This KPI measures the productivity of the call center. This is calculated by obtaining the successful instances of the "Process.Request" activity for every running instance of the "Request.Service" category.

$$P = \frac{\forall_i \in \text{"}Process.Request\text{"}: SC(i)}{\forall_j \in \text{"}Request.Service\text{"}: RC(j)}$$

P = Productivity of the call center.

AC(i) = Number of successful cases for instances of process "Process.Request".

RC(j) = Number of running cases for instances of process "Request.Service".

Overload: This KPI measures the number of correlated events across call centers. The objective function counts the number of executions of the “Switch.Call” activity. When a call center is overloaded the software switches the call to an alternative node, thereby generating a new activity on the target call center with the same CallID but with different source.

3.3 PHASE 3. Execution

The evaluation has been accomplished successfully in a test environment that follows the infrastructure depicted on the Fig. 8. A large amount of event data was generated by the simulation tool whereby inbound calls were generated in order to simulate flows that cross multiple call centers. Moreover, different scenarios were built and configured in the simulation engine in order to produce the desire outcomes on the DSS. These hypothetical cases aimed to detect exceptional situations such as overload, low running resources on peak times, high abandon rates, etc.

The simulation model was based on a discrete event simulation approach. The simulation was built using DESMO-J, which is a java-based simulation library that supports both event-oriented and process-oriented modelling approaches. The events generated from the simulation model were persisted before being forwarded to the specific event channels for processing on the DSS side. The model implementation used three main entity types:

- Calls: whose properties stored details about the caller ID, caller location, calling time and service category;
- Call agents: which hold references to the call center in which they are located and which type of service that each agent can help with;
- Call centers: which store information about the call centers locations and the backup centers in case of unbalancing.

The model defined six different classes of events, the Table 7 presents the events and their descriptions.

Table 7 – List of events and descriptions.

Event	Description
Incoming Call	A new call arrival at a defined point of time.
Dispatch Call	An idle agent is assigned to handle an incoming or awaiting call.
Service End	A call was successfully handled by a call agent.
Enqueue Call	A call was put on-hold because all agents are busy.
Switch Call	A call has been switched to another call center in case that the max on-hold time was exceeded.
Abandon Queue	A call abandoned the queue.

The model included four queues of idle call agents in each call center, where each queue represents a different category of service. Similarly, each call center had four queues of awaiting calls. Since the simulation scenario involved 18 call centers in different locations, 144 queues, collectively, were needed to be created during each simulation experiment. In addition, the event listeners where represented as *dispatchers*. The dispatcher is a core component responsible for relaying the events generated from the simulation engine to the DSS. The dispatcher included the capability to control the timing of the transmitted messages, which could be used to measure the capacity of the framework.

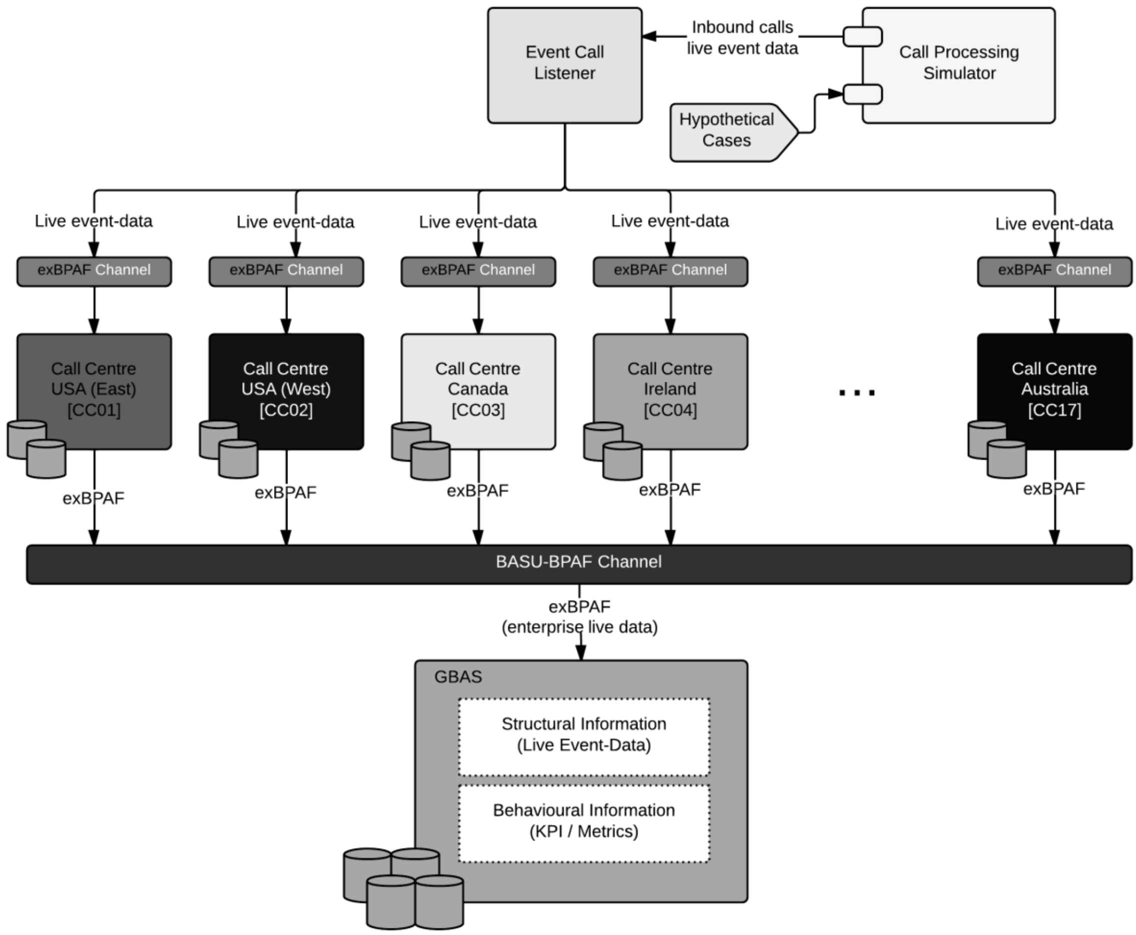

Fig. 8. DSS infrastructure

3.4 PHASE 4. Control

We successfully experienced that the outcomes of the DSS were those expected. The execution outcomes, measures and KPIs did not present any statistical significance in respect with the values set in the simulation engine as input. Likewise, exceptional cases such as bottlenecks, overloads and failure rates (abandons) were properly identified and detected by the system.

3.5 PHASE 5. Diagnosis

This phase is out of scope in this paper since we are designing a case study based on a simulated environment through the use of models that represent diverse hypothetical cases.

4. Conclusions and future work

This paper has presented a methodology and system which leverages the scalability and processing power of Big Data to provide business process monitoring and analysis across complex, multi-level supply chains. The system itself is extensible, and allows a number of event formats to be used in the data collection. The case study has demonstrated the functionality and robustness of the implementation. By using a simulation to generate event data in any quantity desired, and running it in either real-time or in accelerated mode, we can test the scalability of the system. Further work will be devoted to applying the methodology and framework to a variety of application domains, such as manufacturing, logistics and healthcare. Each domain has its own interfacing issues, process and organizational configurations, as well specialized performance measurements. For example, this approach should be highly useful in a distributed, decentralized "system of systems" such as healthcare, where individual business units need their own performance monitoring and evaluation. At the same time, the national health services need to monitor and improve efficiencies and outcomes along multiple care pathways. Additional work is also need to develop improved data visualization and 'playback' facilities for the system to allow process engineers to view and drill-down into aggregate and individual event data.

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An overview of patient acceptance of Health Information Technology in developing countries: a review and conceptual model

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Abstract:
The potential to improve the quality, efficiency, outcomes, patient safety and reduce cost of healthcare by Health Information Technology (HIT) has been established by researchers. But unfortunately HIT systems are not properly utilized or are not widely available. This problem is even more glaring in developing countries. This article presents a review of some available HIT systems in order to assess the level of their presence and the technology used in developing them. Works related to acceptance of HIT systems were also reviewed so as to study the gaps in this area and propose a solution in order to fill the gaps identified. The problems discovered from this review include lack of availability of these systems especially in developing countries, low rate of HIT systems acceptance and insufficient works on patient acceptance of HIT systems. Studying the factors that affect the acceptance of HIT systems by patients and considering the factors while developing the systems will play a significant role in getting over the aforementioned limitations. As Technology Acceptance Model (TAM) is one of the most popular models for studying users' perception and acceptance of Information System (IS)/Information Technology (IT), we proposed a conceptual model of HIT acceptance in developing countries based on TAM.

Keywords:
Health Information Technology; Technology Acceptance Model; User Acceptance; Electronic Health Record; Clinical Decision Support System.

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1. Introduction

The application of Information Technology (IT) in healthcare is a promising area that can be used to extend the delivery of healthcare to different people in different part of the world. This is very important as the world population is growing exponentially, and healthcare delivery is very poor in some countries. Unfortunately, in most of the countries, particularly in developing economies, people do not have access to healthcare facilities due to factors like shortage of healthcare professionals, inadequate hospitals or clinics, and high cost of medical consultation [1]. For instance, it is reported that the physician-patient ratio is 1:3500 in Nigeria, 1:45000 in Sierra Leone and 1:86000 in Liberia; this is really of great concern [2, 3]. Therefore, there is need for bringing other ways of improving the healthcare delivery in order to allow people especially in the rural area to have access to healthcare easily and timely. Meanwhile, healthcare delivery can be improved by using various Information Technology (IT) infrastructures; such application of IT in healthcare is termed as Health Information Technology (HIT).

HIT is a term that describes the management and exchange of health information between healthcare consumers and providers using both computers and mobile devices for decision making. HIT when implemented and used properly has the potential to improve healthcare quality, efficiency, effectiveness, reduce or prevent medical errors, reduce healthcare costs, provide up-to-date information to both providers and consumers, early detection of management of disease, and reduce storage cost. HIT can be implemented in the form of Electronic Health Record (EHR), Computerized Physician/Provider Order Entry (CPOE), Clinical Decision Support System (CDSS), or in some cases combination of two or more of the above.

EHR is a collection of health related information of patients such as demographics, medical and treatment history, laboratory result, etc., in an electronic form. The access to patients' record any time allows them to be monitored and know their status whenever required. Other terminologies related to EHR are EMR (Electronic Medical Record), EPR (Electronic Patient Record), PHR (Personal Health Record), which sometimes may be used interchangeably or as part of EHR. CPOE is a system that allows entry of medical instruction electronically to efficiently deliver care to patient. This has the benefit of reducing misinterpretation and transcription errors, reduce or eliminate order duplication, offer clinical decision support, and provide reminder service. Similarly, CDSS is a system that assists medical practitioners with decision making tasks like diagnosis, analysis of patient data, medication, prediction, reminder, etc. This improves the physician's performance and patient outcomes, increases efficiency, and reduces healthcare costs [4-6].

However, the acceptance of HIT systems specifically in developing countries is very low, so studying the perception of the intended users about the system before the development or implementation is a wise decision; as it is believed to positively affect the actualization of the real system [7-11]. There are theories that describe user behaviors and attitudes towards using a new technology, and these theories also show how this technology can be accepted and spread. The theories include Theory of Reasoned Action (TRA), Diffusion of Innovation (DOI), Unified Technology Acceptance and Use of Technology (UTAUT), Technology Acceptance Model (TAM), and the like.

This paper is structured into five sections. Section 1 introduced the concepts discussed in the article. The background of TAM is presented in section 2. Section 3 discusses previous literatures related to HIT systems and technology acceptance in healthcare. The proposed model with its theoretical background is presented in section 4. Finally, section 5 concludes the paper.

2. Background

Technology Acceptance Model (TAM) is among the popular theory for studying the perception and factors that contribute to the acceptance of a new technology. TAM is an extension of TRA which was developed in 1975 by Fishbein and Ajzen. TRA is a model for predicting human behavior [12]. TAM is considered as the most widely used theoretical framework for information system usage [13]. Chen et al. [14] described TAM as “one of the most influential research models in studies of the determinants of Information Systems and Information Technology acceptance to predict intention to use and acceptance of Information Systems and Information Technology by individuals". TAM as developed by Davis in 1985 is designed for modeling user acceptance of Information Systems. The central idea behind it is to increase the use of IT by promoting its acceptance. The acceptance can only be promoted if the factors that influence it are known; this can be done by examining the perception of the users concerning the use of the technology [15, 16].

TAM focuses on factors that determine the users' behavioral intentions towards accepting a new technology. The model shows that certain factors influence the decision of users when they are presented with a new technology on how and why they will use it. The factors are: perceived usefulness and perceived ease of use. Perceived usefulness is defined by Davis [17] as "the degree to which a person believes that using a particular system would enhance his or her job performance"; while perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort". However, Davis hypothesized perceived usefulness and perceived ease of use as the major factors that determines user acceptance [17]. TAM also hypothesized that the intention to use the system is influenced by individual's attitude towards using the system. Attitude toward using is defined as "the degree of evaluative effect that an individual associates with using the target system in his or her job" [18]. Perceived usefulness is also hypothesized to affect behavioral intention directly as shown in figure 1; this is because users may intend to use a system just by thinking it may help them do their job better [17]. Also, as it is shown that perceived usefulness and perceived ease of use are affected by other external variables and determines users' attitude, perceived ease of use may have impact on perceived usefulness supported by a suggestion that "the easier it is to use the more useful it can be" [17, 19]. The attitude variable is usually omitted in some research because of the argument that it should not be a strong predictor of intention but rather has one of many factors that determine intention [20, 21].

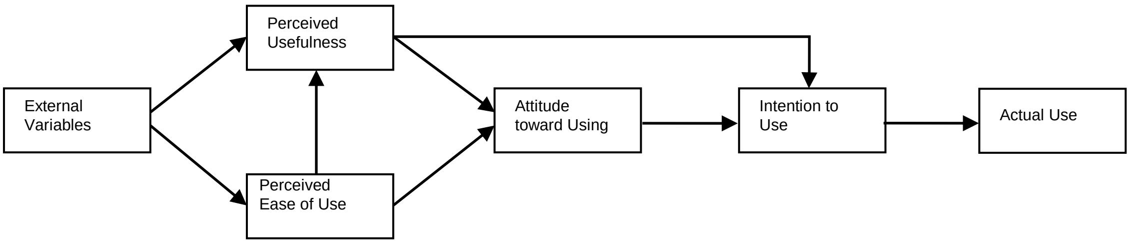

Fig. 1. TAM [15]

One of the earlier researches done on TAM includes *Perceived Usefulness, Perceived Ease of Use and User Acceptance of Information Technology* conducted by Davis [17]. The research developed and validated new scales for perceived usefulness and perceived ease of use, which were hypothesized to be fundamental determinants of user acceptance. Two studies involving 152 users and 4 application programs were conducted in which the definition of these variables were used to develop scale items that were pretested for content validity and then tested for reliability and construct validity. It was found based on both studies that usefulness had a significantly greater correlation with usage behavior than did ease of use. Additionally, regression analyses suggest that perceived ease of use may be causal antecedent to perceived usefulness, as opposed to a parallel and direct determinant of system use.

Since 1980's when it was developed, TAM has been further studied by its pioneer as well as other researchers for either testing its validity and reliability or extension and in some cases combined with other models. One significant improvement that is worth mentioning is development of TAM2 [19]. In TAM2 as depicted in figure 2, attitude variable that mediates some of the effects of perceived usefulness and perceived ease of use was removed. Despite the fact that a variable Subjective Norm was in TRA, but it was not included in TAM based on the explanation from Davis et al., that it is "one of the least understood variables" [15]. Following many criticism on TAM [22], antecedents of perceived usefulness was added including subjective norm.

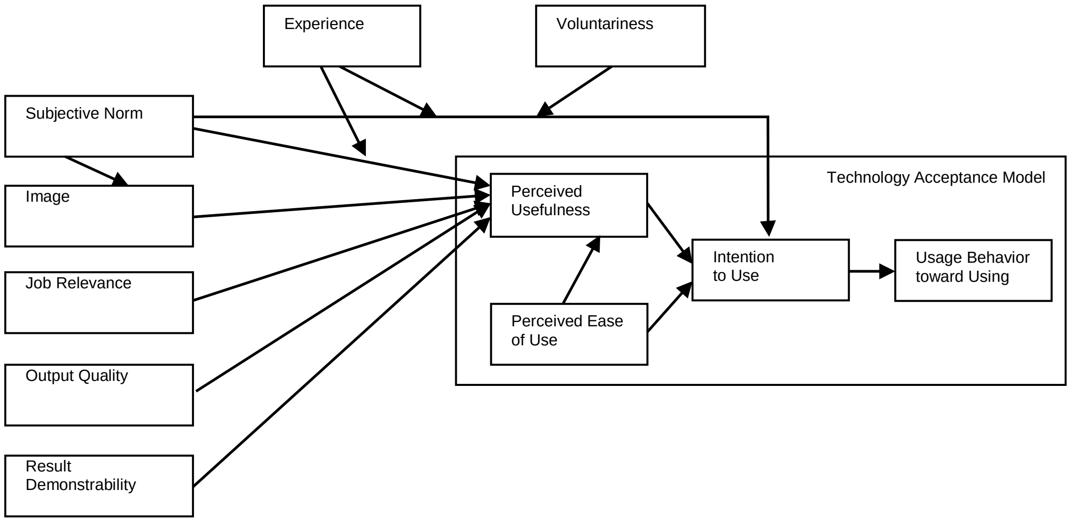

Fig. 2. TAM2 [19]

The perceived usefulness antecedents can be grouped into social influence variables and cognitive instrumental process variables [12],[23],[16, 19]. The variables are explained in table 1.

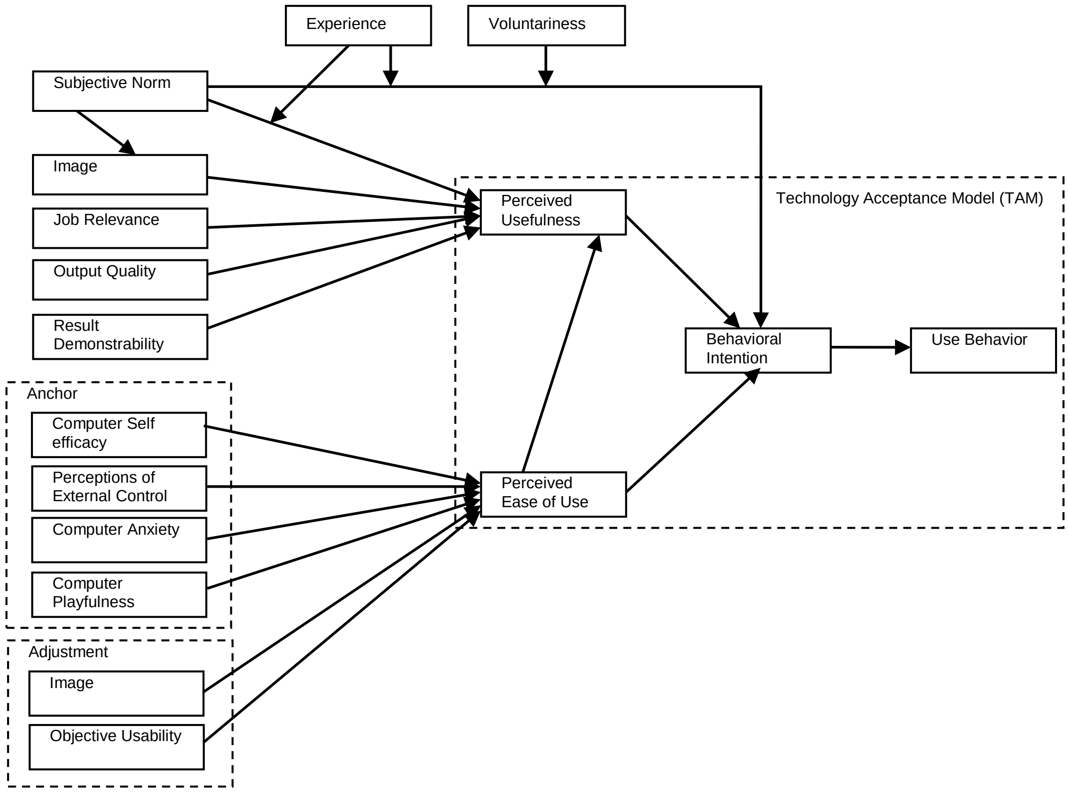

Fig. 3. TAM3 [24]

On the other hand, the leading researchers in TAM related studies developed TAM3 by considering interventions such as user participation, management support, training, etc., as a possible candidate that can influence the acceptance and use of IT through the determinants of perceived usefulness and perceived ease of use. The interventions are grouped into pre-implementation and post-implementation interventions. The pre-implementation intervention include design characteristics, user participation, management support and incentive alignment that lead to the realization of the system, while the post-implementation intervention include phases that come after putting the system into use these are: training; organizational support; and peer support [24].

Table 1. TAM constructs definition [25]

Constructs	**Definition**
Attitude	Individual's positive or negative feeling about performing the target behavior (e.g., using a system)
Behavioral intention	The degree to which a person has formulated conscious plans to perform or not perform some specified future behavior
Computer anxiety	The degree of an individual's apprehension, or even fear, when she/he is faced with the possibility of using computers
Computer playfulness	The degree of cognitive spontaneity in microcomputer interactions
Computer self-efficacy	The degree to which an individual beliefs that he or she has the ability to perform specific task/job using computer
Effort expectancy	The degree of ease associated with the use of the system
Facilitating conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system
Image	The degree to which use of an innovation is perceived to enhance one's status in one's social system
Job relevance	Individual's perception regarding the degree to which the target system is relevant to his or her job
Objective usability	A comparison of systems based on the actual level (rather than perceptions) of effort required to complete specific tasks
Output quality	The degree to which an individual believes that the system performs his or her job tasks well
Performance expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance
Perceived ease of use	See the definition of effort expectancy
Perceived enjoyment	The extent to which the activity of using a specific system is perceived to be enjoyable in it's own right, aside from any performance consequences resulting from system use
Perceived usefulness	See the definition of performance expectancy
Perception of external control	See the definition of facilitating conditions
Result demonstrability	Tangibility of the results of using the innovation
Social influence	The degree to which an individual perceives that important others believe he or she should use the new system
Subjective norm	Person's perception that most people who are important to him think he should or should not perform the behavior in question
Voluntariness	The extent to which potential adopters perceive the adoption decision to be non-mandatory

Other extensions of TAM include UTAUT which was an attempt to unify all the IT acceptance models by Venkatesh et al. [26]; an integration of technology readiness and technology acceptance model (TRAM) by Lin et al. [27]; a model that combine Task-Technology Fit (TTF) and TAM by Chang [28]; a model by Agarwal and Prasad [29] that combines DOI and TAM; etc. [14].

3. Literature review

3.1 Health Information Technology (HIT) for patient monitoring

Various HIT systems for patients monitoring are in existence, the monitoring can be within a clinical setting, or from outside usually from home (remote). Sensor network technology is used by most of these systems in order to collect physiological data of a patient suffering from different diseases like cardiovascular and other diseases. Generally, the common features of the above projects include using sensor technology, sending alert to caregiver or medical personnel. They also have distinctive features like CodeBlue has GPS integrated into the system for tracking the actual location of patients as well as doctors [30]. Other works with distinctive features include a system for managing home care activities in brain-injured children [31]; a system designed for people with cardiovascular disease [32]; a universal system for monitoring patients which do not specify disease [33-35].

Monitoring systems designed for managing patients suffering from a particular disease are many, some of which include those monitoring diabetic patients like a project presented on treatment of diabetic patients with foot ulcers. Larsen [36] designed his system in such a way that the patient and a nurse (home care nurse) will be at home while communicating with the expert at the hospital. This project was carried out at the Computer Science Department in University of Aarhus and Aarhus University Hospital. The Centre for Pervasive Healthcare is also associated with the project group. The patient will have a bandage wrap around the area affected with ulcer, the bandage has built-in sensors that continuously monitor biomedical data concerning the ulcer like: bacteria flora, skin temperature, moisture level, and blood pressure. Similarly, SiSPED 2.0 [37] is an extension of SiSPED ("a monitoring system for diabetic patients with the possibility of developing diabetic foot"), but in this case the monitoring is not remote, rather the system serves as a repository where patients' information is stored. Likewise, a two-tier pervasive healthcare architecture was presented [38]. The client (patient's PDA) and the server communicate via wireless network. Artificial Neural Network (ANN) model were implemented for diagnosing diabetes. The ANN model for diagnosing diabetes runs locally on the client's PDA.

There are also systems developed to monitor physiological data related to diabetes. These systems manage diabetic patients generally without considering any complication that might arise. For instance, Jog Falls [39], is a diabetes management system using sensor devices (for collecting physiological and activity data) that monitors patient's physical activities, food intake, sets some goals and monitor progress towards these goals. Related to this is a system called DI@L-Log, which is a project in collaboration between Ulster Hospital and researchers at the University of Ulster. Weight, blood sugar, and blood pressure are the elements that the patients will be measuring to monitor their status. The system allows the patients to use speech to input and record their measurement [40]. Similar works include a system of monitoring and management of Type 1 diabetic patient using mobile phone [41]; a diet management system that provides patient with information related to his/her diet record, exercise and medication [42]; and a web-based medical diagnosis and prediction model that uses neural network to predict patients' condition based on the previous similar cases [43].

3.2 Health Information Technology (HIT) Systems and Clinical Decision Support Systems

Making decision by healthcare professionals regarding their patients sometimes consumes extra time and resources than expected, hence the need for incorporating decision making component into HIT systems. This decision making capability help doctors and other medical experts to manage their patients with ease. This type of system is referred to as Clinical Decision Support Systems (CDSS). Some of the works related to CDSS include a CDSS which uses data mining techniques to build cooperative knowledge bases from domain experts' knowledge bases, clinical databases, and most recent academic researchers. The data mining engine is connected to the EHR and clinical databases to continuously mine the very recent knowledge and adds it to local knowledge base, specialized knowledge bases from other institutions can also be consulted for relevant knowledge [44].

A model of a cost effective healthcare system for patients residing in remote areas of Pakistan was presented [45]. The complete architecture of the system consists of wearable medical sensor module, data gathering module, PDA, remote server with CDSS and EMR capability, and web enabled remote terminal for accessing services provided by web server. The remote server after processing the data then call CDSS for analysis of the data and finally the EMR will record the data against the patient's profile. After analyzing the data by the CDSS a feedback is sent to the doctor for approval, and then sent to the PDA after approval. The CDSS software analyses the patient's physiological data like ECG, blood pressure, temperature, etc. for possible sign of abnormality. The software can forecast the health status based on the received data and also can make decision based on the health situation. A combination of model-driven and knowledge driven decision support systems were used. The model-driven makes decision based on the statistical model of the patient's data, while the knowledge driven use facts, rules, procedures, etc. to make decision. For diagnosis, a cooperative system is employed in which the decision and action is first send to the consultant for confirmation before sending to the PDA. The EMR store the patient's data and serve as a source for data to CDSS.

Additionally, a DSS was presented that will help surgeons and hospital managers to schedule patients as well as allocate resources. Web service was used for integrating DSS with HIS; a third party integration agent called AIDA was used as a communication layer of the HIS. Enterprise oriented architecture was used to divide the software into four layers: data access; business logic; web service; and presentation layers. To synchronize DSS and HIS, an update service calls a web service in AIDA for a request to synchronize data warehouse with recent data in HIS. Then the update service requests the shared database to update the DSS database [46]. However, another work discuss about creating web-based DSS using Web services. The main components of their DSS are database, user interface, and DSS software system. Three layer design, Rich Internet Applications (RIA) and web services are the core elements that made up the web based DSS. The layers are data, business logic, and view [47].

3.3 Perception and Acceptance of HIT Systems

In spite of all the potential benefits of providing high quality care, reducing costs, and assuring patient safety, more than half of medical information systems are not in use. This is due to factors like extra time needed for entering patient record and reviewing the decisions provided by the system, interoperability, and user and staff resistance [8, 11]. Therefore, there are studies that identify factors that will facilitate the adoption and use of HIT system. One of such study described using cheaper and faster technology, offering incentive for CDSS deployment as some factors that can help to improve CDSS adoption [5]. Some of the works reviewed in this category are summarized in table 2.

A great deal of research has been conducted using TAM as a framework, and new models such as TAM2 and TAM3 were developed from it. TAM2 mainly focused on identifying determinants of perceived usefulness and moderating variables, since perceived usefulness is considered a strong determinant of intention [19]. TAM3, on the other, hand centered on interventions that can affect the acceptance and use of IT in an organization [24]. In addition, researchers apply TAM in healthcare settings with the objective of evaluating the behavior or intention of users regarding the use of new information system. These works include the application of TAM in examining physicians' decisions toward accepting telemedicine technology. In this work the data was analyzed from 421 respondents out of 1,728 distributed questionnaires sent to selected physicians from public tertiary hospitals in Hong Kong. They found perceived usefulness to be significant determinant of attitude and intention, while perceived ease of use was not [48]. A study was conducted with the aim of carrying out a comprehensive review of works on TAM related to health IT, in an effort to know the suitability of TAM as a theory for health IT acceptance and use, and also propose ways of improving its effectiveness by modifying it. Works reviewed include those that: quantitatively test relationships between TAM specified variables; use TAM as a theoretical framework; the end users of the health IT are healthcare professionals; and those that were published on or before July 2008; etc. This study shows that TAM predicts a substantial portion of the use or acceptance of health IT, but the theory can be modified for better prediction. The study proves TAM as a good theory that explains healthcare providers' reaction to health IT. In addition, it shows a significant relationship between perceived usefulness and intention to use with actual use of health IT. Hence, promoting use and acceptance of health IT greatly depend on user perceiving it as useful [16].

In a study conducted to determine factors that affect the acceptance of integrated Personal Health Records (PHRs) for self-care management, a non-experimental descriptive cross-sectional survey was used to get response from 78 diabetic patients in Howard University Hospital. The result shows that users perceived the use of the PHR as easy, and they believed that PHR is useful for self-managing their care and diabetes. In addition, PHR adoption rate can be increased by promoting it by staff [49]. In another similar study, online diabetes self-management intervention participated by African American Type II diabetic patients of the Howard University Hospital (HUH) Diabetes Treatment Centre (DTC) was presented. Out of the 47 participants 26 were randomly assigned to treatment, while 21 were assigned to control conditions. The participants were surveyed at the beginning and end of the intervention. Home visit was organized as part of the practice for the intervention group, in which the participants will be trained by a nurse on accessing the web-enabled patient application. The patients will send their health data and accessed patient education materials through this application. The study showed a significant association between participation in the intervention and achieving glycaemic control; a significant positive relationship between the participation in the intervention and achieving a healthy BMI; and above all the treatment group testify that the intervention increased their diabetes knowledge and improve their adherence to better diabetes management practices [50].

UPMC HealthTrack is a PHR implemented in University of Pittsburgh Medical Centre (UPMC) for self-management of diabetes. The impact of the system was assessed by analyzing the patients' reaction to HealthTrack with five pre and five post implementation focus groups. The focus group participants felt that the system would enhance communication with the centre and they envisage the reminder system as beneficial. The participants also reported their bad feeling when test results were not released and messages were not answered [51]. An exploratory descriptive study using in-depth interviews and focus groups was conducted in an effort to learn how patients with inflammatory bowel disease value access to Internet-based patient records. University Health Network's tertiary centre in Toronto was the study area with 12 participating members. Four themes related to patient perceived usefulness were identified; these are sense of illness ownership, patient-driven communication, personalized support, and mutual trust between patients and their providers [52]. Another group of researchers conducted an online survey of 1,421 respondents of the Geisinger Health System, to valuate patients' values and perceptions regarding web-based access to their record. One-on-one interview with 10 clinicians and focus groups with 25 patients were also used to supplement the survey. The result of the study shows a positive patient's attitudes towards the use of Web messaging and online access to their EHR as dominant. Also patients described their medical information as complete and accurate when using the system. Some patients expressed their concern about the confidentiality and privacy of their information. On the other hand, clinicians prefer other types of communication like letters than electronic communication [53].

Three theoretical models of IT acceptance were studied to investigate the acceptance of e-health from patients that registered for e-health. An online questionnaire was used to test five hypothesized antecedents from subjects who registered for e-health in Midwestern United States. The five antecedents are: satisfaction with medical care; health-care knowledge; Internet dependence; information-seeking preference; and health-care need. The findings showed that all tested acceptance models predict patient's intention to use e-health very well [54]. Information and Communication Technology Acceptance Model (ICTAM) is a new model developed from TAM2 which is an extended version of TAM. The aim of the study is to predict and show consumer's health information and services usage behavior on the Internet. The independent variables that serve as antecedents of perceived usefulness were adopted from TAM2 into ICTAM with the exception of job relevance. The model is simply TAM with additional constructs as perceived playfulness from TAM2, compatibility, and Web site loyalty. The explanatory and predictive power of TAM and TAM2 were improved in ICTAM, with 52-66.1% of the variance in perceived usefulness and 47.6-74% in behavioral intention to use [55]. INTCare is a Pervasive Intelligent Decision Support System (PIDSS) developed to assist the Intensive Care Unit (ICU) professionals in making their decision. The system was evaluated by 14 users, who are nursing staff of the ICU of Centro Hospitalar do Porto. The instrument used was a questionnaire based on TAM3. This study revealed that the users are comfortable with the system since the constructs Perceived Usefulness, Perceived Ease of Use, Behavioral Intention and Usage Behavior received higher positive response. But then they want the systems to perform faster [56].

TAM was used to observe people's readiness and attitude towards accepting self-service technology specifically self-diagnosis system, as a means to reduce cost and improve quality in healthcare setting. A total of 160 participants were chosen randomly from outside the capital of Norway. Among them 132 filled the paper version of the survey, and 28 completed the survey online. Trust was added to the model proposed as another factor that determines attitude and the variable usefulness is replaced by convenience. The result showed that expected usefulness is positively influenced by expected ease of use; there are also statistically significant and positive relationships between trust of service and expected usefulness and expected ease of use [57]. Another study from the perspective of end users was conducted to identify the health consumers' behavioral intention of using HIT. TAM was extended with additional variables from Health belief model, theory of planned behavior. The questionnaire was developed based on the proposed model with additional antecedent and mediating variables on top of the three theories. The participants were 728 members from three Internet health portals in Korea. Web based survey were used to collect the data using structured self-administered questionnaire. The study shows that perceived threat, perceived usefulness, and perceived ease of use significantly affect health consumers' attitude and behavioral intention. Also health status, health belief and concerns, subjective norm, HIT characteristics, and HIT self-efficacy had a strong indirect impact on attitude and behavioral intention through mediators of perceived threat, perceived usefulness, and perceived ease of use [58].

Gagnon studied the factors that could influence the healthcare professionals to use a telemonitoring system. A total of 234 questionnaires based on TAM were distributed among nurses and doctors of cardiology, pulmonary, and internal medicine department of Donostia University Hospital in Spain. The study used 93 responses out of the 234 administered questionnaires. The results of this study described TAM as a good predictive model of healthcare professionals' intention to use telemonitoring systems. The factor that greatly influences nurses' and physicians' intention to use this new technology is perception of facilitators [59]. Another work is presented to examine the factors that influence medical professional's behavioral patterns during the introduction of a new CDSS. The study uses 15 medical professionals as sample for the empirical study. The study found that social influence had no impact on the medical professionals' adoptions of the CDSS. TAM and UTAUT were used together with Decision-Making Trial and Evaluation Laboratory (DEMATEL) for finding the relationship between UTAUT variables. The variables are: performance expectancy, effort expectancy, social influence, attitude towards the use of CDSS, and behavior intention of using CDSS. DEMATEL analysis result showed that performance expectancy and effort expectancy have high impact on attitude; also the level of the impact is higher in attitude than behavior. The result also shows insignificant relationships on social influence to attitude and social influence to behavior towards the use of CDSS, and positive relationship between attitude and behavior towards the use of CDSS [60]. A cross-sectional study was carried out to measure beliefs and acceptance of HIT systems from 133 sample health professionals. Structured questionnaire was designed using modified TAM. Multiple linear regression analysis was used to evaluate the predictors of HIT usage intentions. The result revealed that perceived ease of use, relevance and subjective norms directly predicted usage intentions [61].

Another study was conducted to determine the physicians' attitude towards the use of CDSS, and find out if utilizing CDSS for long time has a positive effect on the intention to adopt them in the future. A TAM based questionnaire was administered to 8 volunteered pediatricians who used a CDSS (e-GuidesMed) for a period of 3 months. The findings show that the attitude towards using the CDSS is good, the participants perceive possible difficulty to integrate e-GuidesMed into their daily routine, and also the facilitators variable shows highest correlation with the intention to use the CDSS [62]. Dentist professionals were examined to explore their willingness and acceptance of CDSS; questionnaires were distributed for the cross-sectional study in the dental department of Riyadh Military Hospital. The response rate was 30% from the 100 distributed questionnaires. The hypothesis that was tested is to find if there is correlation between the factors in the UTAUT model and the intention to use the system and further the user behavior. The result of the study shows that performance expectancy had no significant correlation with behavior intention in contrast to other studies that report strong effect of performance expectancy on behavior intention. Also social influence shows no significant correlation while effort expectancy shows significant positive correlation [63].

There are studies that evaluate the people's readiness to accept e-Healthcare. These include a work by Oio et al. [64] that identifies need-change readiness, engagement readiness, structural readiness, and acceptance and use readiness as factors that affect e-Healthcare readiness in developing countries. Need Change Readiness is described as "a combination of real need, usually based on conditions caused by isolation and a felt of expressed dissatisfaction with current situations, so strong that members of the community in question were willing to aggressively adopt new practices to create desire change". Engagement Readiness is defined as "a process in which community members are actively engaged in the idea of e-Healthcare, weighing its perceived advantages and disadvantages, to provide insight into the factors that potentially encourage or impede further readiness for e-Healthcare adoption". Structural Readiness is "the extent to which there exists efficient structures to support successful implementation of e-Healthcare". Acceptance and Use Readiness is "the intention to accept and use e-Healthcare technology". The model consists of four constructs as defined above; which was pilot tested in Uthungulu Health District of Kwazulu/Natal province of South Africa with healthcare practitioners, the public managers and patients. The questionnaire used was based on the four constructs with 94 items. The questionnaire was later complemented with interviews. The valid responses obtained were 323 from the 500 administered questionnaires. The findings identified acceptance and use readiness as the most important attribute followed by structural, engagement and finally need-change. The healthcare practitioners show their agreement to the readiness of e-healthcare while the public and patient fairly agreed.

Another similar study investigates if physician's perceived professional autonomy, involvement in the decision to implement CDSS and the belief that CDSS will improve job performance increase the intention to adopt CDSS. A survey was conducted in seven public and five private hospitals in Kuala Lumpur, Malaysia from different specialties. A total of 450 physicians were randomly selected and given questionnaire out of which 335 were returned and 309 were used. The hypotheses were tested using SEM and the result shows that Physicians' perceived threat to professional autonomy lowers the intention to use CDSS; Physicians involvement in the planning, design and implementation increases their intention to use CDSS; Physicians belief that the new CDSS will improve his/her job performance increases their intention to use CDSS [9]. In addition, a study was conducted using Unified Technology Acceptance and Use of Technology (UTAUT) theory to examine the factors influencing HIT services. A structured questionnaire was used to collect data from 400 employees (physicians, nurse, hospital staff members) in Thailand. The model was tested using SEM and the result shows that performance expectancy, effort expectancy, and facilitating conditions are the factors that have significant effect. Also they were found to have significant impact on behavioral intention. They suggested based on their findings that healthcare staffs' behavioral intention and facilitating conditions need to be improved by healthcare organizational management in order to increase the adoption and use of HIT by the staff [65].

In another study lack of telemedicine policy, knowledge and skills, and resistance to change by members of staff in the hospital were identified as factors that affect the adoption, implementation, and sustainability of telemedicine in Uganda. Two hospitals were selected (1 private, 1 public) out of the three well known hospitals in Uganda that use telemedicine. In each hospital 75 stakeholders (Information Systems managers, ICT technicians, administrators and doctors) were selected using purposive sampling for the study. In addition 5 participants (1 nurse, 1 doctor, 1 IT technician, 1 administrator and 1 patient) were interviewed from each hospital. The questionnaires distributed were 160, out of which 146 were analyzed. Apart from the factors identified, the respondents suggest some solutions to the challenges like training, computer hardware and software, security for client data and improved confidentiality, telemedicine policy and laws, sensitization of clients, sensitization for staff to embrace changes in technology, reduced cost of telecommunication services, need public-private partnership, government support and government hospitals should provide telemedicine for free [66].

Physicians are said to work and make decision independently, without sharing their knowledge with medical assistants and other clerical assistants. This may be as a result of them perceiving sharing their knowledge as a threat to their profession. In this regards, Esmaeilzadeh et al. [67] proposed an extended TAM (perceived usefulness and perceived ease of use) with three additional constructs: attitude toward knowledge sharing, perceived threat to professional autonomy, and involvement in decision making. This model will explain how healthcare professionals' intention will be influenced by attitude toward knowledge sharing. Perceived Threat to Professional Autonomy is defined as "the degree to which a person believes that using a particular system would decrease his or her control over the conditions, processes, procedures, or content of his or her work" [9, 68].

Table 2. Summary of HIT acceptance literature

Authors, Year	**Country**	**Technology/ Platform**	**Subjects**	**Sample/ used**	**Variables**	**Key Findings**
Buenestado et al. [62], 2013	Spain	CDSS	Physicians	8	TAM Variables	The physicians attitude towards CCGP-based CDSS is good, PU, ATT, OEU, COM, FAC are highly correlated with IU, and SN and HAB are not correlated
Phichitchaisopa et al. [65], 2013	Thailand	HIT users	Physicians, nurses, healthcare staff working in hospital	800/437, 400 usable	UTAUT variables	Performance expectancy had the strongest effect on behavioral intention of all the main determinants
Portela et al. [56], 2013	Portugal	PIDSS	ICU Nurses	13/14	TAM3 (PEOU, PU, BI, UB)	Positive responses for PEOU, PU, BI, UB constructs. The speed of the system need to be improved
Gagnon et al.[59], 2012	Spain	Telemedicine	Healthcare professionals	234/ 93	TAM with compatibility, habits, facilitators, SN	Perception of facilitators greatly influences nurses' and physicians' intention to use this new technology
Ketikidis et al. [61], 2012	Macedonia	Intended HIT users	Health professionals	200/169, 133 usable	TAM 2 variables	Only PEOU not PU significantly predicted HIT usage intention, TAM 2 more suitable for healthcare than TAM
Sambasivan et al. [9], 2012	Malaysia	CDSS	Physicians	450/335, 309 usable	UTAUT variables except FC & SN	Perceived threat lowers the intention to use, involvement increases intention to use, and the belief also increases the intention to use
Kim et al. [58], 2012	South Korea	Online Health Portal users	Users of particular online health portals	728	Variables from HBM, TAM, and TPB	Perceived threat, usefulness, and ease of use significantly affected health consumers attitude and behavioral intention
Morton [49], 2011	USA	PHR	Diabetic patients	78 (48 users, 30 non-users)	PU, PEOU, BI	Both users and non-users intend to use the PHR, perceive the PHR is/could become easy to use, and believe the PHR is useful for self-managing their care and diabetes
Alghaith et al. [63], 2010	Saudi Arabia	CDSS	Dentists	100/30	UTAUT variables	Effort expectancy is the only factor that had a significant correlation with the behavior intention
Winkelman et al. [52], 2005	Canada	Online EMR (iChart)	Patients with inflammatory bowel disease	In-depth interview & focus group	–	Useful IT promotes and supports illness The ability of a patient to act on his/her own behalf to directly influence his/her illness Trajectory

Table 2. Summary of HIT acceptance literature (cont.)

Authors, Year	Country	Technology/ Platform	Subjects	Sample/ used	Variables	Key Findings
Hassol et al. [53], 2004	USA	EHR	Patients and clinicians	4282/ 1421. Interview 10 clinicians, focus group with 25 patients	ease of use, and information completeness, accuracy, and usability	Positive patient's attitudes towards the use of Web messaging and online access to their EHR. Also patients described their medical information as complete and accurate when using the system
Hu et al. [48], 1999	Hong Kong	Telemedicine	Physicians	1728/ 421	TAM variables	PU as significant determinant of attitude and intention while PEOU not
Tsai [69], 2014	Taiwan	Telehealth	Telehealth users	365/370	PEOU, PU, SSE, SP, IT, and ST	SSE significantly affect PEOU; SP, IT, and ST significantly positive effect on PEOU and PU
Isabalija et al. [66], 2011	Uganda	Telemedicine	Users (patients and non-patients)	146/160	-	Telemedicine policy, knowledge and skills, and resistance to change by staff affect telemedicine
Oio et al. [64], 2008	South Africa	e-healthcare	Practitioners, managers, and patients	323/500	Need-change, engagement, structural, and acceptance and use readiness	Acceptance and use readiness as the most important attribute followed by structural, engagement and finally need-change. Healthcare practitioners show their agreement to the readiness while public and patient fairly agreed

There are few works that extend TAM by integrating it with other behavioral theories like Social Capital Theory (SCT), among them is a study which present a model that integrate Social Capital Theory and Social Cognitive Theory with TAM [69]. The model is for analyzing relationships among social capital factors (social trust, institutional trust and social participation), technological factors (TAM, PEOU and PU), and social cognitive factor (system self-efficacy) in telehealth. The model was validated using 365 responses out of 370 recruited subjects from rural community in Nantou County, Central Taiwan. The respondents used telehealth for at least one month from Chu Shang Show Chwan Hospital in Jhushang township. The findings show that elderly residents generally reported positive perception toward the telehealth system. It was also revealed that the social capital factors show significantly positive effect on the technological factors which influenced usage intention. Likewise, the system self-efficacy was confirmed as the salient antecedents of perceived ease of use. Suggestions on how to improve social capital factors like social trust, institutional trust were also given. The model's excellent fit indicates its appropriateness for evaluating and predicting the behavioral intention toward adopting telehealth.

4. Proposed Model of HIT Acceptance

The high number of citations for Davis' (TAM) work is an indication that numerous researches were conducted on the subject. According to Google scholar [70] TAM early work by the founder Davis [71] is cited by 2498 articles, and another highly cited TAM related article also by Davis is cited by 20462 articles. Out of these works some focused on examining and validating the constructs and variables while others focused on extending the model by introducing new variables or constructs [72]. Therefore, the model proposed in this study is an extension of TAM, with additional constructs perceived output quality adopted from TAM2, perceived cost-effectiveness, and trust as depicted in Fig 4. The purpose of this study is to examine the factors that influence acceptance of one HIT system by diabetic patients in developing countries. Based on our review and preliminary study [73] quality improvement, cost reduction, and trust were identified as three important factors that can affect the acceptance of HIT. Even though TAM has variables that can determine the users' acceptance of IT, but the variables are not adequate to better explain users' behavior towards accepting HIT for improving quality and reducing cost of diabetes care. Hence additional variables were added as suggested by Moon [74] that additional factors should be added to the TAM depending on the context of the study.

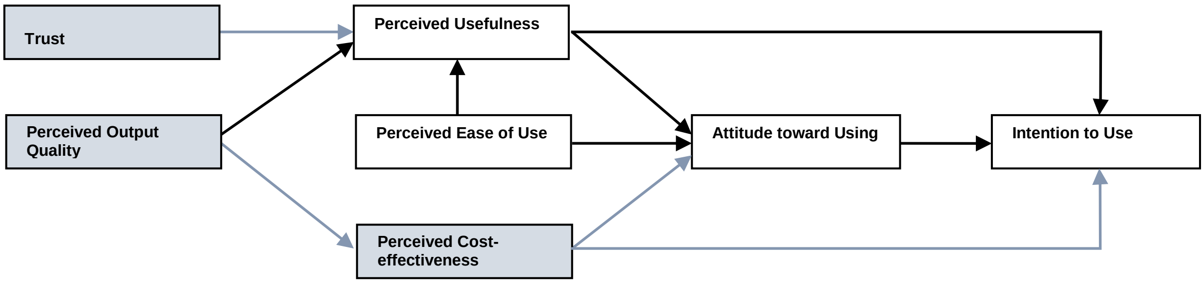

Fig. 4. Proposed model

Davis et al. proposed output quality as the perceptions of people on how well the system performs its tasks [16, 19, 75]. In our context perceived output quality can be referred to as the perception of people on how well the system provides healthcare services to patients. In Davis et al. [75], the relationship between perceived output quality and perceived usefulness was shown. This relationship with additional relationship between perceived output quality and perceived cost effectiveness will be examined in our proposed model [58, 76]. Literatures related to cost analysis, and factors that determine the cost of healthcare were reviewed in order to define how cost-effectiveness will be measured. In our study we identify medication, transportation, loss of time, loss of productivity as the factors that determine the cost of healthcare [77-80]. This is also assumed to directly influence perceived usefulness and perceived cost-effectiveness. Perceived cost-effectiveness was added to measure the perception of the users regarding the cost-effectiveness of the system [81]. Therefore, perceived cost-effectiveness can be defined as the perception of an individual on using a system and achieving the required result at a lower cost compared to its alternative [82]. This is hypothesized to directly affect intention and attitude toward using the proposed system. Trust has been used by many researchers especially in the area of e-commerce; it can be defined as "the extent to which one is willing to ascribe good intentions to, and have confidence in, the words and actions of other people (or systems)" [83]. Health information needs to be controlled and protected carefully because of its sensitivity. This information is confidential in most cases and has to do with the life of those involved. For any system that handles such information to be welcomed by users it has to be trustworthy. Trust was incorporated into the proposed framework as antecedents of perceived usefulness, in contrast to other studies that hypothesized it to directly influence behavioral intention [83-85].

Therefore we combine TAM variables, perceived output quality fromTAM2 and two additional constructs, *perceived cost-effectiveness* and *trust*, to form the new model. The new relationships postulated are *trust influences perceived usefulness*, *perceived output quality influences perceived cost-effectiveness*, *perceived cost-effectiveness influences attitude toward using*, and *perceived cost-effectiveness influences intention to use the system*.

Trust to perceived usefulness: we envisage that when the system is perceived as trustworthy and the patients have confidence in the system then they will consider it as useful.

Perceived output quality to perceived cost-effectiveness: when the quality of the system is high, it is expected that the cost will reduce, in other words the system will be cost-effective. For instance, when the hospitalization rate is reduced, the cost related to the care will also be reduced.

Perceived cost-effectiveness to attitude toward using: if the users believe that the system reduces cost of their care, their attitude toward using it will be positive.

Perceived cost-effectiveness to intention to use: the intention of the patients to use the system will be high if they realize that using it will reduce the cost related to their care.

5. Conclusion

Although healthcare delivery can be improved using HIT, a small number of HIT systems are implemented and used in developing countries. Moreover, there is lack of studies on the patients' perception and acceptance of HIT systems, most especially in developing countries as found in this article. When the factors that lead to low adoption of HIT are known, they can be tackled before implementation which will enhance the rate of user adoption. Therefore, we proposed an extended TAM for assessing factors that contribute to HIT acceptance by patients in developing countries. We chose to extend TAM since it is considered the most influential IT adoption model by many IT/IS researchers, and it can be applied to different context. The additional variables in the proposed model were added in order to better explain the perception and acceptance of HIT systems by patients. This is a contribution to the existing theories of IT adoption, since the study describes patients' perception toward acceptance of HIT system.

In the future, this model should be validated in a real clinical setting. The validation process may start with conducting an exploratory study and later develop an instrument that will be used to collect data from patients in developing countries. Once the model is validated it can be evaluated and compare with existing technology acceptance models. The model can be enhanced further by identifying and incorporating other relevant variables.

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Defining Building Information Modeling implementation activities based on capability maturity evaluation: a theoretical model

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Abstract:
Building Information Modeling (BIM) has become a widely accepted tool to overcome the many hurdles that currently face the Architecture, Engineering and Construction industries. However, implementing such a system is always complex and the recent introduction of BIM does not allow organizations to build their experience on acknowledged standards and procedures. Moreover, data on implementation projects is still disseminated and fragmentary. The objective of this study is to develop an assistance model for BIM implementation. Solutions that are proposed will help develop BIM that is better integrated and better used, and take into account the different maturity levels of each organization. Indeed, based on Critical Success Factors, concrete activities that help in implementation are identified and can be undertaken according to the previous maturity evaluation of an organization. The result of this research consists of a structured model linking maturity, success factors and actions, which operates on the following principle: once an organization has assessed its BIM maturity, it can identify various weaknesses and find relevant answers in the success factors and the associated actions.

Keywords:
Building Information System; project management; Critical Success Factors; information systems; maturity.

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1. Introduction

Integrated information management has increasingly become a matter of concern, despite the fact that ERP solutions have existed since the seventies. At the same time, numerous studies on 3D modeling have shown its benefits; these are especially noteworthy in the aircraft industry [1]. After a couple of decades of efforts focused on 2D-modeling from the Architecture, Engineering and Construction (AEC) industry, interest in a new way of leading projects finally grew in the late nineties. This led to the development of Building Information Modeling (BIM) systems. The initials "BIM" first appeared in 2004 in the normal AEC vocabulary [1].

Today, Building Information Modeling (BIM) is recognized as a form of software or a group of information systems that enable the digital representation of physical and functional characteristics of a facility. A BIM system allows the sharing of knowledge resources for information about a facility over its complete life-cycle. As such, BIM systems fall into the category of integrated collaborative tools that aim for data interoperability and life cycle management.

As indicated in its name, BIM implies modeling, and more specifically building models. 3D models can be particularly advantageous, as such models can be expanded with the use of parametric objects. Those objects do not have a fixed-geometry but rather are defined by sets of parameters and rules to determine their behavior and characteristics [1]. It is therefore possible to encapsulate more information in models, to have more dynamic representations of buildings and to conduct analysis from the models thanks to the use of parametric objects. Additional dimensions can also be introduced in the models: time is the usual fourth dimension, with scheduling becoming available in the building models, and cost estimation can also be cited as the traditional fifth. More than a mere technological evolution, BIM provides a powerful response in terms of information management, communication and coordination between stakeholders. Indeed, BIM enables "an accurate and more complete documentary record of building information throughout the building design and construction process" [2]. To do so, BIM integrates the documents and data produced by stakeholders during construction projects and is bound to become a trustworthy, authoritative and exhaustive source of information (as shown in Fig. 1). The use of BIM has shifted the construction industry's usual information platform from disconnected building models to a networked collaborative platform where business partners can "exchange valuable information throughout the lifecycle" [3].

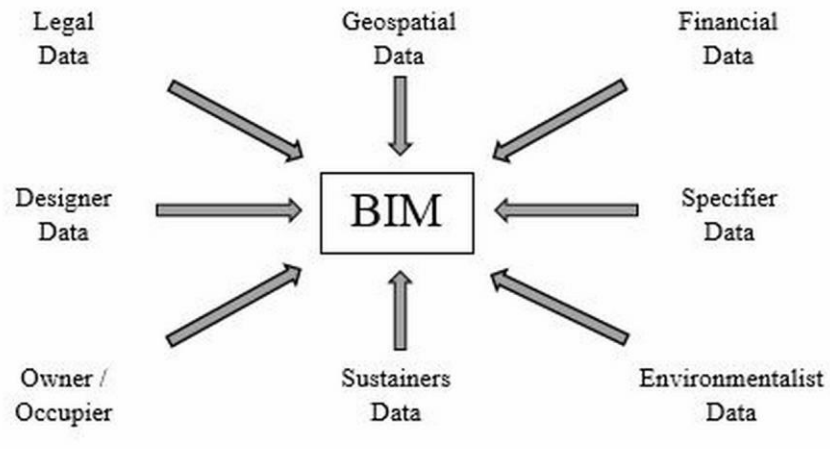

Fig. 1. BIM models integrating documents in order to communicate and collaborate (adapted from [4])

The AEC has seen its productivity stagnate and even shrink a little from 1964 to now, whereas other industries have performed much better [5]. Explanations for this can be found in the high amount of small firms in this sector that are unable to invest to improve their practices, or in the complexity of setting up an appropriate environment for numerous stakeholders to work together. The AEC industry still needs to find a way to raise productivity, efficiency, quality and sustainability and lower lifecycle costs, lead times and duplication [6]. BIM has proven its potential in terms of solving some of these major problems that are encountered in the AEC industry, but is still in the early phase of adoption. By reengineering their business processes by adopting BIM solutions and practices, firms can save time and money, produce more accurate and exhaustive building models and keep track of the information created during projects. BIM allows real-time communication based on the multidimensional models that have been introduced before and permits some additional analysis such as quantity takeoffs or clash detection [1],[7]-[9].

Despite this promising progress, BIM tools have not yet fully delivered their capabilities to professionals in this sector. The explanation for this limited introduction can be found in several factors, such as stubbornness of some firms about keeping the old CAD ways of working alive [10], change management [6],[11] or the need to adapt existing workflows in a lean oriented manner [6]. Consequently, a transition, as well as technical mindset, is compulsory to achieve the benefits of BIM. Another barrier to its widespread use in the AEC industry is the lack of guidance for this transition and the poor amount of studies that are rooted in reality to support firms in its adoption [6]. The most successful companies in this kind of project are the ones that had a clear deployment strategy [2]. By extension, implementation and adoption projects are smoother when ruled by a detailed plan and well-defined objectives, and progress needs to be made on that [12]. Thus, researchers can take part in a common trend towards the establishment of industry standards and best practices in that context and bring their support toward better integration of BIM in the industry.

Recognizing this need, the objective of this paper is to propose a support model for the adoption of BIM based on the BIM maturity of a company. The remainder of this article is organized as follows. Section 2 presents a brief review of the studies on the existing implementation procedures and how it can be assisted. Section 3 describes the model; the three different elements in the model and the linkages between them are depicted. After some consideration about how the model will be validated, we conclude with limitations and improvements that could be made.

2. Background work

As successful implementation needs to be framed by a well thought-out strategy, it is of interest to look into the literature to find out which studies have been realized in order to assist the implementation projects of integrated systems. Indeed, BIM integration is a complex objective to achieve and involves multiple issues that have to be taken into account differently according to the context of each organization.

BIM implementation can be seen from several points of view, depending on what the project owner’s aim is [11]. Technological issues can be the main concern [6],[14]-[16], as well as the new functionalities allowed by the implementation [14],[15] or its maturity [16]. Hartmann and al. [13] also note that the industry suffers from a poor amount of practical experiments led on a theoretical basis and insist above all on the need to adapt BIM to the company’s requirements, and not the other way around, in order to trigger the least possible resistance to change, and to disrupt the existing workflows as little as possible [18]. It also implies that studies often focus only on very aggregate levels and that firms lose from the lack of concrete advice. This point is reinforced by Davies and Harty [19] and their approach toward on-site implementation.

In addition to the definition of the expectations for BIM use, it is also relevant to assess its maturity in the organization with levels depicted in [10],[17]: object-based modelling, model-based collaboration and network-based integration. This evaluation can be used to enlighten firms about their current situation so they can prioritize the jobs to be done. This is indeed a central aspect in order to evolve towards the wider integration of BIM in the industry, as demonstrated by [2] with a description of the *Capability Maturity Model* (CMM). This tool has been developed by the *National Building Information Modeling Standard* (NBIMS), which adapted the Carnegie Mellon University original CMM® (CMM is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University). It provides a maturity index through an organized assessment of BIM use and business processes happening in a company. The final mark obtained with the CMM is built from several criteria about the main issues of BIM.

Moreover, significant challenges can be clearly isolated, which can contribute to better preparation for the implementation if they are known in advance. Organizational culture, education and training, and information management seem to be three essential factors [10]. A comprehensive roadmap should integrate these issues in the implementation plan. In a similar manner, information management is often stated as a complex matter that has to be taken with much care, notably with the concepts of information stewardship, data responsibility and data accuracy [2]. The importance of the external stakeholders in the BIM leap forward [1],[2] can also be cited.

Within the context of implementation procedures and recommended practices, Arayici and al., [3] propose an iterative model for adoption used in a case study and by mimicking the lean principle of Plan, Do, Check, Act. This strategy is, however, restrained to a single case and does not exhaustively describe the steps to follow. It has also been applied in the specific situation of an implementation for remote projects [3]. Migilinskas and al. [7] prefer to focus their research on the identification of benefits, obstacles and challenges of an implementation, through different case studies. On the other hand, the well-known Autodesk Inc. company produced a BIM deployment plan [20]. This plan tackles multiple issues of a BIM implementation project, even though some other issues like change management are completely left aside. Therefore, this proposal has the major drawback of being one-sided and Autodesk-centered. Another interesting approach constructs a BIM adoption framework, which integrates challenges that were pointed out by professionals in specific interviews [16]. Furthermore, recent research conducted by Forgues and Staub-French [21] proves to be extremely relevant and can be compared to the previous deployment plan. The two authors provide a general overview of the benefits, challenges and hurdles encountered during a BIM adoption, based on three Canadian case studies, and continue with a proposal for a precise implementation guide, built upon the lessons learnt from those three experiences. Presented as a cycle, the result is an 8-step procedure, including practical activities, and is meant to cover the whole process of implementation. Its main weaknesses, however, lie in the choice of taking into account only Canadian small and medium enterprises, which directly restricts the study's impact both with regards to country and the size of the companies that are likely to use the guide. Still, this research illustrates the efforts that need to be invested to properly describe the implementation issues and provide appropriate answers.

In light of the above research, it is important to mention how a methodology can rigorously be defined. Braun et al. [22] exhibit several constitutive elements necessary to wholly describe a methodology, four of which are activities included in a given procedure, the associated roles needed to perform them, deliverables produced by them and techniques to assist in their realization. Winter and Schelp [23] corroborate those elements and also add the flexibility and adaptability to any environment as criteria to obtain an exhaustive method. In comparison with what can be found in the literature about BIM, which was concisely explained in the previous review, there is obviously a gap to clear before having exhaustive implementation methodologies.

Instead of trying to treat the matter of implementation fully, some authors stay centered on a particular problem so they can examine it in more depth. Selecting the right BIM tool that fits with the company expectations [6], change management during an implementation project [11] or workflow reengineering [18] are examples. Information management and the associated corporate culture also seem to play a preponderant role and are investigated in depth in Smith and Tardif's book [2].

With regard to that article and its motivations, it is also relevant to investigate which factors could influence how well a BIM implementation will go. Due to the similarities between BIM, PLM and ERP software, a close look at the dedicated literature is important. Many research projects have been carried out on the Critical Success Factors (CSF), which are elements that are seen as essential and that facilitate achievement related to an ERP adoption project [24]-[28]. Business process reengineering [24],[27],[28], change management [25],[27],[28] as well as end-user involvement [28] are three examples of those factors, that have to be taken into account to maximize the likelihood of success of the implementation projects. As far as BIM is concerned, studies have been conducted with a similar objective but no broad consensus has been reached. Analysis on which points gave an edge to acknowledged projects [29], driving factors [14] or key issues [2],[16] tend to be spread.

In conclusion, previous BIM related studies do not provide complete and concrete answers to the issues raised by the adoption and utilization of BIM. On the one hand, exhaustive implementation procedures are relatively non-existent and case studies are, conversely, not general enough. On the other hand, critical success factors of those kinds of projects are poorly documented. In order to comprehensively understand what the main issues of a BIM implementation are and how it is possible to assist in such a process, the objectives of this research are the following:

- Rationalize the scattered information about BIM found in the scientific literature around a structured and formalized model
- Assist the AEC industry in becoming more familiar with the BIM implementation issues and adopting BIM
- Establish a list of Critical Success Factors for a BIM implementation project
- Establish a list of practical actions derived from the literature, cases studies or experts' suggestions that are likely to be put in place in a BIM implementation project
- Build an assistance model for BIM implementation, including maturity assessment, CSFs and actions.

The construction of the assistance model will be carried out inspired by the Françoise et al. model [28], as they described connections between success factors for ERP implementation projects and concrete actions. With the significant role that maturity has to play in the ways to properly lead implementation, the model will also take root in a BIM maturity evaluation in the user company.

3. Model

3.1 Literature review strategy

The approach used to perform the literature review involves several steps. At first, in order to look at the problem as a whole, research was centered on works related to BIM implementation and not only BIM implementation methodologies. As the results highlighted the weakness of representation of adoption procedures, the focus has progressively shifted to this particular matter as well as on how to help the industry integrate BIM into their practices. The significant amount of data scattered in case studies has pointed out that efforts to rationalize it should be made. The objective of the literature study thus has become twofold. On the one hand, it is to clarify factors that have a strong influence on implementation projects. In fact, because research on how to adopt BIM in an organization was scarce, the reflection moved towards which issues are to be prioritized. On the other hand, the literature review also aims to identify concrete examples of BIM adoption, practices and practical advices that could lead to the achievement of critical success factors. As such, there is a need for practitioners to link concrete actions to the desired success factors, as stated by Françoise et al. [28].

Consequently, the literature exploration turned towards defining critical success factors for BIM adoption and collecting empirical studies or proposals for actions to be undertaken in such projects. However, the decision of staying focused on factors deeply influencing both implementation and utilization was made. Indeed, companies suffer from those two issues and it is wise to bring to the table solutions that can best bridge these gaps. The decision to add maturity in the model has also been taken; the assumption, which is revealed through the literature, is that it plays a determining role in implementation. The CMM tool previously presented was immediately a relevant answer because of its ability to assess maturity in an organization.

3.2 Capability Maturity Model

The BIM *Capability Maturity Model* was developed to assess building an information model and the processes associated with creating and maintaining it [2]. It originates from the *National Building Information Model Standard* (NBIMS), an American organization working for the adoption of standards and best practices among the AEC industry to make it more productive, and has proven its reliability in terms of variance of the results (study led by NBIMS Testing Team [2]). It is a measure of the quality of a BIM implementation and an indicator of how profound BIM implementation is in the industry [30]. It has been applied in different engineering domains before being adapted for construction. Though it is not really a model, it provides a maturity index through an organized assessment of BIM use and business processes that happen. This evaluation is distributed into eleven criteria, as presented in Table 1. Each criteria is marked from one to ten, each rank describing a particular condition of the company for the assessed criteria. Then, a global mark is obtained.

The organizations willing to use the CMM to get an overview of their use of BIM can therefore be aware of their global performance as well as their abilities in each of the issues, so they can react according to their weaknesses. In this regard, an analysis took several successful BIM implementation projects to see which criteria they were good or poor in [30]. For instance, it sheds light on the convincing performance of these companies in the Graphical Information criterion. The latter represents how well buildings are modelled, with respect to the available dimensions and analysis. The success of this criterion is also not a surprise, as building models are the primary source of attention when enterprises get in contact with BIM. A brief description of the ten levels included in the first category, Data Richness, is shown in Table 2.

3.3 Critical Success Factors

As explained above, the model developed is grounded in the research conducted by Françoise et al. [28] and on the relationship between success factors and actions that he imagined, with the difference that this is applied to BIM implementation projects, with an additional focus on factors that also have an impact only on utilization and that maturity is deliberately involved in it. Then, one first thing to obtain was a precise list of critical success factors. With the literature guiding the thinking process for this task, the set of CSFs retained is presented in Table 3.

Table 1. Capability Maturity Model categories (Taken from [2]. As descriptions were very accurate, they were inserted as found in [2]. All credits for the formulations are given to Smith and Tardif and NBIMS)

CMM categories	Description
Data Richness	Refers to the degree to which a building information model encompasses the available information about a building.
Life Cycle Views	Refers to the degree to which a building information model can be viewed (and used) appropriately by any players throughout the building life cycle who may have need of the data to execute their responsibilities.
Roles or Disciplines	Refers to the number of building - related roles or disciplines that are accommodated in the modeling environment, and thus is a measure of how well information can flow from one role or discipline to another.
Change Management	Refers to the degree to which an organization has developed a documented methodology for changing its business processes.
Business process	Refers to the degree to which business processes are designed and implemented to capture information routinely in the building information model as an integral part of each business process.
Timeliness/Response	Measures the degree to which BIM information is sufficiently complete, up-to-date, and accessible to users throughout the life cycle.
Delivery Method	Refers to the robustness of the IT environment to support data exchange and information assurance.
Graphical Information	Refers to the degree of sophistication or embodied intelligence of graphical information.
Spatial Capability	Refers to the degree to which the building information model is spatially located in the real world according to Geographic Information Systems (GIS) standards.
Information Accuracy	Measures the degree to which information reflects real-world conditions.
Interoperability/IFC Support	Measures the degree to which data can be reliably exchanged among software applications using the open-standard Industry Foundation Classes.

Table 2. Description of the CMM criteria: Data Richness (adapted from [2],[31])

Data Richness Maturity Level	Description
1	Basic Core Data: BIM has been introduced in the company but there is no data or little basic data to load.
2	Expanded Data Set: Some more data can be entered, but it is still early in the maturity.
3	Enhanced Data Set: The model is reliable for basic data.
4	Data Plus Some Information: Data becomes information.
5	Data Plus Expanded Information: Data begins to be authoritative and the primary source.
6	Data with Limited Authoritative Information: Metadata is introduced, so information is the best available.
7	Data with Mostly Authoritative Information: Data is seen as reliable and authoritative, data checking progressively becomes useless.
8	Completely Authoritative Information: Metadata is entirely linked to the information, which is the authoritative source.
9	Limited Knowledge Management: Knowledge Management strategies are set up and information is beginning to be linked.
10	Full Knowledge Management: Authoritative information is completely linked to Knowledge Management strategies.

As the literature study was going on, several other success factors were identified, such as the essential need for a clear strategic vision to achieve BIM benefits [1],[9],[19],[23],[24],[27]. However, it did not appear as though those factors had any clear effect on the utilization of BIM, whereas the model was intended to include this aspect. Further examination with CSFs correlated to CMM would bring about more clarification.

Table 3. Critical Success Factors for a BIM implementation project, with additional impacts on utilization

CSFs list	Description	Literature references
Business Process Reengineering	Efforts invested to deeply review the current processes and reorganize workflows and ways of doing things in a BIM oriented manner.	[1],[2],[10],[16],[18],[28]
Standardization	Introduction of standards and metadata to better handle information and to tend towards an industry wide paradigm about BIM use.	[1],[2],[16],[20]
External stakeholders involvement	Ability to involve every business partner in the BIM dynamic and get them to facilitate the transition.	[1],[2]
Education to Information Management	Awareness and education of the internal members of the organization to information management practices and philosophy.	[2],[10]
Technical Education	Formation and education of the internal members on the use of the different tools composing the BIM and on the new processes.	[10],[20],[25]
System selection process	Proper selection of BIM tools fitting adequately the needs of the organization.	[1],[10],[20],[24],[25]

3.4 Connections between CMM, CSF and actions

Three entities constitute the model: the CMM, a CSF list and actions. CMM categories can be seen as some of the driving factors for using BIM successfully. However, because it has been designed to assess maturity and because the intention for the model was to generally tackle the hurdles the industry faced when adopting BIM, those categories have been transcribed into CSFs, which form the first relationship between the three parts. As a result, each CMM criterion is associated with one or several CSF(s), meaning that those CSFs can be used as levers to progress in the criterion in question. It is also relevant to note that one CMM criterion can be linked to several CSFs, which shows that multiple issues are included in each category of the formatted CMM tool and justify the linkage. Furthermore, this connection permits the amount of CSFs in the list to be lowered, some of them with only very limited influence, and in the meantime to highlight the significant ones. To return to the preceding example, no clear causal bond can be seen between having a precise strategic vision for BIM utilization and performing better in any CMM category. Nevertheless, it does not imply either that this particular issue has no business enhancing BIM implementation and use, but the link seemed too indirect to include the factor. Following this logic, Table 4 exhibits the connections established between CMM and CSFs for the model.

Table 4. Connections between CMM and CSFs

CMM categories	**Linked CSFs in the assistance model for BIM implementation**
Data Richness	▪ Business Process Reengineering ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education ▪ System selection process
Life Cycle Views	▪ Business Process Reengineering ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education ▪ System selection process
Roles or Disciplines	▪ Business Process Reengineering ▪ Technical Education
Change Management	▪ Business Process Reengineering ▪ Education to Information Management ▪ Technical Education
Business process	▪ Business Process Reengineering
Timeliness/Response	▪ Business Process Reengineering ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education
Delivery Method	▪ Education to Information Management

Table 4. Connections between CMM and CSFs (cont.)

CMM categories	Linked CSFs in the assistance model for BIM implementation
Graphical Information	▪ Technical Education ▪ System selection process
Spatial Capability	▪ System selection process
Information Accuracy	▪ Business Process Reengineering ▪ Standardization ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education ▪ System selection process
Interoperability/IFC Support	▪ Standardization ▪ System selection process

The second pairing is made between CSFs and actions: for every success factor, a set of actions is proposed. Correctly implementing those actions is bound to make the organization better with the corresponding factor. Justifications for the actions are found in the literature among the different case studies and proposals from experts. Fig. 1 summarizes the interrelations within the model.

The intended use for the model is plural. One hierarchical approach prescribes that an organization willing to implement BIM or to update the state of progress of a project that has already been started begins with the CMM evaluation. From there, this organization can identify its strengths and weaknesses and focus its work on the criteria where it performs poorly. This work can in turn be driven by different CSFs as defined in the model and linked to specific CMM categories. Actions are proposed and can be undertaken according to the recommended CSFs. The result of that approach is expected to be an enhancement of the situation in the targeted criteria. Also, only some parts of the model can be used. CSFs and actions are interesting on their own, on the one hand to know the issues involved in a BIM implementation and on the other hand, to know what to do. The entire process that is introduced with the model does not necessarily need to be followed.

3.5 Actions

Finally, there are the actions in the model. The purpose of these is to concretely assist BIM implementation projects. Case studies have been investigated in order to extract what did work for companies from different places in different environments, as well as recommendations made by expert authors on the subject.

As a result, a lot of information about things to do in certain contexts has been gathered and then rationalized through the connection to the CSFs from the list built earlier. Table 5 illustrates three possible actions for every proposed factor, which come from the previous literature study.

Table 5. Actions associated with CSFs

Business process reengineering	**Literature references**
Build models for "As Is" and "To Be" states, both for business processes and information flows.	[2]
Rationalize the production of data by assigning a unique role to get them, where it makes the most sense.	[2]
Track information by mapping out who the successive hosts are.	[2]
Standardization	**Literature references**
Introduce metadata to better manage the information.	[2],[20]
Organize information so that users' access can be controlled.	[20]
Define standards for the components and exclusions of building models.	[20]
External stakeholders involvement	**Literature references**
Adapt contracts to include BIM skills and expertise.	[1]
Adapt deliverables to include BIM documents and BIM analysis.	[1]
Communicate regularly with the partners on the organization's information needs and formats for these data.	[1]
Education to information management	**Literature references**
Increase awareness of the fact that information has to be synchronized with workflows.	[2]
Educate about information stewardship and responsibilities about information.	[2]
Force electronic transfers of information and prohibit paper-based models from communicating.	[2]
Technical education	**Literature references**
List every current and needed skill, who and how many people master each skill, and their average level.	[20]
List training needs for each skill, who and the length of the planned training.	[20]
Set up a training program for new members in the organization.	[10]
Selection	**Literature references**
List which functions are priorities and make sure to adapt software and tools.	[6],[20]
List which analysis the organization wants to be able to make and make sure to get adapted software and tools.	[6],[20]
Develop test cases to assess each potential BIM tool.	[6]

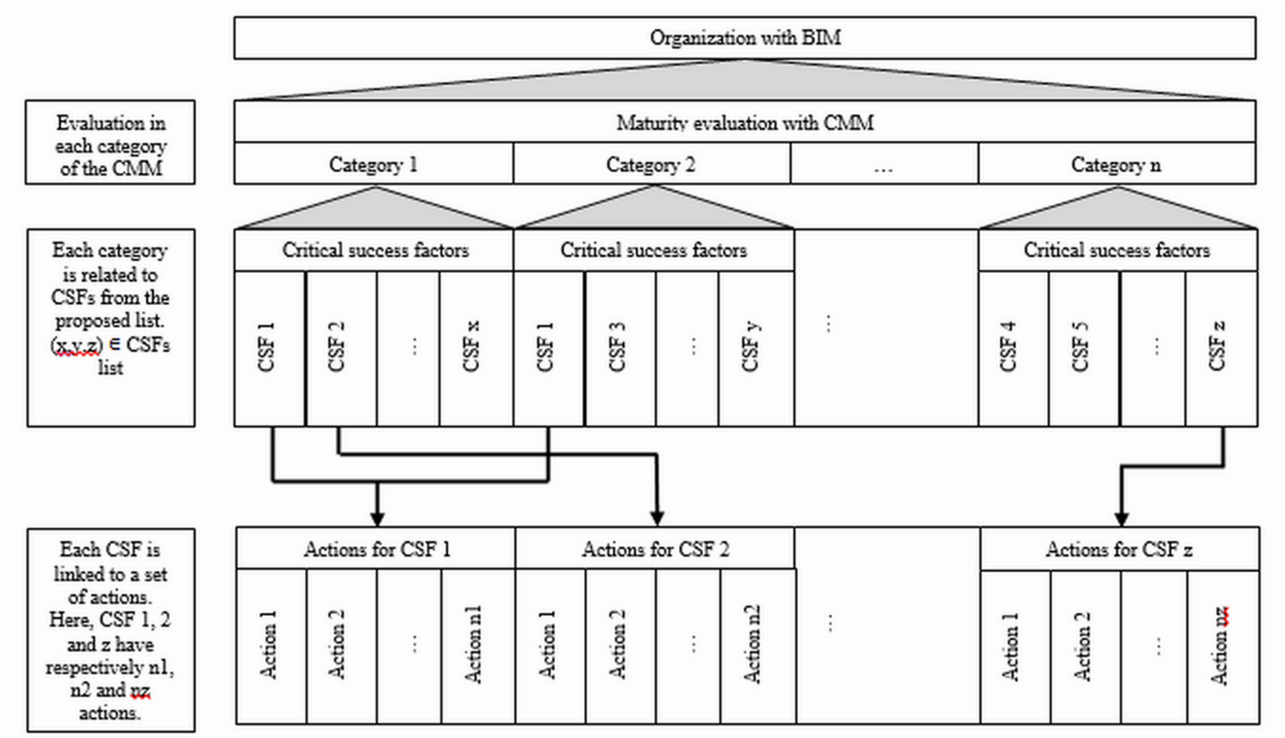

Fig. 2. Interaction model

3.6 Validation

To legitimize the model and the related work, interviews with BIM professionals were conducted with the collaboration of a Canadian engineering and construction firm. These interviews aimed to evaluate how relevant the proposed success factors and actions are and whether some crucial issues are missing. It was also possible to determine what should be excluded from the model as well as what should be added. Notably, it was expected that because of their focus on implementation, the experts would consider some other factors as important. Because of the practical experience of the responders, suggestions for future actions were also anticipated, as well as some suggestions for the adaptation of formulations, given that the clear understanding of each activity and its aftermath relies on few words.

In the validation process, a preliminary interview was conducted with a single expert in order to calibrate the proposed interview process and to obtain a first opinion on the model's consistency. Every factor and action has been reviewed with the underlying objectives of determining what should be added, modified or even suppressed.

As the links between CMM and CSFs and between CSFs and actions were quite obvious, these links were not discussed in the subsequent interviews. In fact, focusing on which stakes should be taken into consideration and what could be done to tackle them adequately seemed to be of more value than arguing the connections.

As a result, the whole model appeared truly coherent according to the experts, who expressed their interest in both lists of factors and actions, but also in the connections between CMM, CSFs and actions. As expected, this validation had some concrete impact on the model. No item was deleted, which provided an additional reason for the model to be legitimate. Some actions were introduced in the model, like the need to integrate quality standards within the metadata management, for the standardization factor. Above all, several adjustments were made to best reflect the realities of the AEC industry and its transition towards BIM. Since information is a preponderant and controversial issue, changes have been applied to some of the actions' formulations in order to be better understood. For instance, information flowing as a project resource has been highlighted instead of saying that information has no specific owner and that the original maker is not proprietary.

An overall evaluation has therefore been possible. It provided confidence in the model's potential, accuracy and relevance. A more robust version has been elaborated upon after that preliminary assessment.

4. Conclusion

This paper summarized the existing literature on this subject, which demonstrated a lack of guidance for BIM implementation projects. In response to the difficulties encountered in adopting and efficiently using BIM in industry, this paper proposed a model that brings together BIM maturity, which plays a preponderant role in approaching implementation, critical success factors and practical actions, as depicted by Françoise et al. [28]. Although the proposed model is not yet an exhaustive implementation model, it addresses the major issues of BIM adoption and brings some concrete responses to the main hurdles that they entail.

However, several improvements could be imagined and applied to this work. As said above, exhaustivity is a first limitation. In fact, as mentioned earlier, the emphasis is on issues that have a strong impact on both implementation and utilization. This choice was made because of the link between CSFs and CMM, which leaves out many implementation questions and assesses maturity and the current use of BIM. To stress critical success factors, it would be a great leap forward to determine and validate a list that entirely takes into account every issue implied in an adoption. This task has begun in the work presented in this paper, but is not the principal objective and no validation or any examination by experts was performed. Once again, taking a close look at the literature dedicated to ERP and PLM would be one approach of interest, as much of the research deals with the subject and has proven to be realistic and complete.

Moreover, the model does not aim to provide a full methodology for adoption through its actions. The model has been designed to have activities that allow for improvement in the CSF concerned, but do not guide an organization through the whole process of implementation. This limitation is explained by the different situations that organizations can be in when evaluating their maturity and the complexity involved in answering each one of these states with a structured plan. Therefore, it would be an improvement to define precise things to do and to prioritize actions according to the CMM results. A complete roadmap for adoption with precise activities, roles and deliverables would be a final objective that would suit the industry's need of guidance.

CMM is also a matter of concern for keeping an accurate and up-to-date model. Indeed, NBIMS regularly adjusts this tool in the AEC industry. The latest version describes the I-CMM, or Interactive Capability Maturity Model, based on the initial CMM, but involves users differently [31]. An alignment between the model and CMM seems to be necessary to keep pace with the trends in the industry.

Several other additions could be of interest. For instance, adding a level of difficulty for the actions would indicate where to begin or the amount of effort that should be invested by the firms using the model.

Finally, validation stays in the remaining part of the research and is necessary to truly justify the content of the model. Further work will surely fill this gap. Expert panels will have to play a crucial role in this process. Above all, the amount of experts and their backgrounds will be critical elements in the validation process.

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