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Prioritizing Information Systems Implementation Using the Amalgamation of Lattice Structures

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Abstract: In this study a method was presented for prioritizing information systems implementation consisting of an evaluation process method and a graph representation model. The method was supported by graphs amalgamation. Two independent graphs were constructed to order the information systems applications. A graph was constructed using a partial order relation from the business/organizational point of view and the other graph was built using a partial order relation from information technology strategic point of view. A new graph that incorporates the most general properties was constructed under the reflexive-transitive closure of both partial ordering relations. Partial ordering relations were implemented by priority functions defined by features that were mostly qualitative: classes, factors, sub-factors, attributes and metrics. To represent the prioritization order proposed a 4×4 matrix chart. The method produces a priority order of the information systems that responds appropriately to the dynamic changes of the business strategy of an organization. This method outlines how a planning model for the automation of the organization must be developed. The prioritization method was supported by an Information Technology Strategic Planning (ITSP) model and methodology. The aim of this study was to validate the ITSP model. The prioritization method was presented under a formal treatment and illustrated with a case study constructed at a non-profit organization.

Key words: Strategic information system planning, system development, prioritization, ordering, amalgamation, planning

INTRODUCTION

ITSP is a methodological process that provides a closer alignment and a continuous adaptation of the Information Technology (IT) to business strategy and organizational behavior as a whole[1-3]. As a result, produces a migration plan which specifies the transition activities from the current business state to its future expected automated state. One of its most important tasks is the identification of information systems opportunities to support the business strategy and the business processes. However, one of the most important problems confronted is the uncertainty related with the decision making of the correct order of information systems implementation in terms of the potential gain, natural precedence and success probability.

Planning success is predicted upon the validity and accuracy of these priority decisions. However, this process is particularly difficult to control in a dynamic environment having variables with incomplete information. Usually, planning responds to the complex environment by applying heuristics or so-called rules of thumb[4,5] generating ineffective decisions[6].

Cognitive psychology investigates how people acquire knowledge, remember it and put it to use to make decisions and conduct effective actions. Studies in this area remark that the human mind has a limited capacity to assimilate and retain large amounts of information, even over short periods of time. As a consequence of such a restriction, decision makers must support their resolutions on incomplete information and on past experience, applying heuristic rules that do not necessarily give the expected results, even in simple cases. In this sense, Tversky and Kahneman[5] outlined a multitude of heuristics that affect the decision-making process.

In information System (IS) prioritization field no amount of information seems to be adequate to make real decisions. The literature proposes a number of approaches for priority establishment[4,7,8] that recognizes the importance of considering quantitative and qualitative characteristics. However, they present some limitations in their definition, organization and proper evaluation of those characteristics.

This is the motivation of the present study. A new method was proposed for IS prioritization. The main idea consists in establishing ordering relations from two

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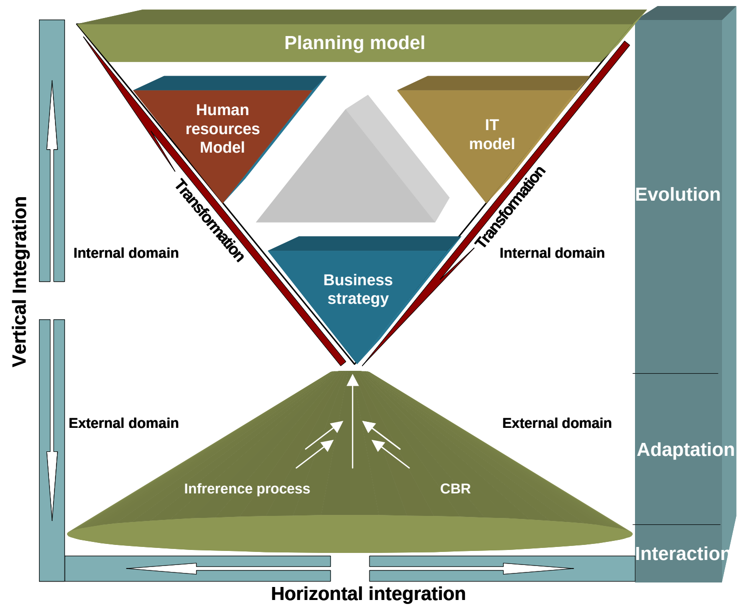

Fig. 1: ITSP model

different points of view: business\organizational and IT. The method integrates both perspectives via the reflexive-transitive closure in a final order. Ordering relations are implemented by priority functions determined by features mostly qualitative: classes, factors, sub-factors, attributes and metrics. The graphics model uses a 4×4 matrix chart to represent the prioritization orders of the information systems. This method outlines how a planning model for the automation of an organization must be developed.

ITSP MODEL AND METHODOLOGY

In the model represented in Fig. 1, the real world is composed of entities representing physical things (people, governments, enterprises, etc.). These entities are related in terms of goals, beliefs, etc. Entities under events generation change the environmental conditions. They take particular strategic positions through the network of relationships with other entities, where they play different roles. The model is based on three fundamental concepts: interaction, adaptation and evolution.

The interaction concept represents the dynamic behaviour of the environment, leading to the incorporation or rejection of beliefs and facts related with environment conditions. Interactions are established by the relationships between the roles that each entity plays in the domain of application. The behaviour of the environment is induced by the interaction of the entities.

When an incident occurs (concerning beliefs, market reactions, etc.) and it changes the environment conditions, it is called event. Each entity has the option to consider an event occurrence and it incorporates or rejects the facts related to changes in the environment. The acceptance or rejection will depend on the entities' interest. Some examples of conditions that can be accepted are: economic plan changes, political beliefs, new technological tendencies, interest rate growth, etc.

The adaptation includes business strategies using a logical inference method, which in turn uses beliefs and facts in order to generate new business strategies. This is a dynamic process where old business strategies are replaced by those corresponding with the present environmental state. In the real world, there are always assumptions which, if proven to be unfounded, can be easily corrected. The environmental changes always take place in the course of events that invalidate previous states. On the other hand, non-monotonic reasoning shows an opposite fact to this problem. It simply allows the retraction of truth whenever contradictions arise by forcing the incorporation of new beliefs.

Evolution is a process in which the business strategy is transformed into operative and IT components (the organizational model, the human resources, the IT model and the planning model). It considers a dynamic application domain which integrates the business/organizational strategic visions and the IT strategic vision in a resulting unified vision.

The evolution process is represented by an inverse pyramid where business strategy represents the axioms of the archetype of the organizations. These axioms are considered as true fundamental principles, in virtue of the

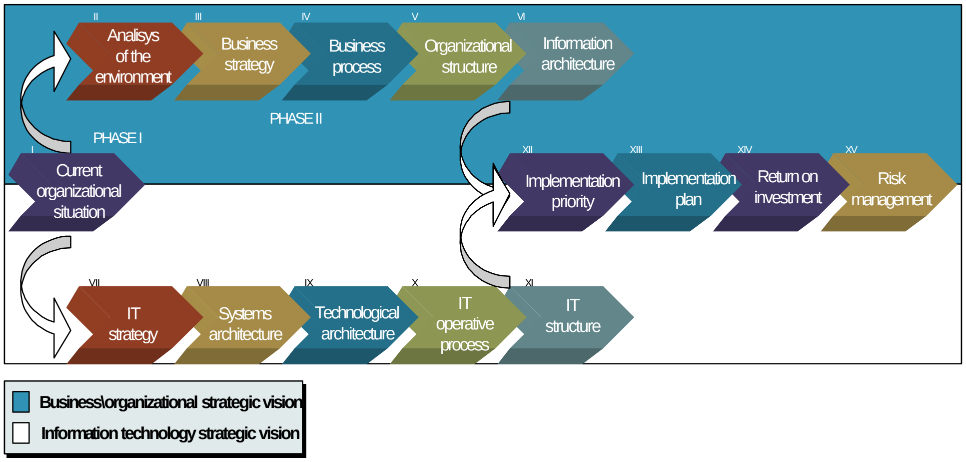

Fig. 2: ITSP methodology

fact that they are congruent with the reality of the environment. In every case, the ITSP tries to be in contact with the real world in order for its construction to be logically coherent. The organization propositions[7] (the organization model, the human resources model, the IT model IT strategy[9] and the planning model) are deduced from the axioms through a logical inference method. Thus, every proposition is true if it can be deduced from the axioms.

This definition is in agreement with the fact that the efficiency of an enterprise and the effective use of the IT depend on the concordance that exists with the business strategy. If the business strategy is incompatible with the physical structure of the enterprise and the configuration of the IT, then the functionality of the organizational areas will be inefficient. It is important to note that the organizational axioms are not necessarily absolute, but they evolve in accordance with the internal and external changes of the environment.

Note that changes in the organization are limited by the core competencies, i.e., an enterprise that sells computational equipment can be transformed into an enterprise that sells telecommunication equipment, but would be very difficult to transform it into a gas station.

The ITSP methodology (Fig. 2) is organized in fifteen modules which are divided in four phases and conceived in two visions. In addition, it is concerned with creating a business/organizational vision, which provides the critical information inputs and it also forms the foundations for later stages of planning. It creates as well a vision of the IT, which exploits new technological solutions and it improves the enterprise situation. The human resources structure module deals with the competencies model. This paradigm is in concordance with the ITSP conceptual model.

PRIORITIZATION CONCEPTUAL MODEL

In this study, a new method was proposed for IS prioritization. The main idea consists in defining priority functions from two different point of view: business/organizational and IT. The method integrates both ordering functions via the reflexive-transitive closure in a final order representing the information systems priority implementation order.

Priorities functions must be defined in terms of linguistic labels. There is no widely used single set of defined linguistic labels. Definition is dependent on the application domain and the viewpoint of the evaluator. Note that these kinds of structures are widely used in software product evaluation area[10,11]. Prioritization functions are structured in different levels: classes, factors, sub-factors, attributes and metrics. Each level represents a refinement of the previous level.

Classes definitions must in agreement with the components of the evolution concept of the ITSP model (Fig. 1). Systems priorities are managed by the strategy components (business strategy and IT strategy) and by the functional models (organizational model, human resources model and IT model). According to this definition a modification in the business strategy produced by changes in the environment will produce a change in the IS priorities.

Every class is associated with a set of factors. For example, the organizational model is related with all the economical, political, philosophic and social aspects of the organization. On the other hand, the IT model is related with the architecture of the systems, the technical infrastructure, others.

However, when a priority function is evaluated, a factor is insufficient to define the function concept in detail. It is necessary to refine each factor into sub-factors and attributes.

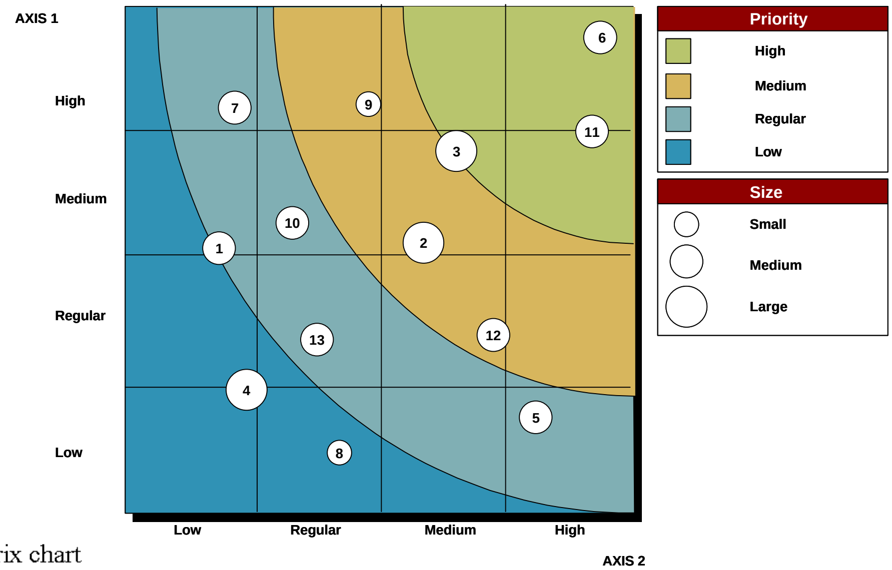

Fig. 3: 4×4 matrix chart

Metrics are functions used to measure attributes. They consist of a measurement scale and a measurement method. One or more metrics could be selected and defined for evaluating each sub-factor. Metrics are preferably measured qualitatively using certainty linguistic values, with out discarding quantitative measurement.

Linguistic certainty values constitute the verbal scale that experts commonly use to express their degree of certainty in factors evaluation. Studies in psychology have shown the practicality of such verbal scales. It is known that people asked to give numerical estimations on a common day situation error, most of the times are inconsistent in their judgment imprecision. However, judgments embodied in linguistic descriptors appear consistent in this situation. Each linguistic value is represented by a fuzzy interval, i.e. the membership function of a fuzzy set on the real line (the space represented by the interval [0,1]).

The evaluation properties (classes, factors, sub-factors, attributes and metrics) could and must be weighted assigning a linguistic value in accordance with the problem domain. Properties are evaluated using the following formula:

$$\frac{\sum_{i=1}^{n} W_i F_i}{\sum_{i=1}^{n} W_i}$$

Where, W_i is the weight of the evaluation property and F_i is the rated value of a evaluation property.

The graphic representation model plays a fundamental role in the interpretation of the information systems priorities. The information systems priority should be expressed as simple as possible, considering that the properties of the information systems priority require different rating levels and weights. The simplicity of it has the specific purpose that the evaluation process would be easily carried out.

In this sense, a 4×4 matrix chart was suggested to represent the priority model (Fig. 3). The chart is composed by to axes representing the classes of the priority function. Each axis is divided in four relatives rating levels: low, regular, medium and high. Every process and information system is represented by circle with an identifier. The circle dimension represents the relative size (small, medium and large) of the process or the information system.

The matrix chart is divided in four arcs representing the rating levels (low, regular, medium and high) of the process or information system priority implementation. In this way the information system priority implementation can be easily interpreted. For instance, if an identifier is in the highest arc then the rating value is high.

The amalgamation of the business/organizational and IT priority orders is determined calculating the average of the priority values associated with each process and information system. By looking their position in the corresponding (matrix chart) arc we assign a new position to the information systems and as a result construct the new matrix chart representing the prioritization of the information system implementation.

ORDERING BY FUNCTIONS

Let $S \neq \emptyset$ be a non empty set and let $f: S \rightarrow \Re$ be a real function. For instance:

- S, is the set of all automatizing processes and $\forall s \in S$: f(s) is the Potential Contribution to the Automation of the Process in the Organization

- S, is the set of information systems and $\forall s \in S$: f(s) is the Support of the IT function to Implement the Organizational Systems

Let $\equiv_f$ be the equivalence relation on S induced by f:

$$\forall s_1, s_2 \in S : s_1 \equiv_f s_2 \Leftrightarrow f(s_1) = f(s_2) \quad (1)$$

then the collection of equivalence classes $(S/\equiv_f) = \{\pi(s)|s \in S\}$ is a poset isomorphic to a subset of $\Re$. Thus, $(S/\equiv_f)$ is linearly ordered and, consequently, it is a lattice. The structure $(S/\equiv_f)$ is indeed trivial: all elements in *S* giving the same value under *f* are identified in this quotient set.

On the other hand, let us consider the relation $\leq_f$ as follows:

$$\forall s_1, s_2 \in S : s_1 \leq_f s_2 \Leftrightarrow f(s_1) \leq f(s_2) \quad (2)$$

This relation is reflexive and transitive, but it is not antisymmetric in most cases. It is antisymetric if and only if f is one-to-one. Thus, $\leq_f$ is not an ordering in S.
For any $s \in S$ let

Successors of s: $t \in suc(s)$ iff $s \neq t$, $s \leq_f t$ and $\forall t_1$: $(s \leq_f t_1 \leq_f t) \Rightarrow (t_1 = s) \vee ((t_1 = t)$

Predecessors of s: $t \in pre(s)$ iff $t \neq s$, $t \leq_f s$ and $\forall t_1$: $(t \leq_f t_1 \leq_f s) \Rightarrow (t_1 = t) \vee (t_1 = s)$

Let G_f be the digraph whose set of nodes is S and for each pair $(s,t) \in S^2$: (s,t) is an edge iff $t \in suc(s)$, or equivalently, $s \in pre(t)$. Let us say that f is consistent if G_f has no cycles. From now on, we will consider only consistent functions. Since $\Re$ is linearly ordered we have:

$$\forall s_1, s_2 \in S : (s_1 < s_2) \vee (s_1 \equiv_f s_2) \vee (s_2 < s_1) \quad (3)$$

thus, f is inducing a hierarchical structure on S.

The minimal elements are those with no predecessors, i.e. nodes with null inner degree in G_f. The maximal elements are those with no successors, i.e. node with null outer degree in G_f.

Let us define the upper distance as d^+ follows:

$d^+(s, t) = 1 \Leftrightarrow t \in suc(s)$
$d^+(s, t) = 1 + r \Leftrightarrow \exists t_1 : d^+(s, t) = r$ and $d^+(t_1, t) = 1$

Similarly, the lower distance d is

$d^-(s, t) = 1 \Leftrightarrow t \in pre(s)$
$d^-(s, t) = 1 + r \Leftrightarrow \exists t_1 : d^-(s, t_1) = r$ and $d^-(t_1, t) = 1$

Thus $d^+(s, t) = d^-(t, s)$. The upper height of a node *s* is $h^+(s) = Max\{d^+(s_1, s) \mid s_1 \text{ is minimal}\}$. The lower height of a node *s* is $h^-(s) = Max\{d^-(s_1, s) \mid s_1 \text{ is maximal}\}$.

Several problems arise at this point: decide successors, minimal and maximal elements, distance and height.

Superposition of functions: Let $S \neq \varnothing$ and let $f_1, f_2: S \rightarrow \Re$ two real functions

Refinements: Let us, say that f_1 is an eq-refinemet of f_2 if

$$\forall s_1, s_2 \in S : (f_2(s_1) = f_2(s_2)) \Rightarrow (f_1(s_1) = f_1(s_2)) \quad (4)$$

In this case, $(s /=_{f1})$ is an homomorphic image of $(s /=_{f2})$ (both are linearly ordered sets).

Let us say that f_1 is an ineq-refinemet of f 2 $f_2$if

$$\forall s_1, s_2 \in S : (f_2(s_1) \leq f_2(s_2)) \Rightarrow (f_1(s_1) \leq f_1(s_2)) \quad (5)$$

In this case, the ordering $\leq_{f2}$ is included, as a set in $S \times S$, in the ordering $\leq_f$. Hence, follows that $G_{f1}$is an homomorphic image of G_{f2}, i.e. G_{f1}can be realized as a graph of G_{f2}.

We may introduce a stronger notion to compare functions. For instance, let Sgn $\Re \rightarrow \Re$ be such that $\forall$ x $\Re$

$$Sgn(x) = \begin{cases} 1 & x > 0 \\ 0 & x = 0 \\ -1 & x < 0 \end{cases}$$

Let us, say that f_2 is a tonal-refinement of f_1 if

$$\forall s_1, s_2 \in S: Sgn(f_2(s_1) - f_2(s_2)) \Rightarrow Sgn(f_1(s_1) - f_1(s_2)) \quad (6)$$

In this case, G_{f1} is an isomorphic to G_{f2}.

General Comparison: Given two functions f_1, f_2: $S \rightarrow \Re$ it is interesting to decide whether there is a common sub-hierarchy to the hierarchies in *S* induced by functions f_1, f_2.

We may proceed with two approaches:

Ordering Product: Let $\Re^2$ be ordered with the product of the usual ordering in $\Re$:
$(x_1, y_1) < (x_2, y_2) \Leftrightarrow (x_1 < x_2) \vee (x_1 = x_2 \wedge y_1 \leq y_2)$
Then,

$$\forall s_1, s_2 \in S: \quad s_1 \leq_{(f_1, f_2)} s_2 \Leftrightarrow (f_1(s_1), f_2(s_1)) \leq (f_1(s_2), f_2(s_2)) \quad (7)$$

then, considering this ordering we get a graph $G_{(f_1, f_2)}$ on *S*.

Graph product: Let G_{f_i} the graph on *S* obtained by f_i, i=1,2. Let $G_{f_1*f_2}$ the union of both G_{f_i} :

((s,t) is an edge in $G_{f_1*f_2}$) $\Leftrightarrow$ ((s,t) is an edge in G_{f_1}) $\vee$
((s,t) is an edge in G_{f_2})

It is clear that $G_{(f_1,f_2)}$ has no cycles provided that non G_{f_i} has cycles. Nevertheless this condition is not sufficient in order to get $G_{f_1*f_2}$ free of cycles.

Products of petri nets: Suppose that two given petri nets P_i = (L_i , T_i) i = 1,2, specifies two processes, A_1, A_2. The process obtained by the synchronized running of both processes can be specified by the product net $P_1 \times P_2$ = P = (L, T) such that

- $L = L_1 \times L_2$
- $T = T_1 \times T_2$
- the procedural semantics of the net is defined component-wise, i.e. a transition (t_1, t_2)can be fired at places((s_{1j}, s_{2j}))$_j$ if and only if each t_i can be fired in P_i at places $(s_{ij})_j$, with post-conditions determined likely.

Nevertheless, some special care should be taken regarding both starting and ending conditions on the product net. Thus, whenever a finite set of processes is specified by petri nets, the synchronized running of all processes can be specified by another petri net.

PRIORITY FUNCTION DEFINITION PROCESS

We propose a scenario of thirteen information systems. According to the process described in section forth we must define a priority function from business/organizational and IT points of view and then we refine each priority function into classes, factors, sub-factors, attributes and metrics.

The priority functions from the business/ organizational and IT are defined as follows:

- The potential contribution to the automation of the process in the organization (business/ organizational).
- The support of the IT function to implement the organizational systems (IT).

The priority function defined as the potential contribution to the automation of the process in the organization is divided into two classes:

- The impact of the automation of the process on the business strategy and
- The impact of the automation of the process on the organizational model.

The interpretation of the evaluation of the previous classes is as follows: a process will have a high priority value if, on the one hand, has an important influence in the satisfaction of the business strategy and on the other hand, plays an important role in the automation of the organizational model.

The two business/organizational classes must be refined into factors. The impact of process automation on the business strategy is concerned with how the automation of a process is related with the organizational strategy and the competitive strategy. In this sense, the organizational strategy is related with the identification of the purpose, politics and direction of the organization. The competitive strategy[12,13] related with adding value to services and to products. As result, the class is refined into the following factors:

Organizational strategy: The satisfaction degree of the vision, mission, objectives, goals, strategies and Critical Success Factors (CSFs)

Competitive strategy: The amount of strategic benefit accrued to the organization in terms of differentiation, low cost and focus

The impact of process automation on the organizational model is concerned with all functional, political and social aspects of the organization. For this class we consider two factors:

Business processes: The satisfaction degree of the operative model of the organization.

Organizational structure: The satisfaction degree of the management of human resources.

Next, each factor is refined in sub-factors. For example, the Business Processes could be refined in:

Performance: The degree to which the operating processes are improved in terms of efficiency and/or effectiveness

Functionality: The degree to which the operating model is improved in terms of social management

Attributes corresponding with sub-factors are as shown in Table 1.

To measure the attributes, we selected qualitative and quantitative (effectiveness) metrics (Table 2). After that, each metric rating criteria was defined and four grade rating levels were applied to these criteria. They are: 1) low, 2) regular, 3) medium, 4) high. An example is presented in Table 3.

Table 1: Attributes description

Classes	Factors	Subfactors	Attributes	Description
impact of process automatization on the organizational model	Business processes	Performance	Efficiency	the degree that a process fuifill its purpose whitout waste of resource
			Reliability	the degree that a process can be expected to perform its intented actions satisfactorly
			Operability	the degree to which a process is complex to operate
		Functionality	Life quality	the extent to which a process impact on users comfort at work
			Organizationality	the extent to which a process improve the operational model management

Table 2: Qualitative and quantitative metric

Classes	Factors	Subfactors	Attributes	Metrics	Description
Impact of process automatization on the organizational Model	Business processes	Performance	Efficiency	Operationality	Effect required to execute a process
				Compactness	The smallness of a process in terms of execution
				Effectiveness	Time required to execute a process
			Reliability	Completeness	Process pars are present and fully developed
				Consistency	Process functionality has a uniform description,verification and operation
			Operability	Understanding	The degree to which a process could be undershoot without difficulty
				Simplification	The degree of reduction in the complexities of operating procedures
		Functionality	Life quality	Comfort	The degree to which a process reduce the stress and workload on users
				Motivation	The degree to which a process generates interest inspiration and attraction to work
				Relationship	The degree to which personal relations are improved at work
			Organizationality	Bureaucratization	The degree to which the operative model flow become simple
				Management	The degree to which a process improve the organizational management
				Coupleness	The degree to which a precess improve individual and group work coordination

Table3: Grade rating levels

Matrics	Criteria
Understanding: The degree to which a process could be understoot with out difficulty	Hard to understand the process
	Complicated to understand the process
	Easy to understand the process
Operationality: Effort required to execute a process	Hard to execute the process
	Complicated to execute the process
	Easy to execute the process
Execution effectiveness: Time required to execute a process	Time estimated in h ours (quantitative metric)

Last, a weight must be assigned to each one of the evaluation properties, showing the relative importance. Application examples are: Operative model (high); Performance (medium).

In the same manner, the priority function defined as The Support of the IT function to Implement the Organizational Systems is divided in the following two classes: 1) the impact of the information systems in the IT strategy and 2) the impact of the information systems on the IT model. The interpretation of the evaluation of the classes is as follows: an information system will have a high priority value if, on the one hand, it has an important influence in the satisfaction of the IT strategy and and on the other hand, it has an important effect on the IT model. A similar process could be carried out to obtain the factors, sub-factors, attributes and metrics.

The 4×4 matrix charts represent graphically the business/organizational and IT priority functions. The vertical axis represents the strategies (business and IT) and the horizontal axis the functional aspects of the organization (organizational and IT model). Each axis is scaled in four grades corresponding to the four grade rating levels, in this case: low, regular, medium, high.

The processes and the information systems are positioned in the matrixes with respect to the perceived business strength and IT attractiveness and are represented by a circle with an identifier. Each circle represents the relative size of the process or the information system. The position of the circle in an arc represents its priority. Figure 4a, b and c depict this concept. The Fig. 4c represents the information system priority constructed by the closure of Fig. 4a and b.

CONCLUDING REMARKS AND FUTURE WORK

This study proposes a formal framework for IS prioritization. The expressive power and the mathematical formalism contribute to bridging the gap between business and IT views. The IS prioritization methodology is supported by an ITSP model which establishes the difference with its predecessors. Prioritization ordering relations are constructed from the business/organizational and IT points of view. For incorporating both perspectives, information systems priorities are identified independently and are integrated into a resulting unified framework. As future work it will be of interest to formally

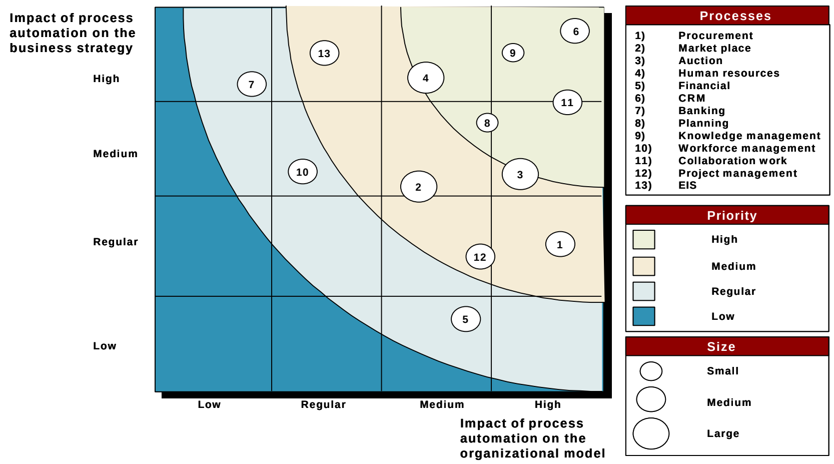

Fig. 4a: Potential contribution to the automation of the process on the organization

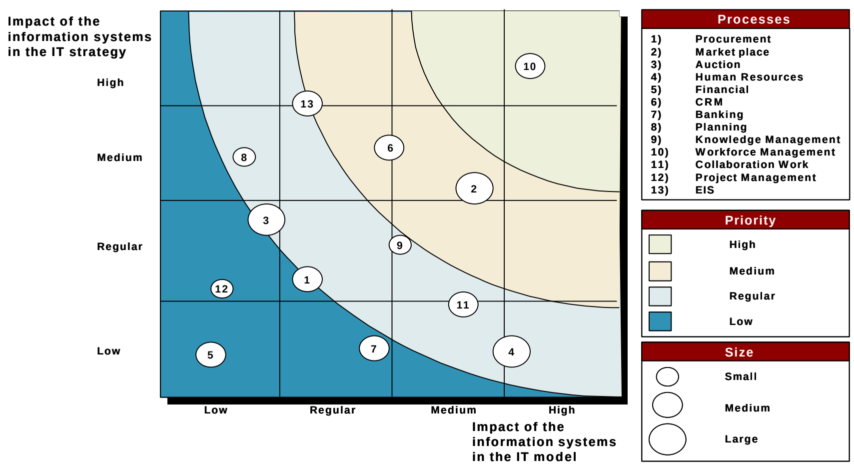

Fig. 4b: Support of the IT function to implement the organizational systems

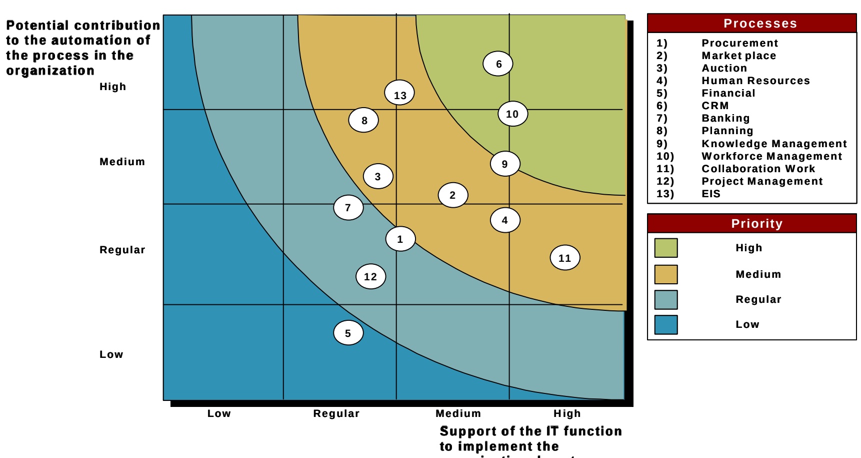

Fig. 4c: Prioritization of information systems implementation

tackle the remaining parts that form the ITSP model. In the near future, we will develop an IS prioritization software tool to implement the prioritization methodology.

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