IS Assessment - Evaluating what should be Evaluated: A new Formal Framework to Study Project Representations.

Yannick MEILLER[1,2] (ymeiller@escpeurope.eu) and Sylvain BUREAU[1] (sbureau@escpeurope.eu)

(1)
ESCP Europe, RFID European Lab
79 avenue de la République
75543 Paris Cedex 11, France

(2)
NOVAPTEN
14, rue Charles V
75004 Paris, France

1 ABSTRACT

Scholarship on the *ex-ante* evaluation of projects is prolific and offers a whole range of tools to assess projects on financial, technical, strategic and organizational levels. All these analyses start from the assumption that everyone knows and shares knowledge on what is to be assessed. Nevertheless, the system under evaluation is rarely just data, but rather a construction of a representation of a tangible physical reality which can appear under different forms, and the chosen representation may strongly influence the evaluation itself. On the contrary, in the field of automatic decision-making, i.e. Artificial Intelligence, the impact of the representation of issues and the structure of such representations in decision algorithms is widely discussed. Building on this structuring approach, we specifically focus on the initial construction stage of a representation and on its impact on evaluation. In order to grasp these representations, to compare one with another and to study this stage of the evaluation process, we propose a conceptual framework - the space of representations, structured by *abstractions* and *scopes*. We propose formal definitions of these concepts. To illustrate and also test our approach, we examine three empirical cases of investment projects related to RFID (Radio Frequency Identification) applications in hospitals. This field study shows that small changes in representation can impact strongly the evaluation results. It also shows how our framework helps us to structure our analysis of the potential representations. Lastly, we discuss how this tool opens several avenues for future research.

Key words: *ex-ante* evaluation, project management, Artificial Intelligence, RFID, representation

2 INTRODUCTION

Scholarship on the evaluation of IS projects is plentiful and provides a wide range of tool to evaluate projects on financial, technical, strategic, or organizational levels [12]. All these analyses seem to assume that everyone knows and shares the same idea of what is to be evaluated. Yet the system under assessment is rarely just data: it is a construct, a representation of a tangible physical reality which can take many forms, and thus strongly influence the evaluation itself.

No matter how sophisticated the evaluation tools are, the quality of the final result (also) depends on initial choices concerning the framing of the object and its representation. Yet these choices are rarely addressed in management scholarship, and neither is their impact on the rest of the evaluation process.

In the field of automatic decision-making, however, within Artificial Intelligence, the impact of the representation of the problem to be solved and the structure of such representations in decision algorithms is widely discussed.

Inspired by the structuring approach of artificial intelligence studies, we focus on the first step of the construction of a representation and on its impact on evaluation—but in the context of a human management process. What do we take into account? What do we discard? To best define our research subject, we distinguish between:

- the object's real and tangible physical components—which we consider to be unique;
- the representations of this tangible reality;
- the actors' interpretations of each representation during the evaluation.

Our medium-term objectives are threefold:

1. to highlight the importance of the construction of representations and the significant risks of ending up with inadequate representations,
2. to provide a structuring framework to become aware of the representation choices already made;
3. to help structure the process of representation creation, in order to avoid its major obstacles.

The remainder of this paper is organized into four sections. Firstly, we will present a literature review: we will synthesize studies relating to the ex-ante evaluation of an IS project, underscoring the lack of contributions relating to the tangible. Secondly, we will propose a formal framework that defines the space of representations of the tangible (and helps navigate that space). This framework rests on notions of scope and abstraction. It is inspired by works in formal decision which are also presented. Thirdly, we will describe a case study we observed—a collaborative RFID application project in the hospital sector—and we will apply our formal framework to this empirical subject. Finally, we will discuss our propositions, both formally and empirically.

3 LITERATURE REVIEW

Ex-ante evaluations of IS projects

The evaluation of IS projects is the subject of much research, be it *ex-ante* or *ex-post* evaluation. The goal of *ex-ante* evaluation, which is our subject here, is to identify a relationship between the projected value of an investment and the analysis (often quantitative) of the benefits, costs, and risks associated to this investment [18].

Criteria for an evaluation decision: what are we looking to evaluate?

A vast majority of the studies debate the type of criteria to select when conducting an evaluation. Some defend an approach based on financial management tools, which they simply want to apply to an IS context. However, the most widely-distributed tools are also the simplest: most often, they include cost/benefit analysis, a calculation of the recovery time, or an analysis of the return on investment (ROI), or to a lesser degree, an analysis of the Net Present Value (NPV) or of the Internal Rate of Return (IRR). While these tools are certainly useful [1] [7], they also have a number of limitations [2].

Several authors think it is vital to use more complex approaches, derived mostly from market finance, which allow one to take into account learning and uncertainty phenomena [11] [13].

Other authors call for more balanced perspectives based on both financial and non-financial criteria [16] [17], ones that use more qualitative approaches in addition to purely quantitative variables [8], and ones that take into consideration not only the direct effects of an investment, but also its indirect effects [11]. Many methods use these composite approaches.

There are three major evaluation types [15]. The first approach focuses on the effect of IS on the company's processes and studies dimensions related to the control process in particular. The second is more focused on the individual's and the organization's reaction to the services offered by IS. Finally, the third approach, more traditional, measures the impact of IS on performance.

This discussion about evaluation criteria, which highlights a great variety of perspectives, should not overshadow another, just as essential, debate about the evaluation process itself.

Process for an evaluation decision: who conducts the evaluation? How is it conducted?

When talking about the evaluation process, it is important to ask ourselves who are the actors involved, what is their role, and what will be their interpretation of the evaluation's results?

Therefore, in order to conduct an evaluation, one must first identify the actors who will conduct it [3] [19] before discussing criteria and evaluation methods, even if both these aspects are related [24].

The lingering problem: evaluating the object to evaluate

In the majority of studies presented, the object to evaluate is not seen as problematic. Criteria and dimensions chosen to evaluate the investment, or actors chosen to conduct the evaluation, are all discussed, but the physical system to be evaluated is not: it is as if it were already reliably defined, an obvious fact. However, the object to be evaluated is not just data.

Some authors point out two problems in particular: on one hand, the scope of the object to be defined for the purpose of the evaluation; on the other, the level of analysis to be adopted for the evaluation. Both have to be defined.

The issue of physical scope is often difficult to determine because it is not always easy to draw a clear boundary: the impacts of the solution often go beyond the single unit using the system directly [2]. This is even more difficult when the IS/IT solution is shared by different actors in a supply chain [4].

In addition, we must challenge the unit of analysis chosen for the evaluation of a project [9], whereas many IS project evaluation approaches focus on a single level of analysis [8]. Others believe that all evaluations should be conducted on two levels: individual and organizational [15]. Some authors go farther and put forward models that are able to apprehend a finer granularity by closely analyzing the data model [16]. However, the solution is not always to increase the level of detail.

Finally, be it for the scope or for the level of analysis, no method or instrument can determine the "right" scope or the "right" level of analysis relative to the context. We would like to address this essential question of the evaluation of the object to evaluate, via a detour through the field of Artificial Intelligence.

4 OUR FORMAL FRAMEWORK FOR THE *EX-ANTE* EVALUATION OF IS PROJECTS

Focusing on the representation of a project in order to conduct an ex-ante evaluation of this project, we need tools to grasp this representation. What are we talking about? How can we compare two representations of a same project?

Considering the components of a representation, one must choose both the scope and the level of abstraction to best conduct the evaluation. These two dimensions – scope and abstraction – form a whole that we will call the space of representations.

Talking about level of abstraction and scope is fuzzy: when we reduce the scope, we omit elements as well as when we raise the level of abstraction. Is there a difference? In order to work on the space of representations, we need to clarify these concepts.

That's why we are going to formalize these notions of scope and abstraction as well as transformations that can be applied to them. Our objective is to provide for ourselves a formal tool to apprehend this stage of the construction of the representation of the project.

Representation and abstraction: a topic studied in Artificial Intelligence

We focus here on studies in Artificial Intelligence (A.I.) that center on automatic decision-making and decision support – in particular action planning. Roughly, from an initial situation and with actions at our disposal, the goal is to create a chain of actions in order to achieve a number of objectives.
Regarding formal decision, the question of the relationship between the representation of a problem and its resolution has been an active subject in recent years: playing on the representation, solving algorithms reach new performances.

Indeed, in action planning, representing a state and a state transition plays a role all the more important as individually manipulating states is extremely costly due to their extraordinarily high number in realistic problems. Two families of approaches can be distinguished.

The first – stemming from formal deduction systems [14] – mostly focuses on the speed of plan production, without optimizing them [25]. It uses an intensional representation in which states are described by logical properties. To manipulate these properties is to manipulate, all at once, all the states for which these properties are true. Thus, the successive algorithms have progressively deconstructed the individual state, yielding planners such as Graphplan [5] that first consider properties individually – manipulating the biggest sets of possible states in the representation. In Meiller's studies [20], this approach is generalized: all research implies a splitting of the search space – the goal is to find the splitting which distinguishes what must be distinguished and which groups into clusters what does not need to be distinguished.

The second family stems from decision-making theory. It allows one to apprehend a plan's optimization (in terms of value and uncertainty). In this vein, Markov's decision processes (MDP) [23] and existing resolution methods (value iteration and policy iteration) form a formal framework adapted to planning. Unfortunately, it rests on an enumerated representation of all the states and all the transitions. Research works have focused on this representation. For example, [10] builds upon the initial space of states to get an abstract space, by grouping states whose differences are useless for the resolution of the problem considered. Then, the works only deal with these groups of states. [6] adapts resolution algorithms to exploit, even down to resolution mechanisms, abstractions (or groupings of states) made possible by an intensional representation.

Modeling: defining representation

Basing ourselves on these studies, we model the space of representations of the tangible with a 3-tuple:

$$R_T = (S, A_s, m_{A_s})$$

Where:

- S is the group of elements included in the representation – what we consider to be its *scope*;
- $A_s \subseteq 2^{S}$[1] so that A_s covers S: $A_s = \{S_i | S_i \in 2^S \text{ and } \cup S_i = S\}$
    - A_S structures the grouping of the elements of the scope of R_T with sets of elements which are so many abstractions at our disposal - it is these abstractions that are manipulated by the evaluation process;
- m_{A_S} is a set of constraints, relationships, applications, etc. relating to A_s. It is the model describing the interactions between the elements of A_s.

Therefore, we define abstraction as the grouping of the elements of a set into clusters of elements, invoking the artificial intelligence studies we have mentioned. Indeed, once these clusters are constituted, we can manipulate them directly, without distinguishing the elements that constitute them – that is, by abstracting this distinction.

A_s structures the scope S into a group of abstractions (that is, a group of state clusters). In our model, it is these state clusters that are manipulated by the evaluation process. S is only apprehended through A_s.

At this stage, we do not define any further what an element is.

In an information system project, we could have:

- Among the elements of S: the collaborators concerned, the technologies used, the processes affected;
- Among the elements of A_S: the back-office and front office sets, the business process and management process sets, categories of actors (Human Resources department, accredited personnel, etc.), functions (data entry operator, counter clerk, network administrator, management controller…);
- Among the elements of m_{A_s}: workflow, regulatory organization constraints, rules for technological compatibility, security rules and procedures for the different elements of S…

Modeling: manipulation and modification of the representation

Once a representation is defined, it can be modified:

- Either by tinkering with the abstractions – A_S;
- Or by tinkering with the scope – S.

Increasing the level of abstraction is the same as no longer considering the distinction between two sets of elements, that is, to group them:

$$abstract^+ : 2^S \times 2^S \to 2^S$$
$$G, H \to abstract^+(G, H) = G \cup H$$

Decreasing the level of abstraction is the same as introducing a distinction between the elements of a same set, that is, to split them in two subsets:

$$abstract^- : 2^S \to 2^{2^S}$$
$$I \to abstract^-(I) = \{G, H | G \subseteq S, H \subseteq S, G \cup H = I, G \neq H\}$$

By applying $abstract^+$ and $abstract^-$ to elements of A_S and by replacing those with the results obtained, we can vary the abstractions offered by the representation. For example:

$$Let\ R_T = (S, A_S, m_{A_S})$$
$$Let\ a_S^i \subset A_S\ and\ A_S' = (A_S \setminus \{a_S^i\}) \cup abstract^-(a_S^i)$$
$$Let\ R_T' = (S, A_S', m_{A_S'})$$

R_T and R_T' are two representations of the same tangible T, using the same scope, but manipulating different abstractions.

The scope is the set of elements used in the representation. Increasing or decreasing the scope is the same as adding or subtracting elements from it:

$$scope^+ : scope^+(S, H) = S \cup H$$
$$scope^- : scope^-(S, H) = S \setminus H$$

Expressivity of our model and operationalizing

Several abstractions can coexist

Let us consider a representation of the tangible $R_T = (S, A_S, m_{A_S})$.

The rest of the evaluation process exploits the elements of A_S and m_{A_S}. Each element a_i of A_S is an abstraction of a sub-set of S: it abstracts differences between elements of a_i. In our model, several groupings are possible for a same group of elements. It reflects the fact that certain elements must be distinguished for a certain type of evaluation, and do not need to be distinguished for others. Let us consider for example a technical evaluation that indicates the need to involve computer science engineers, and a human resources evaluation that must indicate precisely which individuals should be involved...

$$Given\ S = \{S_1, S_2, S_3, S_4\}$$
$$Given\ A_S = \{\{S_1, S_2, S_3\}, \{S_4\}, \{S_2, S_3\}, \{S_1\}\}$$

Here, the element S_1 can be considered either in isolation or grouped with S_2 and S_3.

Quality of representations

For a same project, several representations of the tangible are possible. The question of the evaluation of these different representations then comes up.

The following three elements guarantee that a representation will lead to the evaluation of a project:

- The scope S includes all the elements affecting the evaluation;
- The abstractions used, grouped under A_S, allow the distinction of all the cases that do not have the same evaluation result;
- The model m_{A_S} contains no errors.
- We call “error” an assertion that does not correspond to reality. Here is an example of error:
- “It is not mandatory, in France, to use sterilized instruments in surgery”.

Many representations can satisfy these constraints. Here are two more criteria we can use to evaluate one against the other[2] :

[1] The notation 2^X refers to the set of the parts of the set X, that is, the set of X’s sub-sets.

[2] Beyond any “elegance” in the representation, these characteristics must be apprehended in terms of the treatment

- Every element of the scope that has no impact on the result is useless, the scope should exclude them;
- If two elements of A_S impact the result in the same way, they should not be distinguished.

5 FIELD STUDY

We propose to apply our formal framework to a case study dealing with RFID in hospitals. The question of evaluating what has to be evaluated is often acute in RFID projects as these tend to be collaborative projects spanning beyond the boundaries of a single organization.

Short description of the RFID project studied

The project began at the beginning of 2007.It is fully described in [21] and [22]. It gathers eighteen partners, including six French hospitals, using or planning to use RFID solutions in different applications specific to the hospital context. Among the actors in these projects, we can list eight companies that offer technical solutions to hospitals, as well as the DGCIS[3] that partly funds this project.

The RFID solutions studied all involve issues of traceability – each corresponding to the tracking of a device or a specific container:

1/ medical gas tanks (the oxygen, for example) ;

2/ surgical instruments (during the sterilization process);

3/ ancillaries (specific group of instruments for the implantation or extraction of a prosthesis, traveling from hospital to hospital).

The RFID technology was considered along with alternative technologies – namely Barcodes and Datamatrix.

These projects are listed independently, application by application. However, this presentation structure does not correspond to the logic of our hospital partners, some of which were interested in several applications – the sum of which constituted their investment project. Each application can indeed be considered as an instantiation of a generic hospital issue: tracking medical devices within the hospitals and sometimes between hospitals, under budget and healthcare constraints.

In this context, these projects'objectives are twofold: on the one hand to enhance the management of medical devices , and on the other hand to optimize the allocation to management tasks of healthcare qualified staff.

Application of the model to the field

Let us apply our formal framework to the case studied.

Examples of impacts of the choice of scope and abstraction on the evaluation of technical pertinence

Let us consider three different scopes:

1/ the smallest scope: all the elements relating to the circuit of a given device within a hospital (either surgical instruments, either ancillaries, either gas tanks) and relevant to the proposed solution (RFID technologies, Data Matrix codes, barcodes, software developed by industrial partners…);

2/ a larger scope: elements relating to a hospital potntialy interested in one, two, or three types of systems among those that interest us here (therefore integrating elements related to the three types of devices and to the proposed solutions);

3/ the largest scope: elements relating to a hospital and its suppliers (which, beyond the previous scope, includes the identification of these suppliers, their technical industrial constraints, regulations, their geographic location…).

Let us consider two levels of abstraction:

1/ the generic problem: traceability of medical devices within a hospital or between hospitals– that is, without distinguishing between different types of devices.

2/ the detailed project (lower level of abstraction than for the generic problem), distinguishing between three types of devices (gas tanks, surgical instruments, and ancillaries).

These three scopes and these two abstraction strategies allow one to construct five representations of the tangible. Let us note that the first abstraction strategy is not applicable to the first scope: indeed, formally, because the scope contains elements relating to a single medical device, these cannot be grouped with those belonging to other devices so as to be indistinguishable ($abstract^+$ is not applicable). In other words: it is not possible to consider a scope centered on a specific device when the abstraction level does not allow one to distinguish different types of devices.

Below, table 1 shows a synthesis of these five possibilities with, for each one, the result of the evaluation of the tangible concerning the pertinence of the different technologies (RFID, Data Matrix codes, and barcodes).

Construction of the representation: example of a decrease in the level of abstraction

At the highest level of abstraction, all the technologies seem equally pertinent. However, when the level of abstraction is lowered (that is, when more details are considered), by distinguishing the three types of devices, differences in technological pertinence emerge. The evaluation of technological pertinence is not homogenous among the three different applications. It is therefore necessary to exploit a level of abstraction that allows one to distinguish explicitly between the three cases.

Impact of the scope on technological pertinence analysis

The analysis of the previous section is relevant for the smallest scope (cell 1), when each type of system is considered individually.

If we consider a hospital tracking all three types of systems (cell 3 – larger scope), it emerges that it would be easier for the pharmacy to use the same technology for all of its tracking. Thus, if RFID is used for other systems, then RFID is the most pertinent choice for the gas tanks as well.

Construction of the representation: example in which the abstraction level is increased.

There are three types of hospitals in France: public, private non-profit-making, and private profit-making.

The project's hospital partners could fall under any of these three categories. The scope would include hospitals from all three categories. However, this distinction adds no value in the context of the applications we consider. Consequently, it is possible to use a level of abstraction that considers "hospitals" with no further distinction in status.

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capacity of the evaluation process and particularly in terms of the risk of cognitive overload for the participants.

[3] DGCIS : *Direction Générale de la Compétitivité, de l'Industrie et des Services* – linked to the *Ministère de l'Économie, de l'Industrie et de l'Emploi*

Increasing scope

	Detailed project with 3 types of devices	Generic problem
Hospital and its suppliers	**(5)** Same as cell 3 - In addition: check compatibility with supplier constraints and tools. - Ancillaries: if there is a national database integrating the information, the Data Matrix codes is sufficient. - Medical gas tanks: can we use the same markings for both industrial tracking and internal hospital use? - Regulations demand that supplier mark their tanks with Data Matrix codes.	**(6)** Same as cell 4 - In addition: check compatibility with regulations applicable to suppliers - check compatibility with industrial tracking system used by supplier
Hospital	**(3)** Same as cell 1 - In addition: issue of consistency of applications within the same hospital - If hospital sets up RFID for ancillaries and surgical tools, then RFID is preferable for gas tanks as well.	**(4)** - RFID or Data Matrix codes or barcodes
A device in particular	**(1)** - Ancillaries: only RFID - Surgical instruments : RFID preferred for its resistance and legibility - Medical gas tanks : RFID vs. Data Matrix codes	**(2)** - Not applicable

Increasing level of abstraction

Table 3: Synthesis of the technological pertinence analysis for six representations characterized by the pairing (abstraction level, scope).

Analysis in terms of scope and abstraction of an ambiguous exchange between partners

In the medical gas tanks project, an industrial producer of medical gas declared to a hospital staff member that RFID technology could not be used because the metallic environment made it difficult to use RFID (the gas tanks are metallic).

This explanation is based on an element of the m_{A_S} and it is correct: indeed, a metallic environment complicates the propagation of electromagnetic waves. However, if the industrial environment of this provider is highly metallic, the environment of a hospital is not.

The hospital staff member considered as his scope elements relating to application within his hospital, whereas the producer used a scope that included his own industrial setup. The producer and the hospital staff member were both right, but they were not talking about the same tangible reality.

Scope is ultimately insufficient

For the integration of RFID transponders into surgical instruments, a proven but not normalized technology was considered and included in the scope S. No other technologies were considered. Unfortunately, the only supplier of such transponders ceased its production during the course of the project. Then the project had to be stopped until another solution could be found.

If a search for alternative solutions had been undertaken and integrated into the scope of the representation of the tangible during the evaluation phase, it is possible that the evaluation of the project would have led to a different solution in the first place, reducing the dependency on one provider.

6 DISCUSSION

A representation of the representation

Our approach tried to formally represent the space of representations of the tangible. In doing so, we show that by varying the scope of a representation or its structures of abstraction we obtain different evaluation results.

The underlying idea is to make choices explicit at the time of the definition of the representation of the tangible considered. The explanation for these choices should make it easier to control the construction of this representation of the tangible. It should also foster discussion between actors of a same project. Making a choice explicit sheds light on the possibility of other choices. Why were these not chosen?

Finally, to make explicit the level of abstraction at which the evaluator places himself allows one to make explicit the field in which the evaluation can be used. Did the evaluation cover a service of the hospital? The hospital as a whole? All hospitals? These questions are critical when examining the possibility of transposing the solution to other contexts.

Towards methods aiding the construction of a representation

One of the benefits of formalizing the notion of representation of the tangible, and specifically the space of representations, is to be able to explore this space more efficiently. We believe it can lead to quasi-systematic exploration methods that could help teams conduct evaluations for a project. Starting with an initial representation, the idea is to identify neighboring representations and to assess their pertinence. Concretely, the goal is to, on one hand, start with a given scope and include new elements or exclude existing elements; on the other hand, start with abstractions and group them into higher abstractions or split them into lower abstractions. These simple iterative algorithms will allow us to explore the space of representations from neighbor to neighbor.

Abstractions and abusive generalizations

We define an abstraction as the grouping of elements within a considered scope. In the field, certain abstractions are supported by a generalizing dynamic: from a number of cases studied, the result is generalized to other similar cases. In our formalization, this is equal to proceeding simultaneously to an extension of the scope (to include all the similar cases) and to a grouping of all the elements into an abstraction.

These generalizations are useful. Yet they can be unfounded (if the elements considered are not representative of the whole). Our formal framework is not able to transcribe these aspects. However, these aspects can have an impact on the quality of a subsequent evaluation.

Arbitrary choices for our formal framework

In this formalization of representation, we have used a set theory approach, because on the one hand its expressivity is satisfying, and on the other hand it is easily understandable. In particular, links between cluster, set, and abstraction are easy to express. Nevertheless, other formalizations could work as well. It seems to us possible to use generative grammars, by associating the alphabet to our scope, grammatical rules allowing us to build structures of abstraction. Galois connection and the formal concept analysis, including the ability to manipulate “concepts” both through their extension and their intension, seem interesting to apprehend our notions of scope and abstraction. Future studies could explore whether these formalizations are adequate for our approach.

7 CONCLUSION

From a literature revue of the issue of *ex-ante* evaluation of IS investments, we have shown that the various approaches tend to consider that the object under evaluation is a given, even though this question is far from being obvious from an empirical standpoint. In order to work on this step – the construction of the representation of the project to be evaluated – we propose a new conceptual framework: the space of representations, made up of two dimensions – the scope and the level of abstraction. Our approach is inspired by works in Artificial Intelligence. We have designed a formal definition of this space in order to provide us with a non ambiguous and rigorous tool.

We showed the relevance of this approach on an empirical study: a collaborative RFID project in the healthcare domain. We show the impact of representation in the assessment results, as well as how Scope and Abstraction help us to structure our analysis of different representations.

In future works, this framework should make it possible to address with greater rigor the issue of *ex-ante* evaluation but also to enhance the deliberative process of project management.

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