Technology Innovation – A Reference Model for Decision-Making Processes

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Abstract. This paper presents a reference model to support technology innovation decision-making processes. Based on decision theory, Information Technology (IT) governance principles, practical tools and a developed case study, we propose a reference model to guide IT leaders through decision-making processes, enabling them to make and justify rational decisions related to IT investments. The model includes the foundations, elements and activities of such processes. The main contribution of this work is to provide a tool to enable decision makers to align IT investments and architectures with business goals by raising their awareness on the various elements associated and influencing IT decisions.

Keywords: Decision-Making Process; Technology Innovation; Decision Theory; IT Governance

1 Introduction

People's daily life is being deeply transformed by technology. Smartphones, tablets and social networks are almost embedded in daily activities of e-literate persons. Similar transformations are also evident in enterprises. In a networked eco-system, enterprises are forced to rely on technology innovation not to lose competitive advantage; otherwise, business opportunities are taken by innovator competitors.

The range of new technologies being adopted by organizations is broad. According to [1], a survey completed by 382 respondents involved in technology innovation in organizations with 50 or more employees indicated that tablets represent one of the fastest-growing new technologies being adopted. However, they distinguish between the first tablets and the current definition, including the form factor, operating system approach and connectivity model. Table 1 shows 2011 most emergent technologies.

Table 1. 2011 Most Emergent Technologies

	Under investigation, testing or being used	In testing stage
Tablet devices	93%	31%
Unified communications	84%	27%
Private clouds*	79%	25%
IPv6*	75%	29%
Location-based apps	65%	21%
predictive analytics*	63%	20%
4G wide-area services*	60%	16%
Crowdsourcing*	59%	19%
Context-aware computing	93%	31%
Context aware computing	56%	18%
Semantic Web	53%	17%

* Also 2010 most emergent technology

The survey also shows a high overall level of technology activities in all the processes, a high level of active testing relative to the number of current deployments, or both. The survey shows that new technologies do exist. However, is it enough the fact to be an "emergent technology" to decide on its adoption?

Any Chief Information Officer (CIO) or person responsible for an IT department, regardless whether in the academic, private, or public sector, faces and is required to address issues related to the constant and speedy evolution of technology. As their responsibility is to deliver value through investments in ICT, their decisions related to ICT products and services must be based on the best alternative for the offered services and the expected quality of service. Such main decisions should follow a rigorous decision-making process.

Several issues affect the IT-related decision-making process. On one hand, deciders know about the organization mission, goals, resources and culture. On the other hand, they can be easily impressed by new trends – it is very common that CIOs are IT savvy, willing to acquire the latest IT products and services. Therefore, the relevance for them to make rational IT decisions – those that can be easily justified.

Addressing the problem described above, this paper proposes a reference model for IT-related decision making processes. Based on literature review and a case study describing an imaginary situation, we identify typical scenarios faced while making IT-related decisions, particularly decisions related to technology innovation. The reference model identifies main process elements and activities as well as their relationships. The main contribution of the paper is a reference model guiding decision-making process for technology innovation.

The rest of the paper is structured as follows. Section 2 presents related work, including theoretical foundations and practical tools. Section 3 develops step-by-step a case study illustrating the decision process elements and activities. Section 4 introduces the proposed reference model. Finally, conclusions and future work are discussed in Section 5.

2 Related Work

The following two sections present the theoretical foundations of this work and practical tools used for IT-related decision-making processes.

2.1 Theoretical Foundations

In 1947, Herbert A. Simon [2] introduced how organizations can be understood in terms of their decision-making processes. Enabling him to receive the Nobel Memorial Prize in Economics in 1978, his seminal theory on decision-making processes in economic organizations is based on a classical, ideal, and rational model of human decision-making processes. His studies shown that the rationality of a decision must be defined using appropriate adverbs, such as objectively, subjectively, consciously, deliberately, organizationally, and personally.

Decision theory is concerned with identifying the alternatives, uncertainties and other relevant issues related a given decision, such as its rationality, and the process for obtaining the optimal decision. The theory gives some tools that can help decision makers to organize their reasoning, and to arrive to a justified outcome. The various elements of the decision-making process include [3]: 1) the decider, 2) the objectives, 3) the universe, 4) possible alternatives or action courses, and 5) variables.

An administrative decision is correct when it chooses the appropriated means to achieve the objectives [1]. For making the choice, several alternatives and their related consequences are being assessed. Usually, such process is oriented towards the careful analysis of consequences. According to the decision theory [4], the steps of the decision-making process include: 1) listing all possible alternative; 2) identifying all possible consequences, for each alternative; 3) following a business-oriented approach, assigning a comparative value, for each alternative; and 4) making a decision based on the most valued alternative. The process is illustrated in Figure 1.

Specifically related to IT processes, IT Governance is a framework describing the leadership and organizational structures and processes that ensure that the organization’s IT sustains and extends the organization’s strategies and objectives [5]. IT Governance principles makes IT leaders aware that technology is a medium to achieve business goals and supports them in making rational investments on IT.

In addition, some related work discusses whether financial resources dedicated to IT should be considered an investment or a waste [6][7].

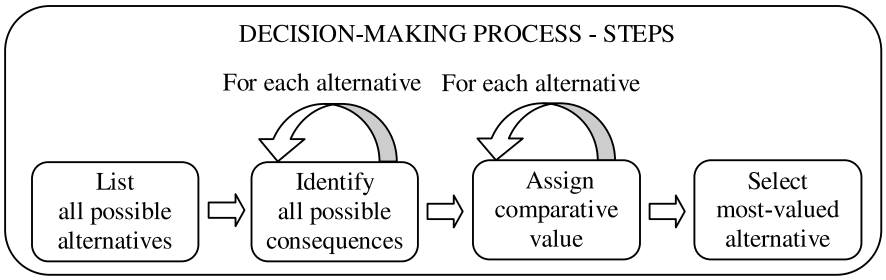

Figure 1. Decision Theory - Decision-Making Process Steps

2.2 Practical Tools

Various practical tools exist to assist IT leaders and decision makers in guiding and supporting them to make IT decisions. Some of the most relevant include the following. The Control OBjectives for Information and related Technology (COBIT) [9] is framework supporting IT process management. COBIT describes the central role of ICT in creating value for business. The Information Technology Infrastructure Library (ITIL) [9] is a set of practices for IT service management. ITIL practices can be used for aligning IT services with organizational needs. ISO standards [11] defines guidelines for process quality assurance (ISO 9000) [11] and information security systems management (ISO 27001) [12]. In the USA, the Sarbanes Oxley (SOX) Act [13] is a law ensuring accountability for public company boards, management and public accounting firms. Finally, the NYSE standards [14] provide a set of corporate governance standards.

3 Case Study

This section presents a case study, developed step-by-step with increasing levels of complexity illustrating the decision-making process and its main elements. The case study refers to a technology innovation-related decision-making process.

3.1 Problem Description

The ABC Company has a heterogeneous Executive Board, including some members exhibiting a conservative approach towards technology innovation, while other member are IT-savvy and have no apprehension to assume risks provided the Company can lead in service provision. A new initiative related to technology innovation will be discussed by the Board members. The Board will make a decision based on the recommendation and action plan formulated by the Company CIO.

In the following sections, we introduce the decision elements considered by the CIO to analyze the alternatives and decide the most appropriate to be recommended to the Board, and we present two possible scenarios for the decision-making process.

3.2 Decision Elements

Based on Decision Theory, in order to make a decision to, the CIO should reply the following questions: 1) who receives the benefits; 2) what are the associated risks; 3) who bears the risks; and 4) what are the required resources; among others. For answering such questions, decision elements should be identified. Below, we illustrate the decision elements for our case study.

The Decider: For the purpose of the case study, which aims at studying and analyzing all possible alternatives related to the decision, the Company CIO is the one playing the decider's role. Although, in reality, the CIO will be recommending an alternative to be adopted, and the final decision will be made by the Board of the Company. A decision-making process will help the CIO to analyze the various alternatives and be able to recommend the best solution, justifying it with rational arguments and evidences.

The Objective: The objective is associated with a future state – the state that the Decider wants to achieve. In this case, the objective is "to innovate and to achieve given service- and business-oriented goals by improving communication".

The Universe: Operating in a very competitive market, the company strongly pursues to have a leading role. While technology innovation is demanded for the Company to be ahead of competitors, at the same time is associated with high risks. Any innovation considered for adoption, either related to the Company's products or services, it must be reliable and give reasonable warranties of security. As an example, a fault produced by an innovation on a service offered on a 7x24 basis, could produce significant losses.

In our case study, the universe is the technological solution to be adopted – new communication services, as well as the resources involved - people, IT infrastructure, data, software applications, business processes and services.

The Alternatives or Courses of Actions: Possible alternatives or courses of actions should present basic properties [4]: 1) *Feasible* – their implementation should be possible; 2) *Aligned* – alternatives should be aligned with the decider's objectives; 3) *Exclusive* – the set of alternatives should be mutually exclusive, without or with minimum overlaps; and 4) *Exhaustive* – the set of alternatives should be complete, avoiding any omission of a possible course of action.

At this stage, we envision two possible alternatives fulfilling the properties: S1) a technology innovation is adopted; and S2) a technology innovation is not adopted.

The **Variables** are the universe elements. Such elements should be analyzed considering various perspectives and at various levels of refinement, while assessing the added-value associated with them, as shown in the next scenarios.

3.3 Scenario 1 – A Simple View

For the simplest scenario, we identify two variables: 1) V1 – technology innovation is aligned with the business objectives; and 2) V2 – technology innovation is not aligned with the business objectives. The degrees of the variables are discussed below.

After identifying the variables, the added-value that each alternative brings to the organizations should be assessed, considering the added-value that the solution could bring to the offered services and to the quality of such services. A decision matrix is built, showing the various identified alternatives (as rows) and the variables (as columns). The intersecting cells are completed with the value propositions identified. Table 2 shows the decision matrix for this scenario.

Table 2. Scenario 1 – Decision Matrix

Objective: To innovate and achieve given service- and business-oriented goals		
	Variable V1 technology aligned	**Variable V2** technology not aligned
Alternative S1 solution is adopted	added value is created	added value is not created wasted technology investment
Alternative S2 solution is not adopted	lost of opportunity	there is no investment

The next step is to convert the decision matrix into a benefit matrix, by quantitatively assessing the identified added-value propositions for each alternative/variable. If quantitative assessments are available – i.e. the probability of the variable to occur, the matrix is filled with such probability figures. Otherwise, value propositions can be estimated through a numerical value, following a ratio scale [16]. Table 3 shows the benefits matrix.

Table 3. Scenario 1 – Benefit Matrix

Objective: To innovate and achieve given service- and business-oriented goals		
	Variable V1 technology aligned	**Variable V2** technology not aligned
Alternative S1 solution is adopted	added value is created POINTS: 2	added value is not created wasted technology investment POINTS: -2
Alternative S2 solution is not adopted	lost of opportunity POINTS: -2	there is no investment POINTS: 0

Following, the alternatives can be assessed following two different approaches: 1) *Absolute Optimistic,* defined by Hurwicz [17] – selecting the variable corresponding to the column with the major value (V1 – technology aligned; value 2), and then the alternative presenting the best value (S1 – solution is adopted; value 2). The assumption of the approach is that the major value is directly related to the major benefit; and 2) *Pessimistic,* defined by Wald [18] – selecting the variable corresponding to the column with the minor value (V2 – technology is not aligned; value -2), and then the alternative presenting the best value (S2 – solution is not adopted; value 0), meaning that in the worst scenario, the best alternative is chosen.

However, in real situations, variables tend to be complex. For example, the meaning of delivering value could be argued. For example, value delivery is a relevant research area in IT Governance and one of the five IT Governance areas [6][9]. The following questions could be considered when analyzing value: 1) What is the real value of technology? 2) Is it possible to differentiate between delivered and perceived value? 3) What is the difference between economic value and perceived economic value? The perceived value depends on its attributes – i.e. the client's own experience, the client's image about the service, etc. In ITIL [10], the value comprises two components: utility/functionality and warranty. Utility refers to the purpose, is directly associated to the benefits, in the sense that differentiates the benefits or advantages over other alternatives. Warranty refers to its use and assesses features like: availability, continuity, and reliability. Finally, value should be defined by the company objectives, usually focusing on customers' expectations.

An essential part of the decision-making process is to define a set of variables representing the universe and to analyze each of them according to their real value. As an example, considering the variable "the technology innovation is aligned with the business objectives" is ill-defined. There is a lot of subjectivity in the phrase, since the variable is defined at a very high-level of abstraction. Variables like that should be refined into a group of variables that better describe the expected world.

3.4 Scenario 2 – A Refined View

As explained above, variables should be refined and in the process, more variables could be added, for example: 1) conducting training to support the adoption of the new technology, 2) outsourcing processes or keeping them in-house; 3) reassigning staff working in other projects or hiring new staff; 4) buying new hardware or renting external processing capacity; etc. In the process of adding variables and alternatives, decision-making scenarios get more and more complex. For managing complex scenarios, decision trees are considered an appropriate tool.

In the following scenario, we illustrate how to refine our objective, alternatives and variables. The decider and universe remain unchanged.

Objective – To improve the electronic communication with customers through email services

Alternatives – S1) to use e-mail services on the cloud, and S2) to rely on a proprietary mail server and proprietary software for mail clients

Variables: V1) reliability of technology; V2) contribution to improve the company image as innovator and market leader; V3) service support of the solution over time

For keeping the case study simple, we keep only the above variables. However, the level of complexity can rapidly increase. Usually, each alternative raises a new set of variables. For example, alternative S1 – use of e-mail services on the cloud, could raise the following set of variables: V4) security of customers' email addresses, V5) privacy issues about information on customers' purchases contained in emails stored in the cloud; V6) national and international regulations about the provision of cloud services, etc.

The alternatives and variables explored in this scenario are shown in Table 4. Considering the probabilities estimated by the Company CIO, the benefits matrix is shown in Table 4.

Table 4. Scenario 2 – Benefit Matrix

Objective: To improve electronic communications through email services			
	Variable V1 reliability	**Variable V2** market leader	**Variable V3** support services
Alternative S1: Cloud e-mail services	0.8	0.25	0.1
Alternative S2: Proprietary e-mail services	0.3	0.4	0.3

Following the absolute optimistic approach, the CIO will choose the column with the highest value (V1 – reliability, value 0.8), and the alternative with highest value (S1 – cloud email services). According to the pessimist approach, the CIO will choose the column with the lowest value (V3 – support services, value 0.1) and the alternative with the highest value (S2 – proprietary e-mail services, value 0.3).

Another approach – *Relative Optimistic*; can be considered if one of the variables is assessed as more relevant than the others. To follow the approach, the Decider assigns weight values (α) to each of the variables. The values should be no less than 0 and no greater than 1 ($0 \leq \alpha_i \leq 1$), and their sum should be equal 1 ($\sum\alpha_i = 1$). The weight values should reflect the relevance of each variable. Following, a numerical value is calculated for each of the alternatives as the sum of the benefit value of each variable multiplied by the corresponding variable weight value. The alternative to be selected is the one with the highest value. As an example, assuming reliability as the most important value, the following weight values are assigned: for V1, $\alpha_1 = 0.5$; for V2, $\alpha_1 = 0.3$; and for V3, $\alpha_3 = 0.2$. For each alternative, the value is calculated:

$$\text{S1-Value} = 0.5*0.8 + 0.3*0.25 + 0.2*0.1 = 0.4 + 0.075 + 0.02 = 0.495$$

$$\text{S2- Value} = 0.5*0.3 + 0.3*0.4 + 0.2*0.3 = 0.15 + 0.12 + 0.06 = 0.33$$

Thus, following a relative optimistic approach, the CIO should choose alternative S1.

4 Reference Model

Based on our literature review and the developed case study, we propose a reference model for technology innovation-related decision-making processes. The model is depicted in Figure 2 and the elements are explained as follows. A `Technology-Innovation Decision` is made by a `Decider`, within a given `Universe`, to achieve a specific `Objective`. For making the decision, several `Alternatives` are considered. Usually, each alternative has many associated `Variables`. For each pair of alternative-variable, the added value that they bring to the organization is identified – `Value Proposition`; and the corresponding `Benefit` is assessed. For analyzing alternatives, various `Assessment Criteria` can be applied; such as `Absolute Optimistic`, `Relative Optimistic` and `Pessimist` approaches. Finally, one alternative is selected as the `Decision` made. The previous steps has been summarized in a `Decision-Making Process`, comprising four tasks: 1) `List Alternatives`, 2) `Identify Variables`, 3) `Assess Alternatives`, and 4) `Select Alternative`. In addition, several theoretical (`Theory`) and practical (`Practice`) tools and frameworks are available to support decision making processes, such as the `Decision Theory`, `IT Governance`, `COBIT`, `ITIL`, `ISO Standards`, `SOX` and `NYSE`.

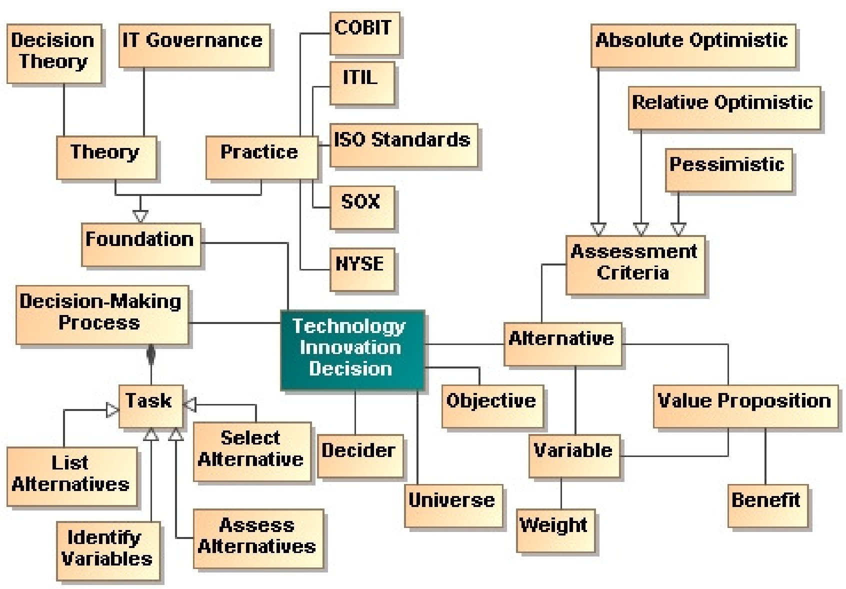

Figure 2. Reference Model for Technology Innovation Decision-Making Process

5 Conclusions

This paper presented a reference model for technology innovation decision making processes. Based on literature review, comprising theoretical work and practical tools, and a stepwise developed case study, we identified the main stages and main elements of an IT-related decision-making process. The main scientific contribution of this work is to present the first release of a proposed reference model for technology innovation decision-making processes. The aim of the model is to provide a rigorous process to support IT leaders in making and justifying IT-related decisions.

Due to the initial stage of our research work, the proposed model presents some limitations - not considering risks as one of the elements in the decision-making process and the regulatory framework typically associated with technological projects. Our future work includes expanding the reference model to address the identified limitations, to explore the relationships between the various model elements as well as between the theoretical and practical foundations for the decision making process and the model elements.

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