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Decisions Sustainability Evaluation System — Software Architecture

Abdelkerim Rezgui, Jorge Marx Gómez
(Carl von Ossietzky University of Oldenburg, Germany)

Abstract: This paper presents a new concept enabling the evaluation of decisions based on their sustainability. It forms a bridge between decision preparation and decision-making. The importance of evaluating decisions is that stakeholders learn from their past choices and can improve the quality of their decisions. In this work we introduce the green decision-making process steps and present a software architecture that enables making, tracking, validating and evaluating decisions sustainability through a computer-based system.

Key words: decision evaluation; green decision-making; decision sustainability; EMIS; BI; DSS
JEL code: M150

1. Introduction

The industrial revolution, the space conquest, electronics, computers, medicines, internet...etc., all these are impacting our planet. They are causing pollution (air, soil and water), resource depletion and climate changes (global warming/dimming, flooding, sea level rise…). Governments and non-government organizations are pushing stakeholder to give more and more attention to the environment by establishing rules and guidelines. In order to meet this rules and guidelines decision makers are using specific computer-based systems like decision support systems and environmental management information systems. Those systems play a major role in delivering information about processes and operations of organizations in user-friendly interfaces in form of reports and dashboards. Stakeholders review the performances indicators given by those systems to understand their situation and make decision with the objective to enhance or maintain achievement level. Of course the classical decision support systems are essential in delivering information and preparing decision, but they lake on delivering information about the decision itself. They miss a very important kind of information the decision evaluation. Even if they will have evaluation, we will get many points of view, which may be different. For instance a decision can be evaluated as poor, from ecological point of view but from an economical one the decision can have a positive impact. From a third point of view the social one it can be acceptable. All these motived the elaboration of a system that forms the bridge between the decision preparation and the decision-making and enables the evaluation of the sustainability of the decision. We are introducing a new concept called Green Decision-Making Process through the evaluation of decisions sustainability. In this work the process

Abdelkerim Rezgui, Dipl.-Wirt.-Inf. (FH), Very Large Business Applications, Carl von Ossietzky University of Oldenburg; research areas/interests: business information systems, decision evaluation, sustainability, decision support systems, business intelligence. E-mail: abdelkerim.rezgui@uni-oldenburg.de.
Jorge Marx Gómez, Dr.-Ing.habil., Professor, Very Large Business Applications, Carl von Ossietzky University of Oldenburg; research areas/interests: very large business applications, business intelligence, interoperability and environmental management information systems. E-mail: jorge.marx.gomez@uni-oldenburg.de.

and the software architecture will be presented.

The organization of this paper is as follow: after a short introduction, section two gives the main background information about environmental management information system. In section three the advantages of using quality management systems and decision support systems to enable environmental management are presented. Section four shows the green decision making process. After that, the software architecture for the decision sustainability evaluation system with its components, sub-components and the interactions between them will be explained. The paper then concludes with a brief summary regarding the contribution of this content and presents future direction.

2. Environmental Management Information Systems (EMIS)

Boosted energy consumption, increased energy costs, environmental sensitivity, and government rules have motivated the establishment of concepts and tools to support green strategies through the management of environmental information (Rezgui & Marx Gómez, 2016). Many countries are working on a target in reduction of greenhouse gas emission. In Europe, for instance, UK and Germany has set goals to reduce carbon dioxide (CO_2) emissions respectively by 60% (in the year 2050) and 40% (in the year 2020) (Kannan, 2009; Röttgen, 2010). In order to achieve such environmental goals, stakeholders need to have adequate systems supporting the management of environmental information. As result Environmental Management Information Systems (EMIS) have become increasingly important in both the academic and the business communities over the past two decades. Industry studies have highlighted this significant development (Marx Gómez, 2004; Rautenstrauch, 2013).

The objectives of those systems are protecting and preserving natural resources, preserving the overall balance and rationalization of energy consumption. They give stakeholders the ability to asses, optimize and report on the current effects of their processes and operations on the environment. Those effects may be measured through a particular type of performance indicators, called environmental performance indicators (EPIs) (Jamous, Schrödl, & Turowski, 2013). They allow also the environmental performance examination of individual projects, products, departments etc. Thus may engage steps of actions, if needed, in order to rectify the deviations from the targets. The actions are the management of decisions. So decision maker are the first responsible of monitoring EPIs and deciding which action should be made. Trying to assure a high level quality of their organization’s products and/or services and respecting the environment, managers should follow standards and guidelines by using a sophisticated quality management system (QMS). This can help the coordination of activities in an organization to control and improve the efficiency and effectiveness of its performance (Petkovska & Gjorgjeska, 2013).

3. Quality Management Systems

QMS is a structured collection of policies, procedures, processes and associated responsibilities that are integrated whereby they work as a single system. This makes it easier for organizations to achieve the required quality. The policies and procedures need to be documented, although they do not have to occur in paper documents. They have to be stored and maintained in an electronic format to access and manage them easily. According to the International Organization for Standardization (ISO), there are seven pillars, the quality management principles (QMP), to an efficient QMS (see Figure 1). Customer focus, Leadership, Engagement of people, Process approach, Improvement, Evidence-based decision making, Relationship management (ISO, n.d.).

In this paper, we will focus on the Evidence-based decision making principal QMP6.

The standard ISO 9000:2015 suggests that in order to be compliant with QMP 6, a QMS should be capable of measuring and monitoring key indicators. It should also make all data needed available to the relevant people. Ensure that data and information are sufficiently accurate, reliable and secure. Analyze and evaluate data and information using suitable methods. And finally, make decisions and take actions based on evidence, balanced with experience and intuition.

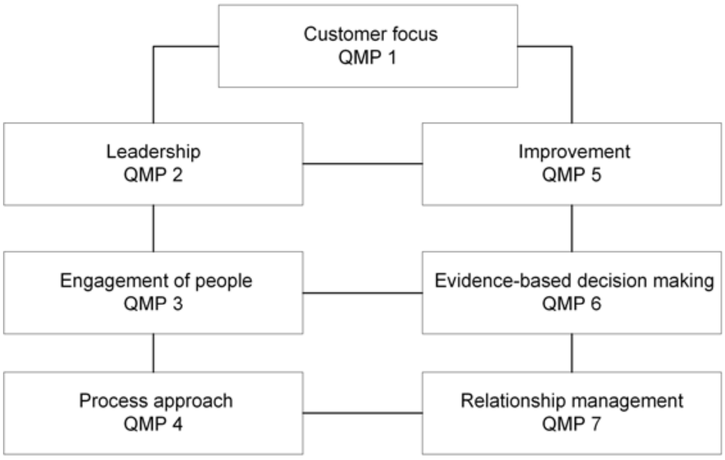

Figure 1 Quality Management Principles based on ISO 9000:2015

In fact, decision support systems (DSS) as information technology-based systems that enable gathering, centralizing, analyzing data for decision-making purposes, can be seen as an adequate match for QMS requirements. They are based on key indicators and present the results in a way that the user can easily understand and act accordingly. DSS play a critical role in ensuring that decisions made by organizations are helpful in achieving strategic goals and specially the environmental ones. The main advantages of such a system are simplicity, clarification and control. Process performance should be measured through indicators and continually controlled and improved. All the above demonstrate the need to integrate a DSS into every QMS. This enables managers to act and change their processes and/or procedures to meet the expected target easily.

The problem with typical DSS is that they are fundamentally designed and optimized around analyzing and presenting information with the objective to support stakeholders preparing decisions (Rezgui & Ben Maaouia, 2016). Of course, this role is very important but not sufficient, since the decision making process is not only preparing decisions, but also making and evaluating decisions. Information about the decision itself and its sustainability are not included. Experience and intuition are neither stored nor shared; they are only in the mind of individual managers.

4. Green Decision Making Process

There have been many researchers trying to deal with the decision-making process. According to Turban et al., it is a process of choosing among two or more alternative courses of action for the purpose of attaining one or more goals (Turban, Sharda, & Delen, 2011). For others, it still remains an invisible process, only thoughts and operations inside the mind of managers. It is very difficult to understand, document or improve a decision process. For many organizations, a managerial decision is treated as a “black box”, subject to neither explanation nor review. The human decision-making process is invisible (March, 1987; Davenport, Harris, David, & Jacobson, 2001; Kahneman, 2003; Lindvall, 2013). Whereas, Simon points out that decision making includes four principal phases: finding occasions for making a decision, finding possible courses of action, choosing among courses of action, and evaluating past choices (Simon, 1977).

He called the first phase intelligence activity. The second phase, design activity, involves inventing, developing, and analyzing possible courses of action. After that, comes the third phase, called choice activity, which consists on electing a particular course of action from the available courses found while performing the design activity. Finally, evaluating the choices already made, called the review activity. So far, the traditional decision-making process deals only with the first phase Simon cited, the intelligence activity. Humans perform all three phases that come after, without any kind of assistance from the system. In fact, DSS is defined as the management of flows of data, to transform it into information, and then into useful knowledge. The system automates the knowledge generation and the human makes the decision outside the system. As we previously mentioned, ISO 900:2015 indicates that the decision must rely on evidence, balanced with experience and intuition. Evidence comes partially from information, and knowledge available in the DSS but the intuition and the experience are exclusively in the manager's head. Our approach proposes to extend the actual DSSs with a new component: the decision evaluation, in order to fill the gap between the ISO recommendations and the actual QMS. This will allow an increased ability to review, challenge and change opinions and decisions, and an increased ability to demonstrate the effectiveness/ineffectiveness of past decisions through the measurement of their sustainability.

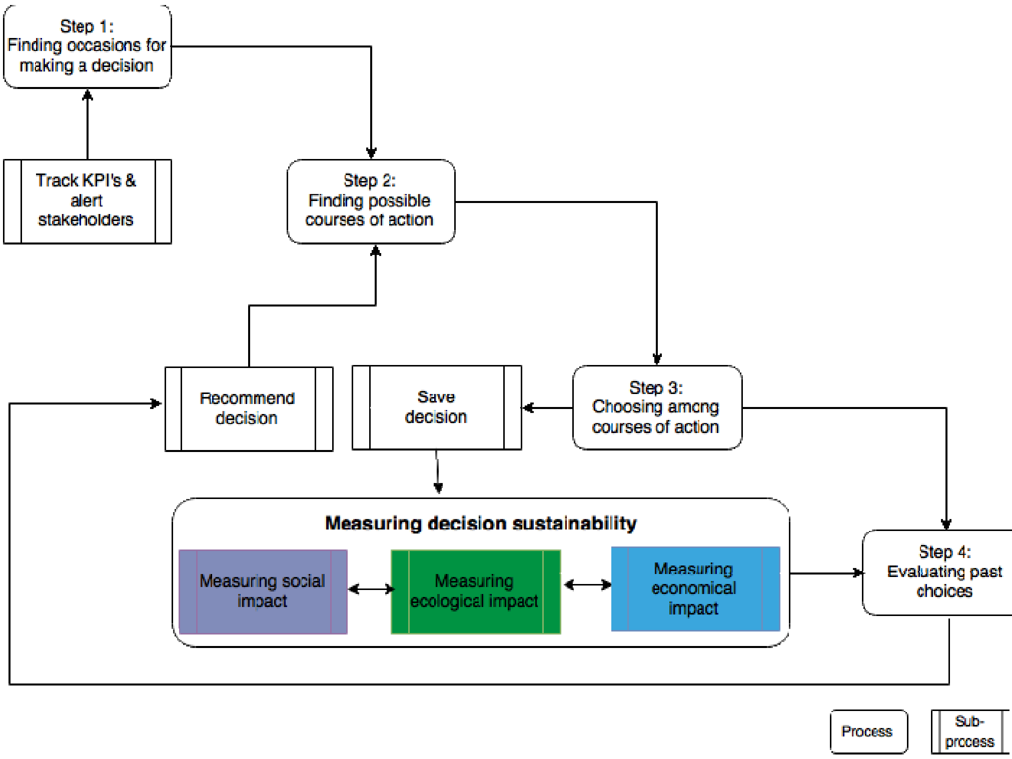

Figure 2 Green Decision Making Process

(Rezgui & Marx Gómez, 2016)

All this motivated the idea of treating the management of decisions over time and through all phases. Such management includes storing, evaluating sustainability, and ranking of decisions. These decisions will be stored in a central repository that serves as a core of the new green decision support system. The evaluation will rebuild the harvested knowledge in a way that is simple to use. Any company will see its decisions sustainability evaluation in the form of a decision dashboard in which each single decision taken in the past can be seen with its reputation.

The proposed process, the green decision making process (GDMP) will be explained in this section. As shown in Figure 2 our approach extends Simon's process with pre-and post-activities in order to meet the ISO recommendations and enable a decision-making based on evidence balanced with experience and intuition.

While monitoring the values of the different EPIs/KPIs, the user can find an occasion for making a decision if there is a deviation from the expected trajectory. Here, we can consider that the trigger of Simon's process (finding occasions for making a decision) occurred. To be able to achieve the next phase (finding possible courses of actions) we need to rely on experience. This can be possible only if the decisions taken in the past are available and evaluated. The pre-activity, "recommend decision" is responsible for making the previous decisions available and presenting their sustainability evaluation. Once the stakeholder gets several options well described with their ecological, economical, and social impact, he will be able to choose among them (step 3: choosing among courses of action). If none of the recommended actions is suitable for the issue that needs to be resolved, the user can create a new decision. In both cases, the decision will be stored. Based on the user responsibility the decision can be saved directly without any validation or his/her manager should review and validate. The post activity "save decision" includes saving all related information: the decision description, the decision maker, the decision time and goals to achieve by applying this decision. Based on Turban et al. (2011), making decisions should occur to achieve one or more goals. A deadline should be also fixed for these goals in order to track their achievement degree.

The selected goals are arranged by domain (logistics, human resources, sales, production…etc.). For each domain indicators are apportioned into three categories: economical, ecological and social. The goals can be set based on target values for one or many types of indicators. Regardless of the type of the selected indicators (economic, ecologic or social) they should be improved by the decision, the other ones in the same domain will be tracked and evaluated (enhancement or weakening). So all pillars of the decision sustainability will be measured automatically.

In order to transform this process into a sophisticated system, several researchers recommend a design of software architecture as a viable approach. "They guarantee the prosperity of software (systems) by defining sets of concepts as principles that guide analysis of specifications, designs, implementation, maintenance and evolution of software systems" (Kateule & Winter, 2016). In the next section the software architecture for the GDMP will be presented.

5. Software Architecture

In this section the common language, standards, specification and support for the validation of the proposed solution will be explained through presenting the software architecture. Based upon Bass et al. (Bass, Clements, & Kazman, 2003), we can define the software architecture as "the structure or structures of the system, which comprise software elements, the externally visible properties of those elements, and the relationships among them". Figure 3 illuminates the decision evaluation system software architecture with its components, sub-components and the interactions between them. It is an enterprise solution that enables decision-makers to make, track, validate and evaluate decisions through a computer-based system. Any system developed to support decision evaluation is expected to consider the following components.

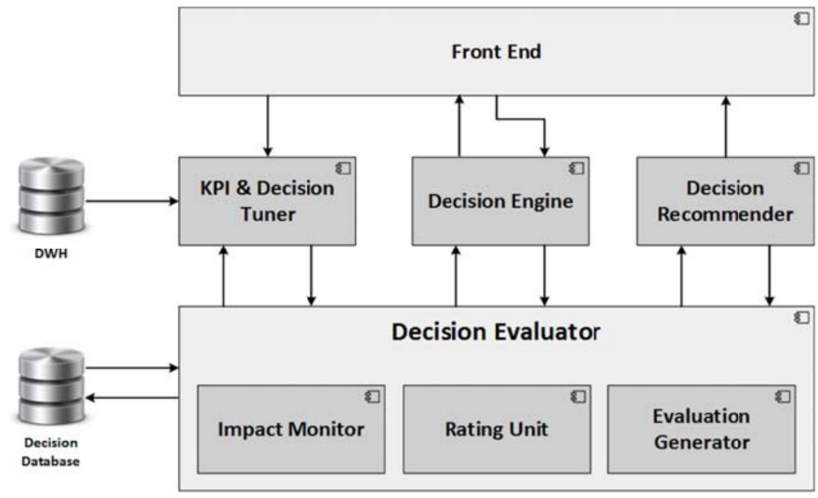

Figure 3 Decision Evaluation Reference Architecture

The Front End component is the primary interface with which the user will handle. It is responsible for presenting the sustainability information and enabling users to interact with the system. The interaction between the user and the system is assured through commands. Each command is used to assume one of the following activities:

- Login/Logout
- Enter/Update software parameters
- Access to KPI Matrix Dashboard
- Access to Impact Dashboard
- Access to Decision Evaluation Dashboard
- Make decision
- Validate decision

In our system the data management and storage will be assured through two main databases, namely the data warehouse (DWH) and the Decision Database. In order to abstract the retrieval of data from the source, data access objects (DAOs) are used. They separate the data sources client interface from its data access mechanism. The problem with accessing data directly is that the source of the data can change. Based on the Core J2EE Patterns, the DAO completely hides the data source implementation details from its clients. Because the interface exposed by the DAO to clients does not change when the underlying data source implementation changes, this pattern allows the DAO to adapt to different storage schemes without affecting its clients or business components. Essentially, the DAO acts as an adapter between the component and the data source (Deepak, Crupi, & Malks, 2001). Independent of the data source technology used in the source system, our components are able to exchange data correctly.

The DWH is an external component wherein the organization's indicators are stored. This component is present in any QMS that uses a classical decision support system regardless of the technology and it represents the target object in the extract transform load (ETL), process which should be undertake with low load conditions, e.g., at nighttime (Jörg & Dessloch, 2009). In our approach, the DWH will be used as a source to obtain the list of indicators, their values and changes (enhancement or deterioration) over time. The Decision Database is used to store the given input by the user through the Front End component and the decision related information. We can split the information mainly into two categories:

- System information:
  - User (id, name, email, …etc.).
  - Authorization (responsibility, visibility and privileges)
- Decision information
  - Indicator (type, values, goals, relationship, domain…etc.).
  - Decision (id, description, maker, time, goal, sustainability evaluation, ranking)

The KPI & Decision Tuner has two main functions (1) generating, classifying (social, ecological, economical) and monitoring (enhancement or weakening) indicators and (2) generating the relationship between indicators and decisions. The Decision Engine component assures the decision management. The core functionalities of this component are summarized in Table 1:

Table 1 Decision Engine Functionalities

ID	Description
F1	Generate indicator list
F2	Classify indicators (social, ecological and economical)
F3	Build relationship between indicators and decision
F4	Assign goals to decisions
F5	Save decision
F6	Validate decision

After making decision the Decision Evaluator component starts the sustainability evaluation process automatically. This function is guaranteed through three sub-components: Impact Monitor, Rating Unit and Evaluation Generator. As initiated in this work, the evaluation is an essential step in the decision-making process to demonstrate the errors that may occur while making decisions (Karlsson, 2013).

The Impact Monitor sub-component is responsible for tracking the changes (enhancement or weakening) occurring in the indicator(s) since the decision is made to serve to second sub-component — the Rating Unit — with this data as its input. The changes that will be tracked are decision's direct and indirect related indicators. With direct related indicators we mean here the goals (in form of indicators) to achieve by applying this decision. Use case: a logistic manger of a retail services company decide to use shared transportation services with a neighbor company with the objective to enhance an economical indicator: the Average cost per product delivery (in €). The domain of the decision is the logistic domain. While evaluating this decision, of course after the deadline assigned by the decision manager, the system measure the enhancement or weakening of this economical indicator. With indirect related indicators we mean the tracking of other indicators in the same domain, the ecological indicators: Average transport energy consumption per product (in liters) and the Average carbon dioxide emissions per product transport (in g). The system monitors also the social indicator: Rate of cooperative engagement in transport. So system gives a complete overview about the decision and its sustainability evaluation.

The Rating Unit provides an automatic ranking of the decision taken based upon the given input from the Impact Monitor. Its output is the decision evaluation in the form of a numeric score through the most commonly used in a five-point balanced scale (Dillman, Smyth, & Christian, 2014) from very poor (0) to very good (5). The final sub-component — the Evaluation Generator — is responsible for generating an evaluation of the taken decision in the form of a user-friendly interface, namely the decision evaluation dashboard.

Jøsang states that the purpose of recommender systems is mainly to generate suggestions about resources that a user a priori is not aware of but would probably be interest in (Jøsang, Guo, Pini, Santini, & Xu 2013). In our approach, the decision recommender has the role of generating suggestions about decisions (the resources) for the end user based upon his responsibility.

We include the Decision Recommender component to provide decision makers with possible courses of actions (step 2 decision making process) and help them by choosing among courses of action (step 3). The listing is compiled after consultation of the Decision Evaluator component, and takes into account the sustainability evaluation of the decision. The fact that a decision received a favorable rate cannot therefore be regarded as a guarantee that it will continue to appear in this listing as first recommended action. Actions (or decisions) listed are formally based on actual situation and selected to be among the best available. Each listing is based on the rating given by the Rating Unit sub-component (the best at first) followed by a brief description of the decision, it’s characteristics and sustainability evaluation.

4. Conclusion and Outlook

Classical Decision Support Systems are primarily designed and optimized to deliver stakeholders with appropriate knowledge about their organizations. In this present work we present the advantages of using such systems as part of Quality Management Systems in the environmental domain. Following the analysis presented in this work we emphasize that decision support systems are dealing only with decision preparation and not decision making. The evaluation of decision (as general requirement) and the sustainability measurement (as specific requirement) are actually not supported. We discovered weaknesses when we tried to compare the state of the art in DSS with the recommendation of the ISO standard 9000:2015, such as the evaluation process. We note also that evidence-based decision-making balanced with experience and intuition is missed. The fundamental and helpful information about the decision (why, when, who, goals and evaluation) are neither stored nor shared. The proposed Green Decision Making Process presents the steps to follow while making decisions. Beginning from the trigger event to start the process (1) finding occasion for making decision followed by (2) finding possible courses of action, which occur based the recommendation and listing of old taken decision with their sustainability evaluation. Then based on this evaluation step three (3) choosing among courses of action is assured. This step is followed by an important activity saving decision. Finally the last step (4) is evaluating past choices, which occurs automatically via measuring the achievement degree of the decision goals and measuring the enhancement or weakening of the indicators in the same domain. The proposed software architecture of the decision evaluation system made the integration of a DSS for better quality management in the environmental domain more compliant with the evidence-based decision-making. With this new architecture, organizations could benefit from an improved assessment of process sustainability performance and ability to achieve objectives and thus an improved green decision-making process through learning from past decisions, allowing the ability to track, evaluate and recommend decisions. It also increased the ability to review, challenge and change opinions and decisions based upon experience as the effectiveness or weakness of the decision can be easily demonstrated through the sustainability evaluation process.

Future directions of this work are: the expansion of the concept to include sophisticated discretization algorithms in order to enable automating of few manual settings. Another potential extension of the concept is the integration of new social component with the objective to give decision-makers more flexibility to discuss and share (comments, videos, images…) around decisions.

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