USING THE AHP METHODOLOGY TO EVALUATE STRATEGIC INVESTMENT ALTERNATIVES OF NEW PARADIGMS IN INFORMATION TECHNOLOGY

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Abstract:
Enterprise adoption of a Product Life Cycle Management (PLM) system is a multi-faceted process that can be simplified by choosing the right information technology (IT) deployment model. Cloud computing has been described as a technological change brought about by the convergence of a number of new and existing technologies. The paper provides a review of the main developments in the AHP (Analytical Hierarchy Process) methodology as a tool for decision makers to be able to do more informed decisions regarding investments in new paradigms that IT offers. The AHP methodology is a multi-objective, multi criteria decision-making approach that employs a pair-wise comparison procedure to arrive at a scale of preferences among a set of alternatives. The selection process of the alternatives is not possible from the result of the financial analysis alone. Identification of the scalability and the risks assessment as criteria's give us the comprehensiveness of the treated problem.
Keywords: AHP Methodology; adoption; PLM software system.

1. Introduction

PLM software is product lifecycle management software which tools are used by companies to accelerate their product innovation. In that way, a look is taken at the lifecycle of the entire product from product conception to end of its life. PLM software vendors mostly collaborate with partners aiming to provide a complete solution, everything from hardware and networking, to technical and business consulting services [Kelley Ch. (2007)].
PLM software is considered as a complex, expensive, service-depended software initiative. Hence, the intention is solving the costs related with information technology and infrastructure investment, both current and future – have we designed the right infrastructure for today and tomorrow?
Investments in solutions such as PLM software are made in order to support business success through improved product development efficiencies, accelerated time to market, and helping to meet customer demands. Investing in technology to support best practices sooner than later can have a significant impact on the success of a company, particularly in this economic climate. PLM software practices are not longer exclusive only to large companies; they are the basis for innovation and improving the performance of all companies regardless of their size [Strategic Direction (2004)].

Statistics from surveys conducted by consulting firm CIMdata Inc. show that PLM software has increased by 10.4% market share in 2010 compared to 2006, or 50% more investment in such systems, from 20 billion dollars in 2006 to 30 billion dollars in 2010 [Alemanni M., *et al.* (2008)]. The growth is due to the continued recognition of all benefits that the PLM software integration brings while improving the companies performances.

Companies are becoming increasingly aware of the need for PLM software solutions integration, primarily from a strategic perspective (maintaining its market competitiveness); but costs are still the critical issue point in the decision process. The complexity of integration projects of these solutions dramatically increase costs, so it is important for the companies to provide a methodological approach to make investment decisions before the implementation [Peslak Alan R. (2008)], [Cresswell A. M. (2004)], [Walsh G., *et al.* (2010)].

To achieve strategically goals and remain competitive on the market, the company or its top management must make the right decision for investments in information technology and infrastructure. Above all, its required to address the following aspects: enabling fast, efficient and reliable access to data required to execute the processes in different departments in a company that are used independently or simultaneously in parallel, management of complex databases, efficient management through maximum utilization of existing technology and information infrastructure and human resources [Walsh G., *et al.* (2010)].

As mention above, product-related data (complex databases) is one of the most important aspects of any PLM software implementation. Whenever discuss about PLM software implementation, the topic of product-related data is very often becomes a center of the conversation. There are multiple sources of this type of data in the company. One of the PLM goals is to have a control of this data and provide tools to manage the overall lifecycle. One of the PLM implementation challenges is to provide wide support for product-related data. The full value of Product Lifecycle Management is directly dependent on what scope of product-related data is covered by PLM. The wider scope can maximize PLM value for companies. With all current developments, PLM is looking on starting from design to manufacturing strategies and development of social-oriented application; sizing can easily become one of the potential bottlenecks related to the ability to support large scope of data.

To understand sizing of product lifecycle data is important in order to build right operational and strategic plans related to data management and future investment in advanced technologies that enable effective data manage and storage. Data is growing fast. Future PLM software implementation can suffer from problems related to data sizing. How to scale up PLM software implementation in terms of size can be one of the most important questions in the future.

The need of flexibility and competitiveness of companies on the one hand, and efficient investment decisions on the other hand, cite the exploration of new business models different from pervious traditional methods of investment in informational technology and infrastructure. PLM will not be able to continue existing business model with mostly direct sales, heavy reliance on the service offering by partners and marathon of new product releases to the market with new features. Generally, investments in advanced technologies and therefore in the information systems due to effectively manage the life cycle of products are associated with large investments in technology, infrastructure and maintenance. Hence, the importance of conducting a comparative techno-economic analysis and setting up system model approach for making investment decisions while selecting advanced information technology is emphasized.

2. New paradigms in information technology

The evolution of Cloud Computing over the past few years is potentially one of the major advances in the history of computing. Cloud Computing might be one of the alternatives for strategic investments in information technology and infrastructure due to the PLM software adoption having in mind the following: companies have to increase innovation and flexibility in meeting the requirements of the market/customers (so they should focus on innovation, not solving problems associated with the infrastructure implementation and its maintenance), „start-up“ companies as well as small and medium enterprises cannot afford large investments in information technology and infrastructure, greater flexibility and speed up launching new products on the market offering the opportunity to access and use of already defined data, etc. [Patel Ah., et al. (2011)], [Marston S., et al. (2011)].

Cloud Computing is transfer of information infrastructure in the network, in order to optimize the load in terms of storage space and connection to the different number of users and reduce costs for managing these resources (hardware, software, networking). Resources are virtually interrelated and have a dynamic provisioning (under so called Service Level Agreement contracts (SLA) concluded between users and providers) to ensure uniform [Cervone H. F. (2010)], [Thomas P.Y. (2011)].

Three basic categories of Cloud Computing services are identified [Thomas P.Y. (2011)]: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS).

(1) Software as a service (SaaS) means software deployed as a hosted service and accessed over the Internet.

(2) Platform as a service (PaaS) means platforms that can be used to deploy applications provided by customers or partners of the PaaS provider.

(3) Infrastructure as a service (IaaS) means computing infrastructure, such as servers, storage, and network, delivered as a cloud service, typically through virtualization.

According to the U.S. National Institute of Standards and Technology, cloud computing consists of five essential characteristics (On-Demand Self-Service, Resource Pooling, Rapid Elasticity, Measured Service and Broad Network Access), three distinct service models (SaaS, PaaS and IaaS defined previously), and three deployment models that we are going to use as alternatives (Public Cloud, Private Cloud and Hybrid Cloud).

Some advantages of Cloud Computing concept are: basically cost savings; scalability; „pay-per-use" model; independence from devices and location; efficiency; providing space for storage and control; probability and transparency of the processes; optimal utilization of resources, etc. [Cervone H. F. (2010)], [Dwivedi Y. K., *et al.* (2010)].

Below are given some of its disadvantages: currently undefined standards between Cloud Computing providers, not techno-economic analysis of costs that will arise in case the company discontinued the use of web based services; the security of data is still not guaranteed by providers with certain regulations/standards, users become „dependent"of providers, or lose control over the management of information resources and services, etc. [Cervone H. F. (2010)], [Dwivedi Y. K., *et al.* (2010)].

3. The main developments of the AHP Methodology

Decision making involves setting priorities and the Analytic Hierarchy Process (AHP) is the methodology for doing that. Most of the decision issues are multi-criteria: maximize profits, satisfy customer demands, maximize employee satisfaction, satisfy shareholders and minimize costs of production, fulfill government regulations, etc. A decision may be too costly to make and its outcome may be uncertain. Evaluating a decision requires that it is considered both its benefits and its costs. We also need to consider both the possible opportunities that it could give rise to and the risks or the likelihood that it may not work out in the face of hazards and uncertainties of the future. In many situations these four aspects of evaluation have different importance. Their importance must be assessed in terms of the values mentioned above and how important these values themselves are for the given decision. Decisions are made by individuals or by groups no matter of their age. Individuals and groups may cooperate to make a decision or may find themselves in a conflict situation that requires the assistance of a mediator. There are scientific methods for dealing with individual judgments working together cooperatively in a group and for conflict situations. Its correctness as a scientific theory has been tested in numerous predictions in business, in economic forecasting and in predicting the outcomes of sporting events, and to the successful outcome of political and social conflicts.

Analytic Hierarchy Process which is a powerful method of multiple criteria decision-making approaches generally can organize selection issues and decides which alternatives are most suitable for the defined problems. The Analytic Hierarchy Process is the way to make decisions implemented by its powerful and user-friendly computer software, Expert Choice and Team Expert Choice and it has been applied in a variety of decisions and planning projects in nearly 20 countries [Alanbay O. (2005)]. With Expert Choice software, AHP enables sensitivity analysis of results which is very important in practical decision-making. The AHP can be used to manage complex problems and to evaluate advanced manufacturing technologies. Sensitivity analyses are conducted to investigate the impact of changing the priority of the criteria on the alternatives' ranking. Dynamic sensitivity of Expert Choice might be performed to see how realistic the final outcome is. Dynamic sensitivity analysis is used to dynamically change the priorities of the criteria to determine how these changes affect the priorities of the alternative choices [Alanbay O. (2005)].

AHP is a systematic approach for dealing with complex decision making problems in which many competing alternatives (projects, actions, scenarios) exists. In our case, the alternatives (Cloud Computing deployment models – Private, Public or Hybrid model) are ranked using several quantitative (investment costs, return of investment assets and companies characteristics) and qualitative criteria (scalability and risk assessment), depending on how they contribute in achieving an overall goal (PLM software system adoption). AHP is based on a hierarchical structuring of the criteria that are involved in a decision problem. The hierarchy incorporates the knowledge, the experience and the intuition of the decision-maker for the specific issue. The simplest hierarchy is consisted of three levels. On the top of the hierarchy lies the decision's goal. On the second level lie the criteria by which the alternatives (third level) will be evaluated. In more complex situations, the main goal can be broken down into sub-goals or/and a criterion (or property) can be broken down into sub-criteria.

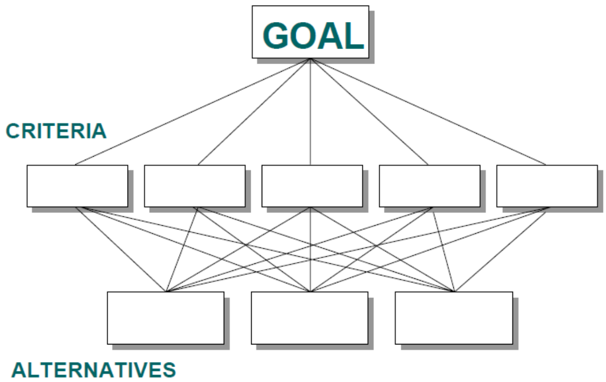

Figure 1. The simplest draw of AHP methodology

Three steps of AHP methodology are recognized:

Step 1 (structuring the hierarchy): Group related criteria should be arranged into a hierarchical order that reflects functional dependence of one criteria or a group of criteria on another. The approach of the AHP involves the structuring of any complex issue into different hierarchy levels with a view to accomplishing the stated objective of an issue.

Step 2 (performing paired comparisons between criteria/sub-criteria): A matrix of pair-wise comparisons is constructed of criteria/sub-criteria where the entries indicate the strengths with which one criteria/sub-criteria dominates another using a method for scaling of weights of the criteria/sub-criteria in each of the hierarchy levels with respect to a criteria/sub-criteria of the next higher level. These values are used to determine the priorities of the criteria of the hierarchy reflecting the relative importance among entities at the lowest levels of the hierarchy that enables the accomplishment of the objective of the issue. The scale used for comparisons in AHP enables the decision maker to incorporate experience and knowledge intuitively and indicates how many times a criteria dominates another with respect to the alternative. The decision maker can express his preference between each pair of criteria/sub-criteria verbally as equally important, moderately more important, strongly more important, very strongly more important, and extremely more important. These descriptive preferences would then be translated into numerical values 1, 3, 5, 7, 9, respectively, with 2, 4, 6 and 8 as intermediate values for comparisons between two successive qualitative judgments. Reciprocals of these values are used for the corresponding transposed judgments.

Step 3 (synthesizing results): These priorities should be synthesized to obtain the each alternative’s overall priority. Then, the alternative with the highest priority is selected.

When there are dependencies and interactions among the criteria in a decision-making model, Analytic Network Process (ANP) is more appropriate methodology; yet AHP assumes linear independence of criteria and alternatives [Alanbay O. (2005)].

As it was mention before, the AHP generally can organize selection issues and decides which alternatives are most suitable for the problems defined. However due to some intrinsic uncertainty in the method (uncertainty associated with the mapping of decision makers judgment to number, is not taken into account by the AHP and also the preference and personal judgment of decision maker have huge effect on the AHP result), a number of authors suggest fuzzy the method.

Saaty, the author of this methodology by himself is against including fuzzy logic into the AHP. He concludes that fuzzy of the process does not give much different results. Moreover, he believes that AHP is already a fuzzy process because most ratios for ranking are not absolute or crisp numbers. In fact, they are already fuzzy numbers and there is no theoretical proof that using fuzzy for the comparison data leads to better results. Therefore it cannot be proved that fuzzy AHP is a confident idea.

From the other side, many researchers like Weck, et al. in 1997 (evaluated alternative production cycles using fuzzy AHP), Yu in 2002 (employed the property of goal programming to solve group decision making fuzzy AHP problem), Kuo, et al. in 2002 (integrated fuzzy AHP and artificial neural network for selecting convenience store location), Sheu in 2004 (presented fuzzy-based approach to identify global logistics strategies), Kulak and Kahrman in 2005 (used fuzzy AHP for multi-criteria selection among transportation companies), and others have studied the fuzzy AHP which is the extension of Saaty's theory and have provided evidence that the fuzzy AHP shows relatively more sufficient description of these kind of decision making processes compared to the traditional AHP method. But, they also concluded that the conventional and fuzzy AHP methodology is not competitors at the same conditions.

Fuzzy AHP is a synthetic extension of classical AHP method when the fuzziness of the decision maker is considered [Leung L. C., *et al.* (2009)]. In most of the real-world issues, some of the decision data can be precisely assessed while others cannot. Humans are likely unsuccessful in making quantitative predictions, whereas they are comparatively efficient in qualitative forecasting. Essentially, the uncertainty in the preference judgments gives rise to uncertainty in the ranking of alternatives as well as difficulty in determining consistency of preferences [Leung L. C., *et al.* (2000)] [Polychroniou P. V., *et al.* (2008)]. These applications are performed with many different perspectives and proposed methods for fuzzy AHP.

In complex systems, the experiences and judgments of humans are represented by linguistic and vague patterns. Therefore, a much better representation of this linguistics can be developed as quantitative data; this type of data set is then refined by the evaluation methods of fuzzy set theory. On the other hand, the AHP method is mainly used in nearly crisp (non-fuzzy) decision applications and creates and deals with a very unbalanced scale of judgment. Therefore, the AHP method does not take into account the uncertainty associated with the mapping. The AHP's subjective judgment, selection and preference of decision-makers have great influence on the success of the method. The conventional AHP still cannot reflect the human thinking style. Avoiding these risks on performance, the fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy issues.

4. Conclusion

Selection of an advanced information technology due to PLM software adoption itself requires evaluation of several competing alternatives. The difficulty arises when the ranking of the alternatives is not possible as the result of the financial analysis alone.

In this paper, we consider AHP model that contains quantitative and qualitative criteria's like investment costs, return of investment and risk assessment, scalability and companies' characteristics and based on it we propose AHP as an effective problem solving methodology. Including qualitative criteria's like scalability and risk assessment, the comprehensiveness of the treated problem is given. Multi criteria decision making techniques based on the linguistic evaluations like AHP helps to make a best selection decision by using a weighting process within the current alternatives via pair wise comparisons. Prior to the evaluation of the alternatives, evaluation of criteria is handled and weighted.

In conventional AHP, ANP, and similar methods, directly the numerical values of linguistic variables are used for evaluation of these criteria. If the environment where the decision making process takes place is fuzzy, then fuzzy numbers are used for evaluation and some deviations of decision makers are concerned. Nowadays, especially in complex economic conditions, many of the decisions are made in such environments.

On the other hand, many comparative research studies show that the conventional and fuzzy AHP methodology is not competitors at the same conditions. If the information/criteria are certain, conventional methodology should be preferred; if the information/criteria are not certain, fuzzy methodology should be preferred. In recent years, because of the characteristics of information and decision makers, probable deviation should be integrated to the decision making processes, and because of that for each decision making method, a fuzzy version is developed and preferable.

Hence, we conclude that the conventional AHP methodology can be used for solving investment decision system model for implementation of advanced information technologies due to PLM software adoption. A comparative analysis and validation of the system might be performed using fuzzy approach, because of the qualitative criteria's taken in consideration. The sensitivity analyses are recommended to investigate the impact of changing the priority of the criteria on the alternatives' ranking and verification of the results from the selection obtained.

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