

The impact of IT investment on firm performance based on MCDM techniques

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Article Info

Article history:

Received Nov 1, 2018

Revised Apr 17, 2019

Accepted Apr 29, 2019

Keywords:

Decision making

Firm performance

Multi-criteria

Non-financial performance

Technology investment

ABSTRACT

In the recent past years, researchers have presented conflicting results regarding the impact of information technology investment on firm performance. Almost all studies on information technology productivity and its role for companies performance are based on data collected and meta-analysis and do not offer a methodology or prototype of analysis in any field. This study presents an attempt to adopt a multi-criteria decision making approach to evaluate the non-financial performance of companies using two famous methods. Furthermore, our results try to investigate the effects of information technology investments on firms' non-financial performance. Findings show that investment in information systems is not necessarily related to achieving a good non-financial performance at the firm level.

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1. INTRODUCTION

An investment is an asset or item acquired with the goal of generating income or appreciation; it can be with money or capital in order to gain profitable returns. Investments can be classified according to their objectives [1], replacement of equipment, increased production productivity, strategic investment, and financial investment. Investing in information technology (IT) is a type of investment widely regarded as having enormous potential for gaining competitive advantage in the past three decades [2-5]. However, there has been a debate of IT investment effects on firm's performance. The majority of researchers confirm that IT investment has a positive impact on firm performance [6, 7], the most of studies are based on data collected and relates to financial performance. The main objective of this manuscript is to develop a multi-criteria decision support approach in order to build a hierarchical model to evaluate the non-financial performance at the firm level and then to analyze the contribution of the investment in the IT to the realization of this performance.

This study focuses on two axes: it validates the interest of multi-criteria decision making (MCDM) in a context that is not traditionally theirs, namely the evaluation of the performance using a combination of two famous and the most used MCDM methods: AHP and TOPSIS, also it investigates the impact of IT investment on the non-financial performance of companies operating in three sectors selected for this study. The structure of this paper is as follows: section 2 offers a literature review of previous studies about non-financial performance and IT investment to demonstrate the purpose of this paper. In the section of methods, the two used MCDM methods are explained. Next section, presents the results of work methodology with discussions of findings. Then, the concluding remarks are presented.

2. LITERATURE REVIEW

2.1. Non-financial performance

Based on the state of the art, performance is defined as the combination of effectiveness and efficiency [8] it can't be defined as a simple notion; it is a concept that encompasses several dimensions. Generally, we can subdivide to financial and non-financial performance. In our case, we are interested to non-financial performance. Non-financial performance can tell managers about what is going to happen with the financial results in the future years [9]. This type of performance includes any quantitative measures of individual or entity's performance that is not expressed in monetary units [10]. Performance measurement [11] is hard because it describes and implements the strategy that is not directly observable, the monitoring of organization and the improving coordination, which are influenced by uncontrollable events.

In this section, we will present an overview of previous studies related to non-financial measures:

- By reviewing previous studies related to non-financial performance, we have found different indicators such as [12-14]: product quality, customer satisfaction, on time delivery, innovation measures, attainment of strategic objectives, market share, efficiency, productivity, employee satisfaction.
- The most non-financial indicators used and cited are [15-17], customer satisfaction, market share, employee feedback, human resources, and product quality.
- The Balanced Scorecard developed by Kaplan and Norton [18] provides financial and non-financial measurements and focused on customer's point of view.
- Abdel-Maksoud [19] proposed a model involving five non-financial performance indicators: customer satisfaction, product quality, and on-time delivery, efficiency and utilization and employee morale.
- Philips and Louvieris [20] introduced three major success factors: quality of service, customer relationship management and customer profiling.
- All these studies confirmed that non-financial performance is very important when evaluation firm's performance even in the financial sector [21-23].

2.2. IT investment and firm performance

The relation between IT investment and firm performance has been investigated since 1980 [24-27]. The majority of results studies confirm the IT investment's impact on firm performance. Many theoretical paradigms in evaluating the IT's contribution to firm performance have cited in literature: theoretical model of IT resources [28], general purpose technology theory [29], the neoclassical theory [30, 31], the resource-based theory [32] and the productivity paradox theory [24]. The findings of all studies can be grouping to three possibilities: studies confirming the positive effects of IT investment on firm performance [2, 3, 5, 33-36], studies confirming the IT paradox [37-39] and studies (minority) have found no impact of IT investment on firm performance [40-41].

3. MCDM METHODS

There are a number of MCDM methods multiple criteria [42-44] that can be used to facilitate decision-making process. In this work we used a combined approach of two most popular methods namely AHP and TOPSIS methods.

3.1. AHP method

The AHP procedure requires the following steps [45-47]:

- Construct the matrix U_{ij} of order m if the compared entities are criteria, or of order n if the compared entities are alternatives
- Construct the comparison matrices whose values are obtained by transforming the judgments into numerical values according to the Saaty scale (Scale of Binary Comparisons), respecting the principle of reciprocity

$$\begin{cases} \sum_{j=1}^n U_{ij} W_j = \lambda_{max} W_i \text{ pour } i = 1 \dots n \\ \sum_{i=1}^n W_i \end{cases} \quad (1)$$

3.2. TOPSIS method

The TOPSIS procedure consists of the following steps [48-51]:

- Normalize performance:

$$e'_{ij} = \frac{g_j(a_i)}{\sqrt{(g_j(a_i)^2)}} \quad (2)$$

Where: $i=1 \dots m$ and $j=1 \dots n$

- Calculate the product of normalized performance:

$$\begin{aligned} e''_{ij} &= \pi_j * e'_{ij} \\ \sum_{j=1}^n \pi_j &= 1 \end{aligned} \quad (3)$$

Where: $i=1 \dots m$ and $j=1 \dots n$

- Determine the positive and the negative ideal solutions:

$$\begin{aligned} a^* &= \{ \max_i e''_{ij}, i = 1 \dots m \text{ et } j = 1 \dots n \}; a^* = \{ e^*_j, j = 1 \dots n \} = \{ e^*_1, e^*_2 \dots e^*_n \}; (4) e^*_j = \max \{ e''_{ij} \} \\ a^- &= \{ \min_i e''_{ij}, i = 1 \dots m \text{ et } j = 1 \dots n \}; a^- = \{ e^-_j, j = 1 \dots n \} = \{ e^-_1, e^-_2 \dots e^-_n \}; \\ e^-_j &= \min \{ e''_{ij} \} \end{aligned} \quad (5)$$

- Calculate the separation measures:

$$D_i^* = \sqrt{\sum_{j=1}^n (e''_{ij} - e^*_j)^2} \quad \forall i = 1 \dots m; \quad D_i^- = \sqrt{\sum_{j=1}^n (e''_{ij} - e^-_j)^2} \quad \forall i = 1 \dots m; \quad (6)-(7)$$

- Calculate the relative closeness coefficient to the ideal solution:

$$CC_i^* = \frac{D_i^-}{D_i^* + D_i^-} \quad \forall i = 1 \dots m \text{ et } 0 \leq CC_i^* \leq 1; \quad (8)$$

- Rank the alternatives.

4. IMPLEMENTATION

4.1. Purpose of study

The study focuses mainly on the contribution of IT investments in achieving the firm's non-financial performance. The purpose is to provide a new methodology to evaluate the non-financial performance of firms using two MCDM methods namely AHP and TOPSIS. The first method was used to calculate the weights of each criterion in evaluating non-financial performance, subsequently; the firms were evaluating using the TOPSIS method. Furthermore, this work analyzes the relationship between IT investment and non-financial performance at firm level. We examine also the interaction between a set of non-financial indicators and the degree of IT investment.

The paper implements the research methodology in three sectors, namely: financial sector, construction industry sector and service companies, chosen based on their variation in the use of information technologies. The majority of previous studies have dealt with the financial performance of firms [52-54], in order to overcome this deficiency, this study aim to introduce a new technique for evaluating and analyzing the non-financial firm's performance using multi-criteria decision making methods and its relation with IT investment.

4.2. Work methodology

The work methodology as shown in Figure 1, consists of four main steps as summarized in the following figure: step 1: review previous studies relating to non-financial performance, information technology investment and their contribution; step 2: choose the sectors in which we will apply our approach, we selected 3 sectors; step 3: identify the evaluation criteria and sub-criteria considered as the most important non-financial performance measures; step 4: apply AHP method; step 5: apply TOPSIS method; step 6: achieve the final ranking results of studies firms; step 7: define investment values of each alternative and step 8-9: analyze the contribution of IT investments in the achievement of non-financial performance of firms belonging on studies sectors. The description of each step will be given in the following sections.

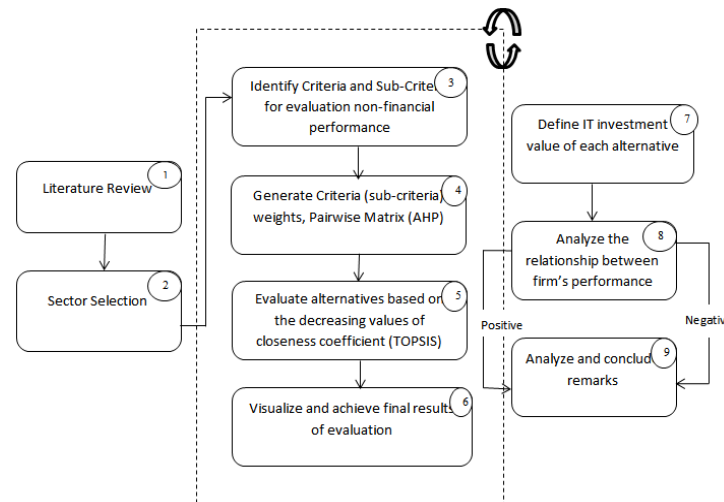


Figure 1. Work methodology

4.3. Implementation

To validate our work methodology, we choose to work on firms operating in three sectors selected for the reasons mentioned previously. Therefore, our first objective was the choice of criteria and sub-criteria that will be used during this research. The evaluation criteria were taken from previous studies and researchers related to non-financial performance evaluation [55, 56]. The hierarchical model contains 6 criteria and 19 sub-criteria as shown in Table 1.

Table 1. Hierarchical representation of criteria

Main Criteria	Sub Criteria
Customer (C ₁)	CustomerNumber (C ₁₁), CustomerSatisfaction (C ₁₂) and ComplaintsNumber (C ₁₃)
Expansion and Market Share (C ₂)	BrancheNumber (C ₂₁), NewProductsNumber (C ₂₂) and NewService (C ₂₃)
Employees (C ₃)	Headcount (C ₃₁), AverageAge (C ₃₂), Satisfaction (C ₃₃) and TrainingInvestment (C ₃₄)
Service Quality (C ₄)	OnTimeDelivery (C ₄₁),CommunicationCapability(C ₄₂), RateDelay(C ₄₃),Availability(C ₄₄)and Access(C ₄₅)
Environment (C ₅)	TotalPaperConsumption (C ₅₁) and EnergyUse (C ₅₂)
Security (C ₆)	RiskRate (C ₆₁) and Breakdown(C ₆₃)

Data collection was conducted among fifty firms in each sector and the weights of criteria and sub-criteria were calculated using AHP method. Thereafter, TOPSIS method was applied and based on the decreasing values of closeness coefficient alternatives are ranked from most valuable to worst. The second part concerns the study of the relationship between IT investment and firm’s non-financial performance. This work enriches the debate on the performance evaluation by adopting a multi-criteria approach to evaluate non-financial performance of firms and to study its relation with IT investment. There are two cases to distinguish; the presence of a positive or negative impact. Furthermore, this work indirectly controls two main factors that can influence the contribution of IT investment in the achievement of non-financial performance at the firm level which are the size of firm and its sector. This observation is confirmed by the results of the study.

4.4. Proposed framework

To implement our work methodology, we propose a prototype of framework that consists of 3 parts as shown in Figure 2.

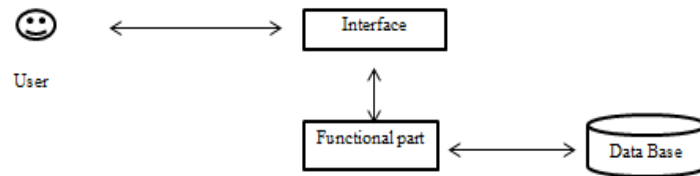


Figure 2. Proposed framework's architecture

Interface: after authentication, the framework user can start the use of application and enter the evaluation data with the possibility to modify criteria and sub-criteria;

- Data Base: its role is to store the various data that will be used in the next steps of evaluation or that will serve as archives to make comparisons. We chose to work with SQL Lite as the size of data is reduced;
- Functional Part: its purpose is to execute the steps of our work methodology based on the implementation of AHP and TOPSIS methods known by the complexity of their calculations. The proposed system begin when the user choose the sector that will be evaluated. The first main step on this part is the implementation of AHP method, through the several interfaces which use combo boxes to input values, the others interfaces lead to calculate the weights of criteria (main criteria and sub-criteria). The second step aims to implement the TOPSIS method based on the data input in by framework's user. The final step consists on the analyses of relationship between IT investment and firm's non-financial performance. A prototype was developed in Java programming language; we could not include all the interfaces in the article to not exceed the number of pages indicated, we present some interfaces as shown in Figure 3.

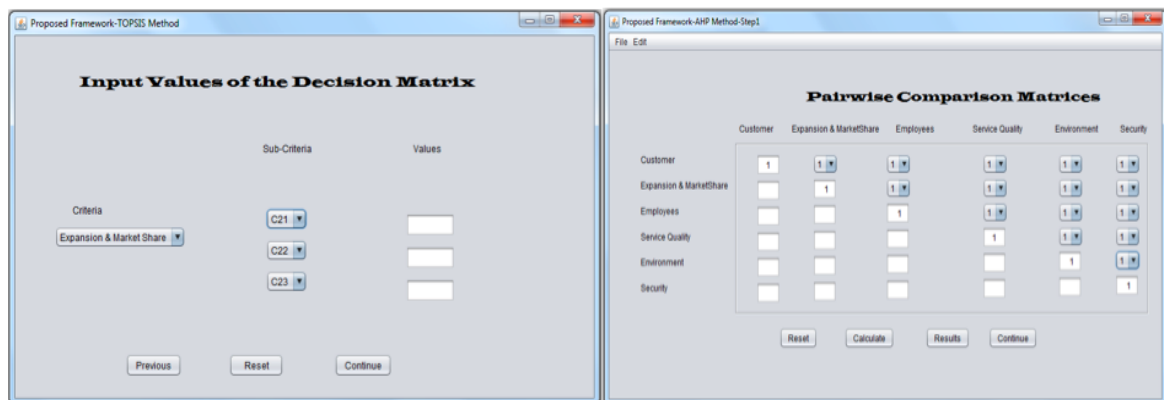


Figure 3. Prototype interfaces

5. ANALYSIS RESULTS

5.1. AHP method analysis

The prototype of resulting system start by asking users to determine the level of importance of chosen criteria (sub-criteria) compared to others. Based on the data, the calculation method of AHP can begin to obtain the weight of each criterion and sub-criterion. The hierarchical structure for evaluating the non-financial performance as shown in Figure 4 .It should be noted that the values of this study were obtained by calculating the average values given by the experts responsible in each of the three sectors.

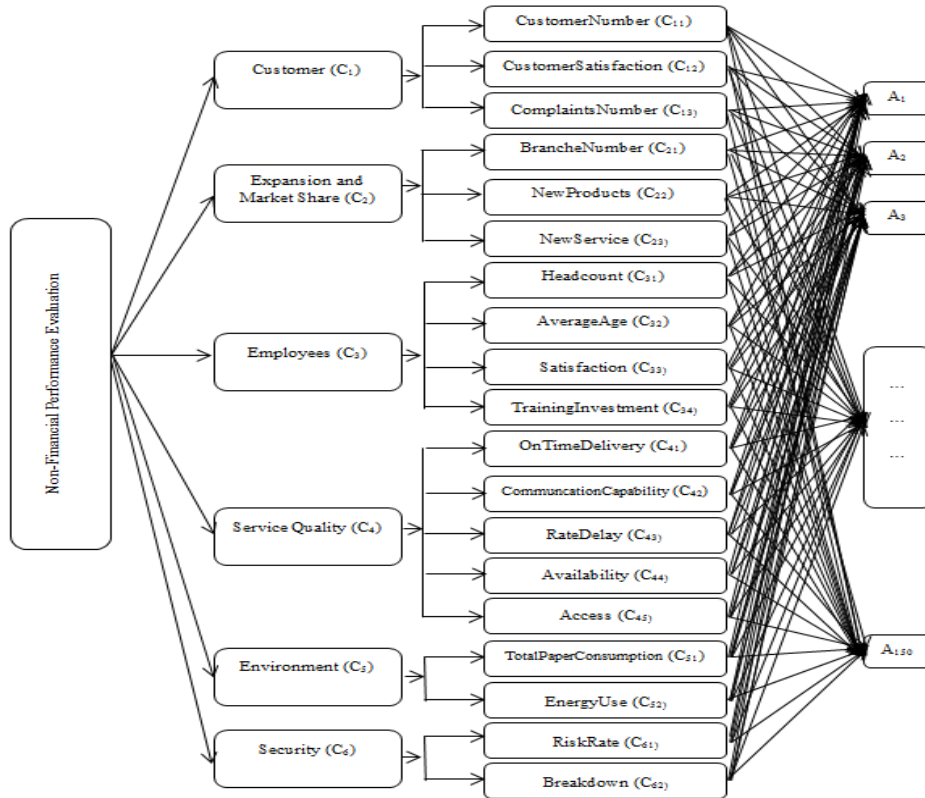


Figure 4. Hierarchical structure for the non-financial performance evaluation

Starting by the financial sector and implementing the AHP equations (1), through the proposed prototype interfaces, the normalized weight vector of main criteria is: $W = (0.36; 0.20; 0.17; 0.16; 0.07; 0.03)$ as shown in Figure 5, the most valuable criterion with the weight of 0.36 is “Customer”.

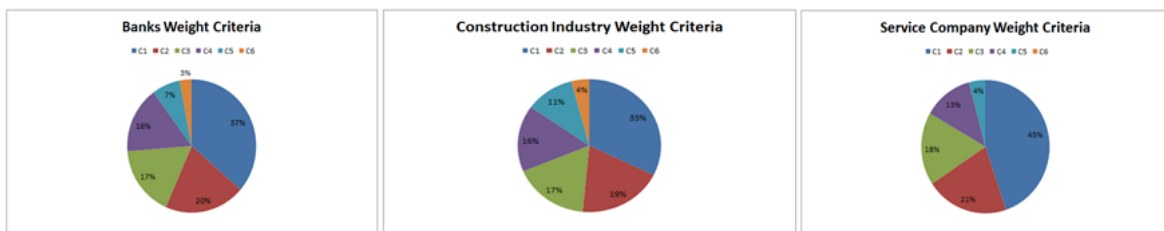


Figure 5. Sector's weight criteria

In the construction industry sector, the priority vector of criteria weights is: $W = (0.32; 0.19; 0.17; 0.16; 0.11; 0.04)$ as shown in Figure 5, the highest weight is 0.32 which corresponds to the first criterion presenting customer. Concerning the third sector, the main criteria weight is: $W = (0.43; 0.20; 0.17; 0.12; 0.04; 0.02)$ as shown in Figure 5, the first criterion still having the greatest value.

From these results, we can conclude that for the evaluation of non-financial performance of firms, the most dominant criterion is the customer regardless of the sector or the size of the company. It is a logical result given the importance of the customers who are the mark of a service quality and a good image of the firm, and then we have the other criteria. Still analyzing the results of AHP method implementation, we notice an increase in weight for the last two criteria namely environment and security in the construction industry sector that have passed from 0.04 to 0.11 and 0.02 to 0.04 which is normal given the particularities of this sector being a risk factor and its impact on the environment.

5.2. TOPSIS method analysis

From the pairwise comparison, the normalized weight of criteria and sub-criteria are obtained. Then, we have process to the TOPSIS method implementation, the process is begun data values based on each alternative. Given the large number of alternatives, we chose to display just one example as shown in Table 2. To facilitate the task of data entry by evaluators, we chose to work with intervals of values to make the evaluation.

Table 2. Scoring alternative1

Criteria	Sub-Criteria	Values	Criteria	Sub-Criteria	Values
C ₁	C ₁₁	A	C ₂	C ₂₁	C
	C ₁₂	AC		C ₂₂	AA
	C ₁₃	F		C ₂₃	E
C ₃	C ₃₁	A	C ₄	C ₄₁	A
	C ₃₂	AA		C ₄₂	AC
	C ₃₃	F		C ₄₃	D
	C ₃₄	G		C ₄₄	I
C ₅	C ₅₁	B	C ₆	C ₆₁	EA
	C ₅₂	AA		C ₆₂	HB

From the data of this alternative, we perform the conversion to form such a decision matrix as shown in Table 3. To rank the different alternatives, we implement in order the (2)-(8). We continue the process of calculating the distance between the values of each alternative against the positive ideal solution and the negative ideal solution. Further, the ranking of alternatives of the study is obtained.

Table 3. Decision matrix (alternative1)

Criteria	Sub-Criteria	Values	Criteria	Sub-Criteria	Values
C ₁	C ₁₁	1	C ₂	C ₂₁	3
	C ₁₂	3		C ₂₂	1
	C ₁₃	3		C ₂₃	2
C ₃	C ₃₁	1	C ₄	C ₄₁	1
	C ₃₂	1		C ₄₂	3
	C ₃₃	3		C ₄₃	1
	C ₃₄	1		C ₄₄	3
C ₅	C ₅₁	2	C ₆	C ₆₁	2
	C ₅₂	1		C ₆₂	1

5.3. IS investment and firm performance

This study is based on data of fifty firms belonging to the three studied sectors, each with a different information technology consumption rate. We first propose a hierarchical model to evaluate the non-financial performance of these firms using MCDM methods. Since the majority of research studying the correlation between information system investment and financial performance worked with financial performance, we chose to treat non-financial performance. Subsequently, we studied the correlation between the two variables; the results from previous researches are mixed. In general way, firms invest on IT to achieve better competitive advantages through reducing costs, but the IT budget is varied from one sector to another. Given the number of firms in each sector, ten companies from each sector were selected based on the results of the non-financial performance evaluation (the first three, the four averages and the last three).

The financial sector is considered as the biggest investor in the IT. The Figure 6 shows the results of the IT investment percentage compared to the firm's turnover. It can be concluded that more than 80% of financial firms invest between 21 and 60% of their turnover in information systems; which is a huge investment given the large turnover of banks. The curve shows the ranking of the firm's non-financial performance according to the IT investment as shown in Figure 6, we find that the impact of IS investment does not always ensure the performance of the company, as shown concretely the example of the B3 bank which is ranked third performance rating but in return invests only a percentage between 1-20%. Unlike the B9 bank which invests 61-80% of its turnover but is ranked among the last three firms in terms of performance. These two contradictory examples lead us to believe that there are other factors that influence the contribution of IT investment in achieving the non-financial performance.

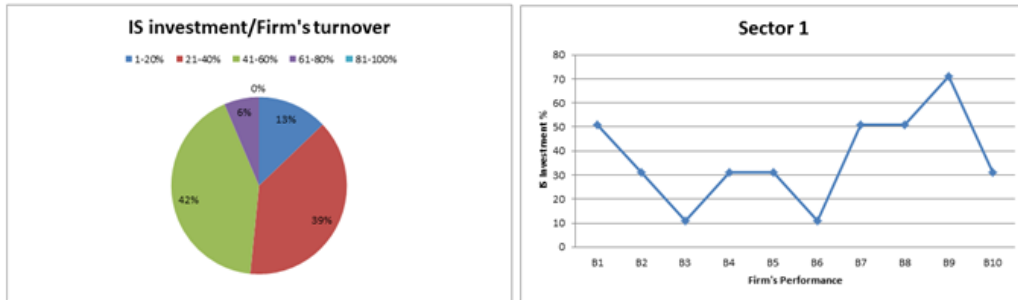


Figure 6. Financial sector results

Concerning the construction industry sector, as shown in Figure 7, only 6% of the firms in the construction industry invest between 21 and 40% of their turnover in information system and almost all firms contribute between 1 and 21% of their turnover in the investment, a result that proves more than this sector uses almost no computer and even more does not believe that with the use of information system it can improve the performance of its companies.

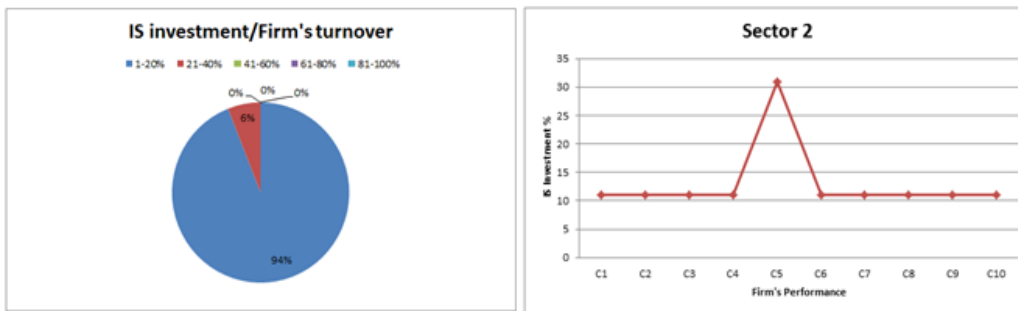


Figure 7. Construction industry sector results

For the results of the study of the impact of IS investment on performance, we find the same remark as the first sector; IS investment is not always a factor in the firm's non-financial performance, C1 ranked first performance only invests 1-20 % of its turnover yet C5 is among the minority of companies that invest between 21-40% but it is not ranked among the first.

The last sector is the one that ensures the balance between the two previous ones, it invests moderately in information systems and this is clear from the results shown in Figure 8, even if we notice an increase of number in the first tranche which concerns 1-20% IT investment; this can be explained by the fact that in this same sector, there are companies that believe more than the value created by the IT but hesitated in terms of investment.

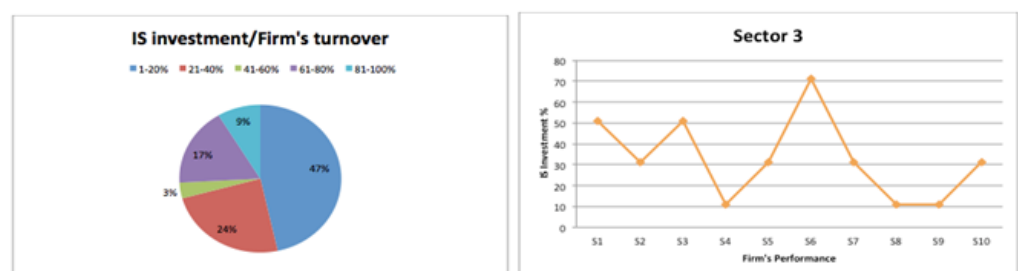


Figure 8. Service companies sector results

The contribution of IT investment in the achievement of non-financial performance of service companies is one of the objectives of this study, in the Figure 7, we always come back to the remark we made since the beginning of the analysis of this correlation and it is that the investment in IS does not always ensure the performance of the companies, we notice the company S6 which invests between 61-80% of its turnover but still not ranked the first; it confirms more that a successful company is not necessarily the one that invests the most in information systems.

6. CONCLUSION AND PERSPECTIVES

This study uses data from 150 companies operating in three sectors to determine the contribution of IT investment in the achievement of non-financial firm's performance. This paper proposes a framework based on MCDM methods to analyze firm's performance; criteria and sub-criteria were chosen from previous researches. Based on the results obtained, we can conclude that the weight's criteria and sub-criteria change from one sector to another. For example, weight's criteria of environment and security increases when we have passed from financial sector or service companies to construction industry, so it is unfair to establish a generic model to evaluate the non-financial firm's performance belonging in different sectors.

This paper also investigates the correlation between IT investment and non-financial firm's performance. This relation is qualified as a very complicated issue, it can be influenced by many factors: sector's type, firm's size, employee's skills and firm's organizational culture. Coming back to the first sector chosen, it is the most consumer computer sector, that is clear from IT investment percentage; more than 80% of financial firms invest between 21 and 60% of their turnover in information systems, which is a huge investment, unfortunately, this not ensure a good performance; we have financial firm's who invest heavily on IS but there are ranked at last among the others on term of non-financial performance, so the IS investment don't ensure a good performance, the same remark is valid for the others two sectors. What varies is the IT investment values; for the construction industry sector, 94% of firms invest just between 1 and 20% of their turnover on IT investment which is mediocre given the firm's size and their turnover. Service companies invest moderately on information systems. To summarize, the results of this study show that investment in information technologies is not necessarily related to superior non-financial performance, on the other hand, IT investment depend on the size and the type of the firms.

The work done in this article has yielded interesting results. In fact, the approach developed for the construction of a performance evaluation model has shown the interest of a hierarchical model for modeling a vague concept such as performance and thus to study the contribution of IT investments. For the future work, we will work on a larger sample to verify the accuracy of our results and even on other sectors while identifying a proprietary valuation model for each one.

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