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Multi-objective IT Project Selection Model for Improving SME Strategy Deployment

Abir El Yamami, Khalifa Mansouri, Mohammed Qbadou, El Hossein Illousamen
Laboratory: Signals, distributed systems and Artificial Intelligence (SSDIA), ENSET Mohammedia, University Hassan II of Casablanca, Morocco

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ABSTRACT

Due to the limited financial resources of small and Medium-sized enterprises (SMEs), the proven approaches for selecting IT project portfolio for large enterprises may fail to perform in SMEs; SME top management want to make sure that the corporate strategy is carried out effectively by IT project portfolio before investing in such projects. In order to provide automated support to the selection of IT projects, it seems inevitable that a multi-objective approach is required in order to balance possible competing and conflicting objectives. Under such an approach, individual projects would be evaluated not just on their own performance but on the basis of their contribution to balance the overall portfolio. In this paper, we extend and explore the concept of IT project selection to improve SME strategy deployment. In particular, we present a model that assesses an individual project in terms of its contribution to the overall strategic objectives of the portfolio. A simulation using the model illustrates how SME can rapidly achieve maximal business goals by deploying the multi-objective algorithm when selecting IT projects.

Corresponding Author:

Abir El Yamami,
SSDIA laboratory,
ENSET Mohammedia,
Hassan II University of Casablanca,
Morocco.
Email: abir.elyamami@gmail.com

1. INTRODUCTION

Considering the problematic of IT project selection when deploying the corporate strategy, SMEs have been seeking new ways to select IT projects that will better fit the SME's business goals with limited investment.

Project portfolio is a strategic activity for enterprises that want to compete in environments trough the development of technological innovations [1]. It helps IT managers to prioritize IT projects that have the greatest impact on achieving strategic objectives. The aim behind the use of project portfolio is to verify that expected benefits are planned, realistic, and in fact delivered by programs and projects [2] in order to maximize the value generated by project investments. In this context, the Project Management Institute expressed that a project portfolio is "a true measure of an organization's intent, direction, and progress" [3].

Convincing the top management to invest in IT projects remains a key issue for IT managers. IT managers refer to project prioritization techniques to order IT projects in such a way that increases the rate of return on investment. Therefore, balancing IT project portfolio remains a key issue for IT managers who seek to maximize the return on their investment in information systems.

One project may be related to one or more business goals. Consequently, any variation on performance in a project may become critical because of its impact on the achievement of more than business

goal. Therefore, when several projects are processed simultaneously, it is important to rank the projects according to their relative importance in keeping portfolio balanced. Such ranking enables the project manager to focus his managerial efforts and control on the most important projects. The aim is to maximize the probability of the project portfolio success. Thus, the way project priority are calculated at the project portfolio level might be highly relevant for both project and portfolio success and deserves research attention.

In spite of the importance of the strategic performance metrics to calculate the priority of projects, most metrics used for selecting projects are based on financial terms or based only on the isolated performance of projects [4], taking into consideration cost, schedule, and quality [5-7].These metrics, focuses on project effectiveness instead of efficiency [8]. As a result, the proposed metrics presented in the literature for calculating project priority have been criticized for not supporting the deployment of the corporate strategy [9].

Due to the limited resources of SMEs, the number of selected IT projects to be implemented is scarce. Consequently, it may happen that some business goals are not covered by any IT project. This paper aims to overcome this limitation and it proposes a multi objective model for selecting IT projects, it takes six typical project prioritization objectives into consideration and merges the existing methods from multiple dimensions. The new defined approach can produce more flexible project prioritization and ensures the rapidly achievement of maximal business goals.

The rest of this paper is organized as follow: firstly, a literature review about the subject is presented in Section 2, then the background of the existing single objective formulation of project prioritization problem is presented in Section 3. Section 4 introduces the proposed multi-objective IT project prioritization algorithm. Finally, the results of a case study are analysed and discussed in Section 5 before concluding.

2. LITERATURE REVIEW

Project Portfolio management is a dynamic decision process that can be presented as an impacting factor in the long term result of a company [10]. The aim behind the use of project portfolio is the selection of the group of projects that maximizes the achievement of strategic objectives.

The concept of project portfolio has been introduced in 1952 by Harry Markowitz [11] which has earned him the Nobel Prize in economics in 1990. However, the application of the concepts and approaches of portfolio management derived from finance in information systems confronts some limitations because it is difficult to calculate the expected value of IT projects [12].

Most researches conducted on this topic concluded the importance of the strategic alignment of IT [13], [14]. As such, effective management of IT projects will require alignment among a complex of choices reflecting both a strategic and a functional perspective. Several contingency models have been proposed in Information system studies. These models have been used to study the relationship between business strategy, structure, IT strategy and IT structure [15], [16]. Moreover, the alignment between information requirements and information processing capacity has been underlying the objective of great number of researchers [17-20].

According to Mark A. Langley, a PMI President and CEO [21] many organizations have no effective benefits realization management processes in place, these organizations are messing an opportunity to ensure that their projects deliver the expected strategic impact. Many empirical studies have shown that the business value from IT projects investments can be greater than the one being currently achieved [22]. Organizations that value project management as the strategic capability that drives change already perform better than their counterparts [21]. Therefore, a good IT project management should enable the business and IT executives to understand how IT contributes to the accomplishment of business goals in the past and in the future.

Project prioritization techniques try to order projects in such a way that increases the rate of return on investment, several methodologies for project priority calculation were proposed by both practitioners and researchers. The first provides techniques for describing and scoring projects in order to range them according to their advantage [23] , these techniques provides only general indications and recommendations for managing project portfolios. The second group focuses on the technical aspects, the most appropriates ones propose the use of multi-criteria decision making approaches when selecting projects [1], [24], scoring models [25], [26] or economic methods [25], [27], [28]. Several criticisms have been expressed against such approaches [29], most of them simplify the problem too much or require the employment of sophisticated tools which makes their implementation very limited.

From our literature review, we have concluded that:

a. The conventional project ranking indexes are prone to errors, most of project priority calculation approaches focuses on the technical aspects rather than on the achievement of the business goals

crafted by the company. Average economic project success is measured by the achievement of objectives related to target costs, target revenues, customer satisfaction, and profitability.

b. Ongoing control mechanisms to ensure the validity of a project's alignment are rarely implemented in practice. There is no effective proposed metrics for calculating the alignment score of a given project.
c. Lack of metrics that take into account the interdependencies between projects that the portfolio is composed of. Project priority is calculated separately without taking into consideration the interaction between projects.
d. There is no mechanism for ensuring that the selected IT project portfolio covers all the business goals that it has been designed for.

Responding to those needs and enabling organizations to realize optimal value with acceptable risk and affordable costs, we propose a set of project prioritization objectives which allows the early detection of performance variances that hinder or facilitate the achievement of a portfolio's business goals. Then, we provide our multi-objective model that takes all the objectives in consideration to increase the accuracy of project prioritization.

3. RESEARCH METHOD

Project prioritization is a research hotspot in the field of portfolio management. It can be defined as follows:

Definition 1: IT Project Prioritization Problem

Given: P, a project suite already existed, PI, the set of all possible prioritization of P, and f, an objective function from PI to the real numbers.

Problem: Find P' ∈ PI such that (∀P'') (P'' ∈ PI) (P''≠ P') [f (P') ≥ f (P'')].

f assigns a real value to a permutation of P according to the project adequacy of the particular permutation. The ideal order would be the one that covers all the business goals earliest. Currently, IT project prioritization approaches derived from professional literature mostly aimed at single objective, including:

3.1. Prioritization based on Alignment Score: AS(p)

COBIT is an integrated framework that facilitates the achievement of the business's strategic goals through an effective IT governance and management approach [30]. COBIT proposes a goals cascade that supports the identification of stakeholder needs and enterprise strategic objectives through the achievement of technical outcomes. COBIT 5 emphasizes aligning IT initiatives with business requirements first before building a system that is being considered for acquisition [31].

The strategic objectives define the manner in which the organization should interact with its environment in order to reach its purpose. It is essentially focused on the external perspective of the organization.

The business goals define what needs to be achieved to realize the strategic objective. They have usually a long term focus, both business goals and strategic objectives are concerned with what must be achieved and not how it will be achieved.

The IT Goals need to be linked to business goals, Kaplan and Norton introduced the concept of linkage in 1996 [32], but they do not supply any further notions or methods to support their concept. They explain, "Without such linkage, individuals and departments can optimize their local performance but not contribute to achieving strategic objectives."

Therefore, organizations must clearly define the hierarchy of the Business /IT Goals (Figure 1) which allows rapidly propagating changes.

Our goal is to identify the strategic interdependencies between IT projects, and calculate the alignment score of each project with the strategic objective desired by the implementation of a project portfolio.

Let O be the strategic objective that an organization want to achieve by the realization of a project portfolio, N the total number of Business goals B, M the total number of IT goals T, and I the total number of projects P.

To be considered in the project portfolio selection phase, each project P must contributes at least to the achievement of one IT goal, and each IT goal T must contributes at least to one business goal.

The alignment score ASP of a project P with a strategic objective O can be calculated as follow:

a. A_{PT} : the involvement degree of each project P to achieve IT goal T
b. A_{TB} : the involvement degree of each IT goal T to achieve Business goal B

c. A_{PO} : the alignment score which is the involvement degree of each project P in achieving the strategic objective O

$$A_{PO} = \sum_{T=1}^{M} A_{PT} \times A_{TO}$$
$$A_{PO} = \sum_{T=1}^{M} A_{PT} \times \sum_{B=1}^{N} A_{TB} \times A_{BO}$$
$$A_{PO} = \sum_{T=1}^{M} \sum_{B=1}^{N} A_{PT} \times A_{TB} \times A_{BO}$$
$$AS_P = \frac{A_{PO}}{\sum_{P=1}^{I} A_{PO}}$$

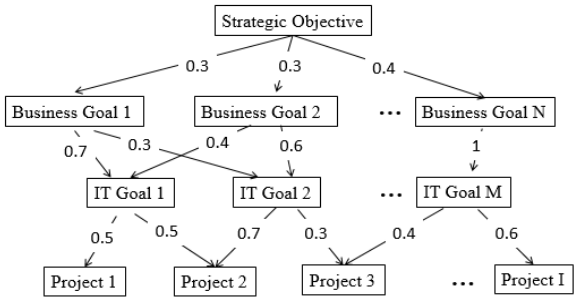

Figure 1. Business/ IT Goals hierarchy sample

3.2. Prioritization based on Benefit/ Cost ratio: BCR(p)

A cost benefit analysis is used to evaluate the total anticipated cost of a project compared to the total expected benefits in order to determine whether the proposed implementation is worthwhile for a company or project team. The BCR can be calculated as follow:

$$\text{BCR} = \frac{\text{Discounted value of incremental benefits}}{\text{Discounted value of incremental costs}}$$

3.3. Prioritization based on Intangible Benefit NIB(p)

Projects generate many intangible benefits that cannot be determined by conventional evaluation methods. Therefore, using a method that only measures the financial benefit is not sufficient for proper project evaluation. We calculate the number of intangible benefit that can be realized by a project as follow:
Suppose that the intangible benefit that the portfolio aims to provide is B= {b1, b2….bm} and given a project suite P= {p1,p2,…pn}. For each intangible benefit b ∈ B, there is at least one project p∈P which satisfies b. this relation from P to B is denoted as S(P,B)n*m
We provide below the algorithm for the calculation of S:

Algorithm 1: calculate the relationship S between IT projects and Intangible benefits

```
for (i=1; i<=n; i++)
{
        for(j=1; j<=m; j++)
        {
        if(pi satisfies bj)
        then S(pi,bj) =1;
        else S(pi,bj) =0;
        }
}
```

S can be considered as a n *m matrix. NIB(pi) is used to calculate the set of all intangible benefits satisfied by project pi, where NIB(pi)= {b| S(pi , b)=1}.
| NIB(pi)|is used to denote the number of intangible benefits.

3.4. Prioritization based on Payback Period: PB(p)

The payback period is calculated by counting the number of years it will take to recover the cash invested in a project. The formula to calculate payback period of a project can be calculated as follow [8]:

$$\text{pb} = \frac{\text{Initial Investment}}{\text{Cash Inflow per Period}}$$

$$\text{PB(p)} = \frac{1}{\text{pb(p)}}$$

Where pb take the reciprocal value, the grater the value, the higher the priority.

3.5. Prioritization based on Risk Priority Number: R(p)

The PMI define project risk as a probability of threat or damage which any occurrence can impact resources and activities [33]. According to [34], risk is the potential harm caused if a particular threat exploits a particular vulnerability to cause damage to an asset. Risk prediction helps to recognize tangible and intangible risks and then measure the organization's risk tolerance.

Risk Priority Number is a systematic and proactive metric for identifying critical risks associated with the project. Each risk gets a numeric score that quantifies the likelihood that the risk will occur, the likelihood of the risk will not be detected and the amount of damage that the risk may cause to the project. The RPN is calculated as follow:

$$\text{RPN(p)} = \sum_{r=1}^{n} Severity_r * \text{Occurecne}_r * \text{Detection}_r$$

n the number of risks that may be encountered by the project p.

$$\text{R(p)} = \frac{1}{\text{RPN(p)}}$$

Where RPN(p) take the reciprocal value, the grater the value, the higher the priority.

3.6. Prioritization based on business goals coverage C(p)

Despite the importance of the project prioritization metrics presented above in calculating project priority, it may happen that some business goals are not covered by any selected IT project. With the aim of balancing the project portfolio, we propose an additional metric that counts the total number of business goals covered by each project. The idea is to pick the project with the greatest coverage and then successively add those projects that cover the most yet uncovered business goals. Algorithm 2 presents the prioritization based on business goals coverage.

Algorithm 2: Prioritization based on business goals coverage

```
        Input:
                P: a queue of projects
                B: a set of business goals
        Output:
                P': a well ordered queue
                cover(p): the goal coverage set of p
        P'= ∅;
        B*= ∅; // set of goals that has been covered
For each p∈ P
        Count cover(p); // number of goals covered by project p
while(P'!=P)
                        {
if (B==∅)
        { B=B*;
        B*=∅;
         } else
{

        If (p covered the maximum subset B' of B)
{
        p join P' in the tail;
        B=B-B';
        B*=B*+B';
}
    }
}
```

The coverage based prioritization is as follow:

$$c(p) = |cover(p)| + \alpha$$

It may be a case that the coverage of IT projects picked in the latter is higher than in the former. Thus, after all the business goals being covered by a set of projects, these projects should be grouped and the appropriate value α should be added based on the number of the projects.

4. THE PROPOSED MULTI-OBJECTIVE PRIORITIZATION ALGORITHM

Suppose that a project suite p = {p1, p2, p3 … pn}, for each p in P a prioritization value initially 0 is assigned. For each project we calculate the project priority individually on six dimensions: Alignment score AS(p), Benefit Cost Ratio BCR(p), Number of intangible benefit NIB(p), Payback Period PB(p), Risk Priority R(p), Business Goals Coverage C(p) (1), and then get the results from each objective to establish the decision matrix (2). Due to the different measurement of each dimension, the results need to be processed by normalization in order to process the data conveniently (3). After the normalization, the values from every aspect are unified on one dimension according to the classical weighted sum approach in order to get f' (4). Finally, projects are sorted in descending order according to their priority value f': the greater the f', the higher the priority (5).

Algorithm 3: Multi-objective Prioritization Algorithm

Input:

P= $\{p_1,p_2,\ldots p_n\}$: a queue of projects
W= $\{w_1,w_2,\ldots w_m\}$: Objectives weights

Output:

P': a well ordered queue
f': priority value of each project

1. For each p∈ P Calculate AS(p), BCR(p), NIB(p), PB(p), R(p), C(p);
2. Establish the decision Matrix;
3. Calculate a normalized decision matrix

$$f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

4. For each p∈ P Calculate the single objective f' based on the weighted sum

$$f' = \sum_{i=1}^{M} w_i * f_i$$

$$\sum_{i=1}^{M} w_i = 1$$

5. Reorder P according to f' to form a new queue P';

5. RESULTS AND DISCUSSION

5.1. Case of Study

To investigate IT project prioritization and to compare and evaluate the prioritization techniques described in section 3, we perform a case study.

Given an IT project suite P = {p1, p2, p3, p4, p5} to be executed by an SME. Since it is not possible to know the business goals achieved by IT projects in advance. Table 1 presents the expected coverage of business goals.

Table 1. Business goals coverage

	BG1	BG2	BG3	BG4	BG5	BG6	BG7	BG7	BG8	BG9	BG10
P1	●	●						●	●	●	●
P2	●	●	●	●							
P3	●	●	●		●	●	●				●
P4	●	●					●				●
P5	●	●	●		●	●	●				●

According to the priority objectives presented in section 3, the results of each objective are shown in Table 2.

Table 2. Decision Matrix

	AS	BCR	NIB	PB	R	C
P1	0.3	5	6	1/2	1/100	11
P2	0.25	10	4	1/1.5	1/200	9
P3	0.2	15	7	1/2	1/100	12
P4	0.05	20	4	1/1	1/300	4
P5	0.2	10	7	1/3	1/400	7

Normalize the computation of each objective, the result is shown in Table 3.

Table 3. Normalized Decision Matrix

	AS	BCR	NIB	PB	R	C
P1	0.3	0.083	0.214	0.166	0.324	0.255
P2	0.25	0.166	0.142	0.222	0.162	0.209
P3	0.2	0.25	0.25	0.166	0.324	0.279
P4	0.05	0.333	0.142	0.333	0.108	0.093
P5	0.2	0.166	0.25	0.111	0.081	0.162

Calculate the prioritization value of each project with the six objectives, Figure 2 shows the results:

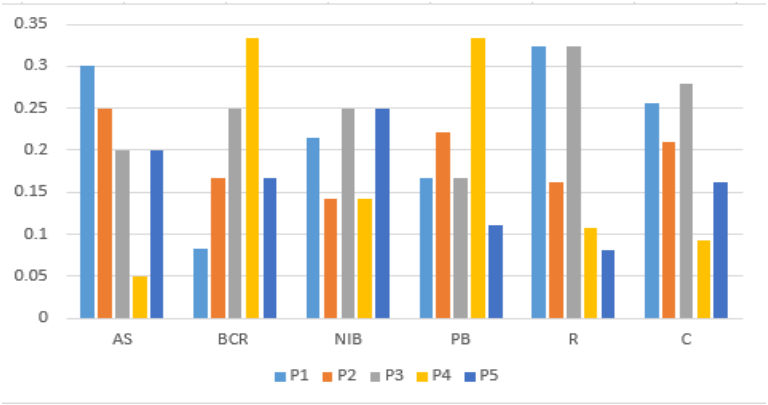

Figure 2. Comparison of results

As it is shown in Figure 2, IT project P4 can achieve high benefit with minimal payback period, but it cover less business goals than the other IT projects. Thus, high benefit cost ratio doesn't guarantee high business goals coverage. The optimal efficiency cannot be obtained by only one objective, that's calls for integrating multiple objectives in order to meet IT project portfolio strategic goals better.
Calculate the single objective f' based on the weighted sum:

f'(p1)=1/6*0. 3 + 1/6*0.083 + 1/6*0.214 + 1/6*0.166 + 1/6*0.166 + 1/6*0.255 =0.224
f'(p2)= 1/6*0. 25 + 1/6*0.166 + 1/6*142 + 1/6*0.222 + 1/6*0.162 + 1/6*0.209 =0.192
f'(p3)= 1/6*0. 2 + 1/6*0.25 + 1/6*0.25 + 1/6*0.166 + 1/6*0.324 + 1/6*0.279 =0.245
f'(p4)= 1/6*0. 05 + 1/6*0.333 + 1/6*0.142 + 1/6*0.333 + 1/6*0.108 + 1/6*0.093 = 0.176
f'(p5)= 1/6*0. 2 + 1/6*0.166 + 1/6*0.25 + 1/6*0.111 + 1/6*0.081 + 1/6*0.162 = 0.161

We sort the project by f', the obtained order is P'= {p3, p1, p2, p3, p4, p5}.

5.2. Evaluation of the Proposed Algorithm

Due to their limited resources, SMEs cannot proceed multiple projects simultaneously. Thus, the way IT projects are ranked in project portfolio remains critical and impact the success of SME strategy deployment.
In this paper, we are interested in the following research questions:

a. [**Q1**]: can multi-objective IT project prioritization improve the SME strategy deployment?

b. [**Q2**]: how do various IT project prioritization objectives presented in section 3 compare to one another in terms of effects on rate of business goals realized?

The classical metrics used for calculating project priority are based on financial terms (benefit cost ratio, payback period…) or based on the isolated performance of projects. These metrics cannot support the deployment of the corporate strategy. To overcome this problem, IT project alignment has emerged as a critical objective.

The mechanisms to ensure the validity of IT project alignment are rarely implemented in practice. Thus, we have proposed a new approach for quantifying IT/Business project alignment (Alignment score). It may happen that some business goals are not covered by any selected IT project. For balancing the portfolio, we have added a new metric for calculating business goals coverage. Finally, we have proposed a multi-objective algorithm for supporting the automatic selection of IT projects. In order to measure the effectiveness of our algorithm, we measure the percentage of IT project realized against percentage of business goals achieved.

To address our research questions, a metric is required to assess and compare the effectiveness of various project prioritization techniques. This metric plays the role of the function f presented in definition 1.

As a measure of how rapidly a prioritized IT project suite achieves the corporate business goals, we use a weighted average of the percentage of business goals achieved (APBG). This metric values range from 0 to 100. Higher APBG numbers mean faster business goals achieved. Figure 3 presents the results of calculation of APBG when performing a project portfolio based on single objectives and when using the multi-objective approach.

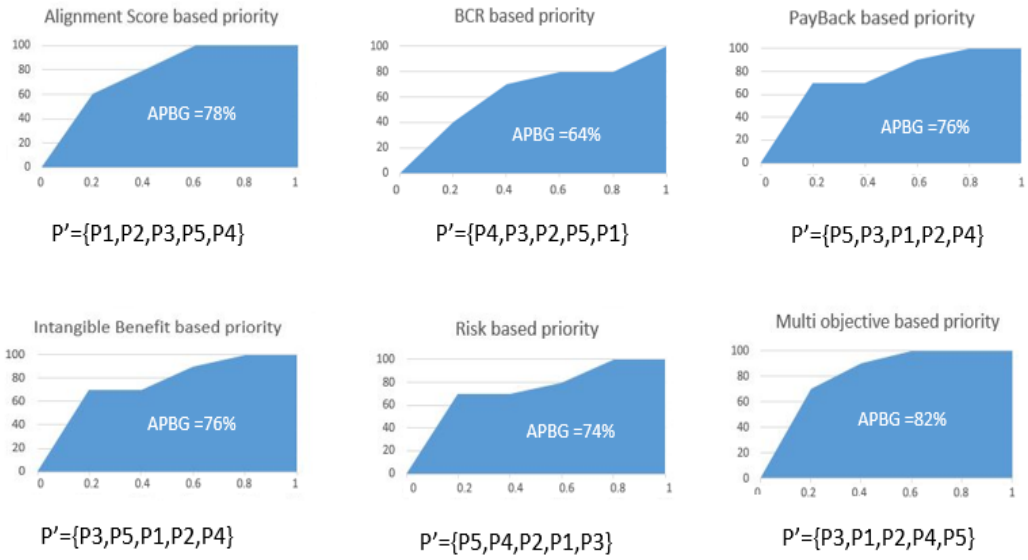

Figure 3. Comparison of results

As it is shown in Figure 3, the multi objective prioritization proposed algorithm is better than the others in terms of how rapidly the business goals are achieved over the life of a project portfolio. The area under the curve represents the weighted average of the percentage of business goals achieved over the life of a project portfolio. The results indicate that the proposed algorithm lead to improved rate of business goals achievement in comparison to single objective IT project prioritization.

5.3. Discussion of Results

With the aim of increasing the accuracy of project prioritization and maximizing the probability of the project portfolio success in small scale environment, this paper proposed a multi-objective algorithm for supporting SME strategy deployment trough project portfolios. In fact, the SME environment is totally different from that of large companies, so the concept of portfolio management need to be re-considered.

The proposed metrics presented in the literature for calculating project priority have been criticized for not supporting the deployment of the corporate strategy; there is a lack of metrics that take into account the interdependencies between projects that the portfolio is composed of. Project priority is calculated

separately without taking into consideration the interaction between projects. Further, there is no mechanism for ensuring that the selected IT project portfolio covers all the business goals that it has been designed for.

To fill this gap, we have introduced the concept of multi-objective optimization to the problem of project portfolio balance, by providing a multi-objective algorithm for the automatic selection of IT projects. As matter of fact, several elements which have a remarkable impact on affecting the project portfolio success has been taken into account to ensures the rapidly achievement of maximal business goals.

a. Alignment Score: we have proposed this metric to identify the strategic interdependencies between IT projects and calculate the alignment score of each project with the strategic objective desired by the implementation of a project portfolio.
b. Benefit Cost Ratio, Intangible benefits, Payback period and Project Risk: these metrics has been selected from latest researches to calculate the project risk/value.
c. Business goals coverage: we have proposed this metric to calculate the number of business goal covered by each project. The aim is to balance the project portfolio by selecting the project with the greatest coverage and then successively add those projects that cover the most yet uncovered business goals.

In order to measure the effectiveness of our algorithm, we have proposed a measure that calculates the percentage of IT project realized against percentage of business goals achieved (APBG). We have assessed and compare the effectiveness of our algorithm against various existing project prioritization techniques. It is found that our proposed algorithm can improve the rate of business goals achieved over the life of a project portfolio compared to single objectives presented in the literature.

6. CONCLUSION

This paper introduced the concept of multi-objective optimization to the problem of project portfolio balance. It proposed a new prioritization technique for improving the rate of business goals achieved based on six objectives: Alignment Score, Benefit Cost Ratio, Intangible benefits, Payback period, Project Risk, and Business goals coverage.

For comparing the effectiveness of various project prioritization techniques, we have developed a metric that calculate the average of the percentage of business goals achieved (APBG), it shows how rapidly a prioritized IT project suite achieves the corporate business goals.

The proposed IT project priority calculation technique is validated by analysing a portfolio of 5 IT projects, we have simulated several techniques for prioritizing IT projects and examined their relative abilities to improve how quickly business goals can be achieved over the life of a project portfolio.

Results obtained reveal that the proposed algorithm lead to improved rate of business goals and that single objective based priority is not always efficient and cannot support the corporate strategy deployment.

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