A METHOD FOR PORTFOLIO MANAGEMENT AND PRIORITIZATION

An Incremental Funding Method Approach

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Abstract: In today's very competitive business environment, making the best possible use of limited resources is crucial to achieve success and gain competitive advantage. To accomplish such a goal organizations have to maximize the return provided by their portfolio of future investments, choosing very carefully the IT projects they undertake and the risks they are willing to accept, otherwise they are bound to waste time and money, and still be likely to fail. This article introduces a method that enables managers to better evaluate the investment to be made in a portfolio of IT projects. The method favors the identification of common parts, avoiding the duplication of work efforts, and the selection of the implementation order that yields the highest payoff considering a given risk exposure policy. Moreover, it extends Denne and Cleland-Huang's ideas on minimum marketable feature modules and uses both Decision Theory and the Principles of Choice to guide the decisions made under uncertainty.

1 INTRODUCTION

In today's dynamic business environment where most organizations strive to gain competitive advantage over a myriad of competitors, the use of information technology (IT) is seen as a crucial tool to achieve such a goal. With its growing strategic importance, the expenditure on IT keeps on increasing rapidly and has become a dominant part of the capital budget of organizations in many markets (Chen et al., 2007).

Although businesses have invested enormous sums in IT, these investments have often proved to be unsuccessful, exceeded budget, and even harmed companies (Bingi et al., 1999; Chen, 2001; Somers and Nelson, 2003). Because of that, while IT projects are becoming more complex, due to the uncertainty about their economic impact, technological complexity, rapid obsolescence, implementation challenges, and so forth, the pressure imposed on managers to keep the balance between risk and payoff on their decision making is getting even bigger (Chen et al., 2007; S. Dewan, 2007).

To make information technology investment decisions easier McFarlan suggests that portfolio theory should be used to analyze and manage the money to be spent on IT (McFarlan, 1981).

An important lesson that comes from portfolio theory is the understanding that the values of investments or assets within a portfolio are often highly correlated. In other words, investment decisions are seldom taken in isolation (Markowitz, 1952; Silvius, 2008). Hence, project portfolio management (PPM) has been receiving increasing attention from both practitioners and researchers, as PPM practices advocate that the entire portfolio of projects have to be considered before a decision is reached on which projects should be given priority on implementation and which ones should be added or removed from the portfolio (Jeffery and Leliveld, 2004; Reyck et al., 2005).

This article introduces a method that enables decision makers to better evaluate the investments to be made in a portfolio of IT projects. Based on an organization risk taking or risk averse culture the method identifies the implementation order that yields the highest payoff and avoid the duplication of work.

The method extends Denne and Cleland-Huang's Incremental Funding Method (IFM) and their modularization ideas of minimum marketable features. Also, it uses both the Decision Theory

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and the Principles of Choice to support the decision making process under uncertainty.

The reminder of this article is organized as follows. Section 2 presents the conceptual framework the paper is based upon. Section 3 introduces the Incremental Funding Portfolio Management Method (IFPMM) with the help of a real world inspired example. Section 4 presents a discussion on the impact of the IFPMM on IT portfolio management and business strategy. Finally, section 5 presents the conclusion.

2 CONCEPTUAL FRAMEWORK

2.1 The Incremental Funding Method

The Incremental Funding Method (IFM) is a financially informed approach to software development that uses the Functional Class Decomposition concept (Chang et al., 2001) to decompose the system to be constructed into small self-contained software units that can be delivered quickly and whose features have value to business. This kind of units are called minimum marketable features, or MMF for short (Denne and Cleland-Huang, 2003; Denne and Cleland-Huang, 2004).

Besides MMFs, projects usually have an architectural infrastructure they may rely upon. As claimed by the IFM, this infrastructure can also be decomposed into self-contained deliverable units, which are meant to be constructed and delivered on demand (Denne and Cleland-Huang, 2003; Denne and Cleland-Huang, 2004). Such units are called architectural elements (AEs).

By decomposing a project into units that can be managed as "miniprojects", the IFM increases the likelihood of success for large-scale development efforts (Denne and Cleland-Huang, 2004). The benefits of this approach to software development projects are numerous:

- Large and complex systems can be developed from a relatively smaller investment,
- Bring financial discipline into software development practice,
- Return on investment is maximized,
- Demand for shorter investment periods and payback time are addressed,
- Favor faster time-to-market of projects that depends upon software development, and
- Position the software development process as a value creation activity in which business analysis is an integral part of it.

In the IFM, once the MMFs and AEs are identified, a window of opportunity is established in which these units are developed and provide value to business. When the window closes the software units are replaced by a more valuable alternative or discarded altogether.

Although MMFs and AEs are self-contained units, it is often the case that they can only be developed after other MMFs or AEs have been completed. This creates a dependency relation among such units, constraining the order in which they can be developed, thus limiting project sequencing options (Denne and Cleland-Huang, 2005).

For example, consider the set of MMFs and AEs whose development schedule is constrained by the precedence graph introduced in Figure 1. In that figure an arrow going from one unit to another, e.g. $AE_4 \rightarrow MMF_1$, indicates that the development of the former (AE_4) must precede the development of the latter (MMF_1). Table 1 shows the cash flow elements of these software units within their window of opportunity.

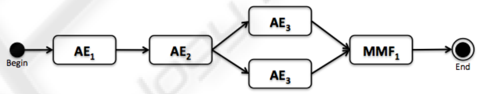

Figure 1: The project precedence graph.

Table 1: AEs and MMFs cash flow elements (US$1,000).

Unit	Period					
	1	2	3	4	···	30
AE_1	-27	0	0	0	···	0
AE_2	-70	0	0	0	···	0
AE_3	-40	0	0	0	···	0
AE_4	-14	0	0	0	···	0
MMF_1	-12	25	28	35	···	80

Note that while the AEs require some initial investment to be developed, they do not generate any revenue during the project lifecycle. For instance, AE_1 can be developed in just one period, requires US$ 27 thousand to be completed, and yield no revenue until the window of opportunity closes 29 periods later.

Although MMFs also requires some initial investment to be developed, once deployed they provide revenue to business over a certain number of periods. For instance, MMF_1 can also be developed in just one period, requires US$ 12 thousand to be completed, and generates US$ 25 thousand in the second period, US$ 28 thousand in the third, and so on and so forth. The revenue returned by an MMF is often the result of cost savings, competitive differentiation, brand-name projection, and enhanced customer loyalty (Denne and Cleland-Huang, 2003;

Denne and Cleland-Huang, 2004).

Counterpointing to the IFM objective, looking at just one single project at a time and optimizing its Net Present Value (NPV) is not quite the main goal of most organizations, which usually have limited resources, several investment options and prefer to benefit from the analysis of portfolios of IT projects instead (Jeffery and Leliveld, 2004; Reyck et al., 2005).

Moreover, the way the cash-flow elements of MMF and AEs are calculated by Denne and Cleland-Huang (*op. cit.*) prevent them from adequately reflecting real world circumstances, where it is often the case that the investment required to develop a software unit and the revenue it generates cannot be precisely determined in advance.

To deal with real world situations, one has to consider the inherent uncertainty associated to future values of cash-flow elements. Besides, the literature has repeatedly indicated software development as a complex and risky activity (Westerman and Hunter, 2007). Hence, as results obtained under uncertainty can be quite different, the valuation of software projects should always take uncertainties into account (Abdellaoui and Hey, 2008; Barbosa et al., 2008; Schmitz et al., 2008).

In many circumstances, a triangular probability density function (TPDF) is used to represent the uncertainty described in cash flow elements. This TPDF is obtained by estimating a lower bound (*Min*), an upper bound (*Max*) and the most likely value (*ML*) for each period, as presented in Table 2. According to Hubbard (Hubbard, 2007), the lower bound, most likely and upper bound values are more easily obtained considering the worst, most likely and best case among all reasonable scenarios.

Table 2: Cash flow streams under uncertainty (US$ 1,000).

Unit	Period			
	1 (Min,ML,Max)	2 (Min,ML,Max)	···	30 (Min,ML,Max)
AE_1	(-35,-24,-20)	(0, 0, 0)	···	(0, 0, 0)
AE_2	(-80,-75,-60)	(0, 0, 0)	···	(0, 0, 0)
AE_3	(-50,-35,-30)	(0, 0, 0)	···	(0, 0, 0)
AE_4	(-18,-12,-10)	(0, 0, 0)	···	(0, 0, 0)
MMF_1	(-15,-12,-10)	(20,23,30)	···	(70, 85, 90)

2.2 Decision Making under Uncertainty

When all the possible alternatives have known outcomes and their consequences can be described using a single measure, then making a choice among them is an easy task. Otherwise, whenever any sort of uncertainty is present, the choice becomes more difficult.

As presented by Holloway (Holloway, 1979), there are four characteristics that can increase the difficulty of making choices, turning decision problems into complex decision problems, namely:

- *a large number of factors* – which is often the case for financial problems, such as investments decision making;
- *more than one decision maker* – a common situation to most of the existing business;
- *multiple attributes* – whenever more than one aspect is needed to describe the outcome of a decision and one has to balance between them, such as profit and risk; and
- *uncertainty* – which is inherent to any kind of IT project and to the dynamic environment that surrounds software development.

When handling portfolios of IT projects and analyzing the resulting investment options, an organization usually faces all these difficulties. As the variables of interest incorporate uncertainty, they become random variables and, consequently, may be represented as Probability Density Functions (PDF) (Kotz and van Dorp, 2004).

Therefore, a method to analyze these PDFs and make investment decisions under uncertainty is a "must have" for every single IT decision maker. The methods of direct choice under uncertainty are classified in three groups (Holloway, 1979): probabilistic dominance, summary measures and aspiration-level.

As stated by the *probabilistic dominance criterion*, in circumstances where the probability of one of the alternatives achieving any value is greater than or equal to the probability of any other alternative achieving that value, then this alternative probabilistically dominates all the others.

Hence, probabilistic dominance is a compelling reason for choosing one alternative over another. Figure 2 presents an example where alternative *1* probabilistically dominates alternative *2*.

However, it is not often the case that probabilistic dominance can be applied. In circumstances where dominance does not exist, each alternative must be analyzed regarding its risks and payoffs. During this analysis, it is very important to consider whether one is dealing with a risk-taken or risk-averse organization. Figure 3 presents the cumulative density function of three alternatives, namely *A*, *B* and *C*, where none of them probabilistically dominates the others.

Despite trying to assimilate the entire probability distributions, the analysis and further comparisons of alternatives can be done through the use of *Summary*

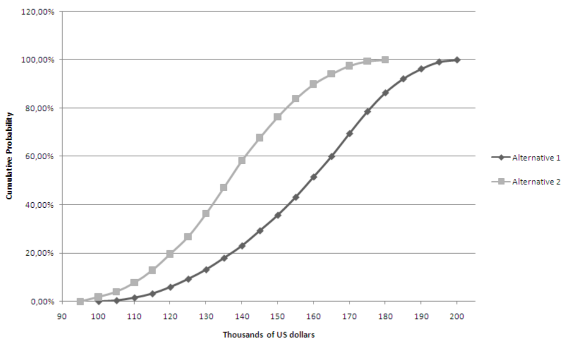

Figure 2: CDF with probabilistic dominance.

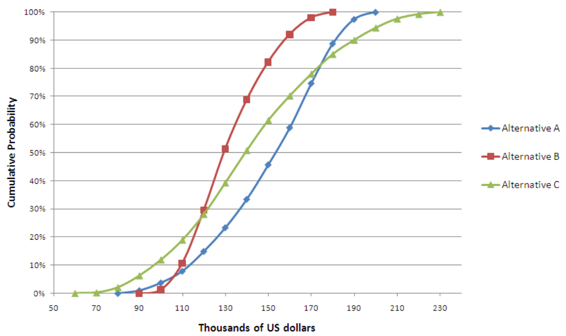

Figure 3: CDF without probabilistic dominance.

Measure Criterion, which consider values such as mean, minimum, and maximum, among others (Holloway, 1979). According to the decision theory (Lang and Merino, 1993; White, 2006), the following principles are used to take decisions under uncertainty based on summary measures:

- *Maximin or Minimax Principle* – this principle always considers the worst case scenario in the decision making process, choosing the alternative that has the highest minimum revenue or the lowest maximum cost, depending on the criterion one is using. To analyze the example introduced in Figure 3, the organization would compare the **minimum** values presented in Table 3, choosing alternative *B* as the best investment option, which yields at least a US$ 90,000.00 profit.

Table 3: Return of each investment option (US$ 1,000).

Alternative	Minimum	Mean	Maximum	H_{CV}
A	80	150	200	164
B	90	132	180	153
C	65	142	230	179

- *Maximax or Minimin Principle* - In contrast to the previous principle, the Maximax and Minimin principle always consider the best case scenario in the decision making process, choosing the alternative that has the highest maximum revenue or the lowest minimum cost. Using the Maximax principle within the example of Figure 3, the organization would consider the **maximum** values presented in Table 3, selecting *C* as the best investment option, which can yield a revenue as high as US$ 230,000.00.
- *Equal Likelihood (Laplace) Principle* – this principle assumes that all possible outcomes are equally likely to occur. Based on this assumption, it considers the mean value of all the possible alternatives and selects the highest one. Table 3 also presents the **mean** values from the alternatives within the Figure 3 example. By using the Laplace principle, the organization would choose the alternative *A* as the best investment option.
- *Hurwicz Principle* – instead of making decisions based on just one summary measure such as the previous principles, Hurwicz combines both minimum and maximum values, creating a balance between them. Such a balance is achieved by using an index of optimism (α), which is estimated by specialists and vary from organization to organization. Once α is defined, the Hurwicz criterion value (H_{CV}) is given by Equation 1.

$$H_{CV} = \alpha * Max(\text{Profit}) + (1-\alpha) * Min(\text{Profit}) \quad (1)$$

Table 3 presents the H_{CV} of each alternative within the example, considering α equal to 70%. In this scenario, an organization using the Hurwicz principle would prefer alternative *C* to any other investment option.

- *Minimax Regret (Savage) Principle* - analogous to the Hurwicz principle, it also considers both minimum and maximum values to analyze each one of the alternatives, but in a completely different manner. The objective is to compare these two values and compute the maximum regret of each alternative, which is calculated considering the difference between the best and the worst outcome that it can achieve. The maximum regret table from the Figure 3 example is presented in Table 4. Once the maximum regret is computed, this principle chooses the alternative that minimizes it. In this case, the decision maker would choose alternative *B* as the best investment option.

Another useful criterion to be applied is to base the comparison on some aimed output value that is very important to the organization. The *Aspiration-Level Criterion* maximizes the probability of achieving such a value. To illustrate, assume that in the

Table 4: Maximum regret per alternative.

Alternative	Maximum Regret
A	US$ 120,000.00
B	US$ 90,000.00
C	US$ 165,000.00

Figure 3 example the decision maker defines that it is extremely important to have at least a US$ 120,000.00 profit. Table 5 presents the probability of achieving a profit equal to or greater than US$ 120,000.00 for each alternative. Using the aspiration-level criterion, alternative *A* would be chosen.

Table 5: Probability of achieving the aspiration level.

Alternative	Prob. of US$ 120,000.00 or more
A	85%
B	70%
C	72%

As aforementioned, it is up to organizations to define which is the most suitable criterion to be used in their decision making process under uncertainty. This criterion of choice may vary from organization to organization, depending on their objectives and predefined risk-exposure policy.

3 THE METHOD

For better understanding, the method proposed in this paper is introduced and explained step-by-step throughout this section with the help of a real-world inspired example[1].

Step 0: Context Information. Consider a large mobile telecommunication carrier such as AT&T, Verizon, Sprint, T-Mobile, Vodafone, Telefónica and many others, which have millions of subscribers and provide different kinds of services for voice, data, and broadband. For the purpose of this paper this organization is called World Mobile Telecom Corporation, or WMTC for short.

Technology advances in telecommunications have brought significant changes in the services provided by mobile carriers around the world. As a result, WMTC's competitors are struggling for strategic advantages that would enable them to gain market share and even surpass WMTC.

Furthermore, a growing number of customers conscious of their bargaining power are demanding for better products and services for reduced prices, so the need for innovation and differentiation is increasing rapidly. Therefore, as WMTC wants to advance its position as a major player in the mobile telecommunication business, it must undertake the right tactical and strategic projects, making the best possible use of its limited human and financial resources.

Considering that there is not enough resources to run all projects that are necessary to increase its market share, WMTC Board of Directors became firmly convinced that the company has to adopt decision theory and principles of choice to get the most out of its investment in IT.

However, due to shortage of funds caused by the world financial crises, WMTC was forced to reduce drastically its number of employees. Counting on just one development team, they need to ensure that the company concentrates their efforts on maximizing the benefits of their diversified portfolio of IT projects.

Table 6 presents the projects comprising WMTC's portfolio, which are meant to support a strategic move against growing competition in its market.

Table 6: WMTC's portfolio of strategic IT projects.

Id	Project	Description
GSP	Goods and Services Purchase	Allows subscribers can go shopping with nothing else but their mobile phones, using it as a credit card to pay for goods and services in associated stores.
EP	Mobile Entertainment Pass	Lets subscribers to search for movies, plays and shows, browse their synopsis and buy tickets directly from their mobile phones. Subsequently to purchasing a ticket, subscribers receive an SMS with a queue avoiding electronic ticket.
M^+	Message+	Enables subscribers to have an e-mail browser experience when handling SMS (short message service) and MMS (multimedia message service). Users can store, search, send, forward, redirect, auto reply, copy, and also maintain an e-address book of their contacts.
VM	VideoMail	Make it possible for subscribers to receive, store and retrieve messages whenever they can not answer an incoming video call.
VoIP	VoIP Service	Delivers voice over internet protocol to subscribers who already have an unlimited data plan.

Step 1: Identifying the MMFs and AEs within WMTC's Portfolio of IT Projects. If one is willing to take advantage of Denne and Cleland-Huang's ideas on minimum marketable features (*op. cit.*), the

[1]The data used to obtain the results presented in this paper is closely related to real data provided by one of the Latin America's largest mobile network operator. Because the data reflects the current portfolio of on-going IT projects of this organization and, as a result, part of its business strategy, the authors have been kindly requested not to disclose its name.

projects in the WMTC portfolio have to be decomposed into AEs and MMFs, so that they can be incrementally delivered to customers as “miniprojects”. Tables 7, 8, 9, 10 and 11 introduce the AEs and MMFs identified by the WMTC’s Project Management Office (PMO).

Table 7: Goods and services purchase MMFs.

Id	Type	Name	Description
GSP_1	AE	Service subscription	Allows customers to subscribe to and unsubscribe from the service
GSP_2	AE	Credit analysis	Figures the likelihood of a customer paying a debt according to pre-established dates and values
GSP_3	AE	M-Payment	Lets customers pay for goods and services they want to buy in associated stores
GSP_4	AE	Refund	Allows customers to be refunded when returning goods and services they bought in associated stores
GSP_5	MMF	Shopping	Entitles customers to shop for goods and services in associates stores. This includes paying and on occasion being refunded for the goods and services they have bought

Table 8: Mobile entertainment pass MMFs.

Id	Type	Name	Description
EP_1	AE	Service subscription	Allows customers to subscribe to and unsubscribe from the service
EP_2	AE	Credit analysis	Figures the likelihood of a customer paying a debt according to pre-established dates and values
EP_3	MMF	Search movie	Allows customers to search for movies, plays and shows based on multiple criteria such as: title, cast, district, theater and genre
EP_4	MMF	Browse synopsis	Make it possible for customer to browse among movie, play and show synopses
EP_5	AE	Captures customer location	Gathers information about the current customer location (GPS or tower based)
EP_6	MMF	Buy ticket	Allows customers to choose which specific theater or showroom seat they would like to purchase, charges the ticket value to the customer’s account and provides a queue avoiding electronic ticket
EP_7	MMF	Browse nearby places	Provides information on all theaters and showrooms in the vicinity of the current customer location

Step 2: Establishing the Precedence between identified Software Units. One of the main benefits of organizing MMFs and AEs in a portfolio is the possibility of more easily identifying common software units. By factoring out such units one may reduce the portfolio’s time-to-market and cost, at the same time that increases quality (Pressman, 2009).

Table 9: Message+ MMFs.

Id	Type	Name	Description
M_1^+	AE	Service subscription	Allows customers to subscribe to and unsubscribe from the service
M_2^+	AE	Credit analysis	Figures the likelihood of a customer paying a debt according to pre-established dates and values
M_3^+	AE	Store messages	Stores SMS and MMS messages received by customers
M_4^+	AE	Organize inbox	Allows customers to order messages by different parameters, delete messages and search for specific messages
M_5^+	AE	Reply	Allows customers to edit a text and use it to reply to a message
M_6^+	AE	Send & Forward	Sends a new and an existing message to a given address (email or phone number) or a set of addresses
M_7^+	MMF	Manage inbox	Allows customers to organize their message boxes, send, reply to and forward messages
M_8^+	MMF	Auto reply & redirect	While “on” automatically replies to any received message or redirects all received messages to a given address (email or phone number)
M_9^+	MMF	Use contacts info	Lets customers to use informations from their contact lists when sending or forwarding messages, such as contact name, phone number and email address

Table 10: VideoMail MMFs.

Id	Type	Name	Description
VM_1	AE	Service subscription	Allows customers to subscribe to and unsubscribe from the service
VM_2	AE	Credit analysis	Figures the likelihood of a customer paying a debt according to pre-established dates and values
VM_3	AE	Recorder	Lets callers to record a video message when their incoming video calls are not answered
VM_4	AE	Password input	Authenticates subscribers, granting access to their VIDEOMAIL accounts
VM_5	MMF	Listen to video mails	Allows customers to retrieve a recorded video message from their mail boxes
VM_6	MMF	Manage video mails	Allows subscribers to store or delete a video message, change their VIDEOMAIL welcome message and also retrieve the caller’s id

When analyzing the portfolio of strategic IT projects, the WMTC PMO identified two software units that are common to two or more projects, i.e. “Service subscription” (CSU_1) and “Credit analysis” (CSU_2).

Table 11: VoIP service MMFs.

Id	Type	Name	Description
$VoIP_1$	AE	Service subscription	Allows customers to subscribe to and unsubscribe from the service
$VoIP_2$	AE	Credit analysis	Figures the likelihood of a customer paying a debt according to pre-established dates and values
$VoIP_3$	AE	Manage buddies	Allow subscribers to search, add and delete buddies from their buddy list
$VoIP_4$	MMF	Call buddy	Call a buddy directly from the buddy list using voice over internet protocol (VoIP)
$VoIP_5$	AE	Link buddy and contact	Link a VoIP buddy to an existing contact in the subscriber contact list
$VoIP_6$	MMF	Call contact	Call a buddy directly from the contact list, using the link between the contact and the VoIP buddy

Figure 4, together with Figures 5, 6, 7, 8 and 9, introduce the precedence graph of all software units in the WMTC's portfolio of strategic IT projects.

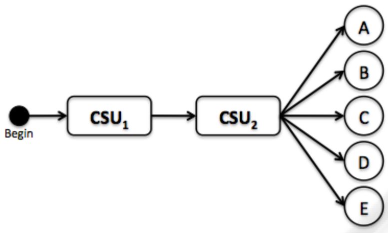

Figure 4: WMTC's portfolio precedence graph.

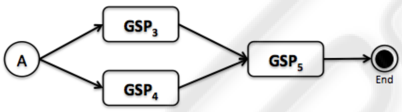

Figure 5: Goods and service purchase precedence graph.

Figure 6: Mobile entertainment pass precedence graph.

Figure 7: Message+ precedence graph.

Step 3: Forecasting the Inflows and Outflows of Software Units within the WMTC Portfolio. Once the AEs and MMFs have been identified and arranged into a precedence graph, their estimated

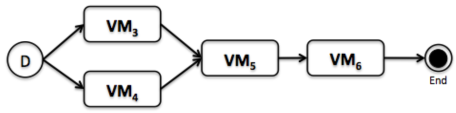

Figure 8: VideoMail precedence graph.

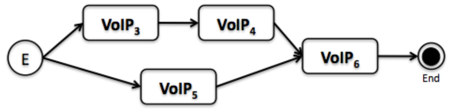

Figure 9: VoIP service precedence graph.

costs and revenues should be calculated and, subsequently, analyzed over the window of opportunity that defines the portfolio lifecycle. See (Hubbard, 2007) for guidelines on how IT project cost and revenue may be properly calculated.

To take uncertainty into account WMTC decided to consider the worst (*Min*), the best (*Max*), and the most likely (*ML*) scenario for the value of each MMF and AE cash flow element. Then, these elements were modeled as triangular probability density functions. Table 12 presents these values.

Table 12: WMTC's AEs and MMFs cash flow (US$ 1,000).

Unit	Period			
	1 (Min,ML,Max)	2 (Min,ML,Max)	⋯	30 (Min,ML,Max)
CSU_1	(-35,-24,-20)	(0, 0, 0)	⋯	(0, 0, 0)
CSU_2	(-80,-75,-60)	(0, 0, 0)	⋯	(0, 0, 0)
GSP_3	(-50,-35,-30)	(0, 0, 0)	⋯	(0, 0, 0)
GSP_4	(-18,-12,-10)	(0, 0, 0)	⋯	(0, 0, 0)
GSP_5	(-15,-12,-10)	(20,23,30)	⋯	(70, 85, 90)
EP_3	(-34,-29,-25)	(15,17,25)	⋯	(45, 58, 60)
⋮	⋮	⋮	…	⋮
$VoIP_6$	(-20,-16,-10)	(10,13,20)	⋯	(0, 0, 0)

Step 4: Generating Scenarios and selecting the Best Sequencing Options. Once the portfolio's precedence graph is built and their unit's cash flows are estimated, the PMO must identify the most attractive sequencing option, together with its net present value (NPV).

Considering that their cash flow elements are statistically correlated and that this correlation exists both between elements of the same cash flow stream (CFS) and elements of different CFSs within the portfolio, the NPV can not be approximated by Laplace's Central Limit Theorem (CLT), which is only suitable to a sum of n independent random variables. However, good computational approximations can be obtained using sampling procedures like the Monte Carlo method (Robert and Casella, 2005).

Using a Monte Carlo simulation tool, the WMTC

PMO decided to sample values for each cash flow element based on its triangular distribution to generate one possible scenario and then use these values, together with the branch and bound algorithm, to obtain the optimal portfolio sequencing option, which is the one that yields the maximum NPV. See (Alencar et al., 2008) for guidelines on how to use the the branch & bound algorithm to compute the optimal implementation order in IT projects.

Posterior to the generation of 10,000 scenarios, there was a total of ten sequencing options that were chosen as optimal in one or more scenarios. Table 13 presents these sequences.

Table 13: Selected sequencing options.

Id	Sequence
Seq_1	CSU_1, CSU_2, EP_3, EP_4, EP_6, $VoIP_3$, $VoIP_4$, EP_5, EP_7, GSP_3, GSP_4, GSP_5, VM_3, VM_4, VM_5, $VoIP_5$, $VoIP_6$, VM_6, M_3^+, M_4^+, M_5^+, M_6^+, M_8^+, M_7^+, M_9^+
Seq_2	CSU_1, CSU_2, EP_3, EP_4, EP_6, EP_5, EP_7, $VoIP_3$, $VoIP_4$, GSP_3, GSP_4, GSP_5, VM_3, VM_4, VM_5, $VoIP_5$, $VoIP_6$, VM_6, M_3^+, M_4^+, M_5^+, M_6^+, M_8^+, M_7^+, M_9^+
⋮	⋮
Seq_6	CSU_1, CSU_2, EP_3, EP_4, EP_6, EP_5, EP_7, $VoIP_3$, $VoIP_4$, GSP_3, GSP_4, GSP_5, $VoIP_5$, $VoIP_6$, VM_3, VM_4, VM_5, VM_6, M_3^+, M_4^+, M_5^+, M_6^+, M_7^+, M_9^+, M_8^+
⋮	⋮
Seq_{10}	CSU_1, CSU_2, EP_3, EP_4, EP_6, EP_5, EP_7, $VoIP_3$, $VoIP_4$, $VoIP_5$, $VoIP_6$, GSP_3, GSP_4, GSP_5, M_3^+, M_4^+, M_5^+, M_6^+, M_7^+, M_9^+, M_8^+, VM_3, VM_4, VM_5, VM_6

Step 5: Resampling the Selected Sequencing Options. As the number of sequencing options generated in *Step 4* is quite small and some of them did not have enough values to generate the cumulative density function (CDF) of their NPV, all of them were taken through a resampling, generating another 10,000 scenarios.

The data collected in these new scenarios was used by WMTC to built the CDF of the NPV from selected sequences and reach the required error margin, within a predefined confidence interval. Figure 10 presents these results.

Step 6: Choosing the Best Sequencing Option. Afterward, WMTC PMO compared all the simulation results obtained in *Step 5* to decide which is the best implementation order, considering all the sequencing options.

As the WMTC's board of directors has defined that the organization needs to generate at least a US$ 4,000,000.00 revenue from the portfolio to advance its position as a major player in the mobile telecommunication business and also to reach the Latin

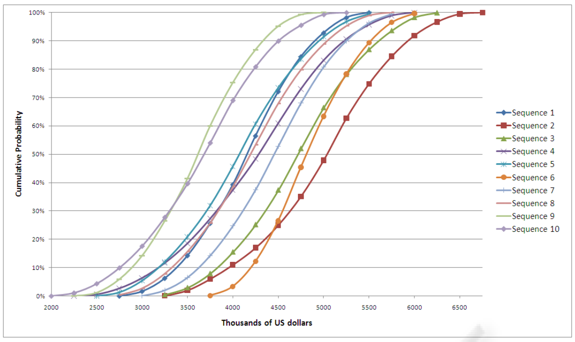

Figure 10: Portfolio's NPV for the selected sequences.

America's leadership on the last key performance indicator, which is the average revenue per user (ARPU). Considering this aspiration, the PMO has decided to maximize the probability of attaining such a goal.

In the first step, making use of the Probabilistic Dominance criterion, the PMO was able to restrict even more the number of sequencing options which should be compared. This was accomplished by eliminating sequences 1, 4, 5, 7, 8, 9 and 10, which were outperformed and probabilistically dominated by sequences 2, 3 and 6.

Applying the Aspiration Level criterion on the comparison of the remaining options, the PMO stated that sequences 2, 3 and 6 have, respectively, 89%, 84% and 97% probability of achieving an actual revenue equal to or higher than the targeted one. For that reason, the PMO defined that Seq_6 was the best implementation order for the WMTC's portfolio.

These results were presented by the PMO to the WMTC board of directors, who decided to undertake the presented strategy as a guidance to manage their portfolio and prioritize their projects.

In fact, it should be noted that Seq_2, which presents the best results under the mean value, is outperformed by Seq_6 when taking uncertainties into account and considering the Aspiration Level criterion with the values previously defined by the WMTC's board of directors.

4 DISCUSSION

At the outset of this paper the authors presented a method that provides a comprehensive way to analyze investment options, balance their expected return against their risk, and decide how to prioritize the IT projects within one's portfolio, enabling organizations to maximize their payoffs. In this section, some of the key questions regarding the use and implications of the proposed method are addressed.

A. Why have MMF and AE's Cash Flow Elements been Extended?

As presented in the IFM (Denne and Cleland-Huang, 2003), each one of the cash flow elements should be estimated using the cost and revenues projections made by the development team and the customer, respectively.

The literature has stated that that IT projects are provenly high-risk investments and have high rate of failure (Whittaker, 1999; Biehl, 2007; Westerman and Hunter, 2007). When the proposed method considers the worst (*Min*), the most likely (*ML*) and the best case (*Max*) scenarios to each cash flow element, it automatically includes the inherent uncertainty from real world circumstances, where there is an associated risk to each cost and revenue projection.

Consequently, the method transforms each one of the cash flow elements into random variables (Kotz and van Dorp, 2004), which are presented as a triangular probability density functions that are to be used to balance between risks and benefits of a given module's cash flow stream (Hubbard, 2007; Schniederjans et al., 2004).

B. How to define the Most Suitable Decision making Criterion?

After the resampling, there are some scenarios that are possible to be presented. Depending on the organization's risk-tolerance policy, a different method is to be used in their decision making process. These methods and corresponding situations where they shall be applied are presented below:

1. Probabilistic Dominance – it is a compelling reason for choosing one sequencing option over another, despite of being a risk-taken or risk-averse organization.
2. Maximin Principle – comparing the worst case of alternatives, this is a pessimistic decision making and it is usually used by extremely conservative organizations, which are willing to choose the alternative that would have the lowest impact in case of going wrong.
3. Maximax Principle – comparing just the best outcomes, this method should be considered by organizations that are risk-seeking, with the objective of having the highest possible return on investment.
4. Laplace Principle – whenever all the attainable outcomes have the same probability to occur, the comparison of alternatives using their mean is a reasonable approach for risk-neutral decision makers.
5. Hurwicz Principle – balancing between methods that are either too optimistic or too pessimistic, it should be considered by risk-neutral organizations that are able to define the index of optimism in which this principle relies on.
6. Savage Principle – considered a risk-averse method, its main objective is to minimize the risks and choose the alternative that yields the lowest variance, which is an alternative for the Maximin principle for conservative decision makers.
7. Aspiration Level – it is often the case where an organization defines a result that is very important to obtain. To maximize the probability of having an actual result equal to or higher than the desired one, this method shall be used.

C. How do Organizations benefit from the Method?

As technology investments are inherently risky and are becoming the dominant part of many organizations' expenditures, IT projects are becoming even more complex and difficult to undertake. Therefore, the use of a comprehensive investment management tool – to effectively allocate the resources and prioritize IT projects within a portfolio – is a "must have".

By decomposing IT projects into self-contained software units that can be managed as "miniprojects", analyzing their risk-return information, and providing insights into the existing sequencing options, the proposed method unveils the power of combining together the IFM (Denne and Cleland-Huang, 2003), Decision Theory (Holloway, 1979) and Principles of Choice (Lang and Merino, 1993; White, 2006) to maximize the investments' efficiency. The benefits of this approach to PPM are numerous:

- Enable portfolios comprised of large and complex IT projects to be managed with a relatively smaller initial investment,
- Identify units that are common to different projects, remove duplication and improve quality,
- Bring financial discipline into the IT portfolio management,
- Identify risks and investment prioritization options,
- Identify the most suitable investment option to each organization,
- Maximize the efficiency of investments in portfolios of IT projects,
- Demand for shorter investment periods and payback time are addressed,

- Favor faster time-to-market of the portfolio, and
- Position the IT portfolio management as a value creation activity in which business analysis is an integral part of it.

5 CONCLUSIONS

To the best of our knowledge, this work is the first to create a portfolio management method based upon the Incremental Funding Method (IFM).

The Incremental Funding Portfolio Management Method (IFPMM) extends the IFM to decompose software projects into self-contained software units, including the inherent uncertainty of software development process into their cash flow streams and considering the whole portfolio of IT projects, rather than making investments decisions in isolation. Besides, it uses decision theory together with principles of choice to analyze each unit risk-return information and prioritize their implementation, defining the best sequencing option considering the organization's risk tolerance.

The IFPMM provides crucial insights into the business value of IT portfolios, facilitating the decision making process and considering the organization approach to business. Besides, it also provides a technique to assure that investment choices are always as efficient as possible, permitting portfolios comprised of large and complex IT projects to be managed with a relatively smaller initial investment, demanding for shorter investment periods, and also providing shorter payback times and faster time-to-market.

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