Maximizing the Appropriation of the Intangible Benefits Yielded by IT Investments in the Public Sector

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***Abstract*— These days information technology (IT) is well known for the critical role it plays in earning and sustaining competitive advantage, and also for yielding a myriad of intangible benefits that are hard to quantify. If an investment in IT is aimed at improving services in the public sector, then the chances of running into intangibles are much higher. After all, voters' support, spontaneous media exposure, pressure-groups' reactions, public security and people's well-being are common concerns in the conception and deployment of government ideas and projects. This paper presents a method that facilitates the evaluation of IT investments in the public sector. The method enables public officers to maximize the appropriation of the intangible benefits yielded by the investments they make in IT.**

***Index Terms*— IT investment analysis, intangible benefits, public sector, value-based software engineering.**

I. Introduction

Since the government is one of the main gatherers, processors and users of information in modern society [1], the interest of civil servants in IT emerged quite naturally in the early stages of the electronic information era in the 1950s. For instance, the first commercial electronic computer produced in the United States, the UNIVAC I, was delivered to the US Census Bureau, a government agency, in 1951, which used it to analyse social and economic series, and make predictions [2].

The next five UNIVACs produced were delivered to the US Air Force, the US Army Map Service, the US Atomic Commission (which received two UNIVACs) and the US Navy. These government organizations used their brand new UNIVAC computers, among other things, to control stock, calculate ballistic tables, predict election outcomes and transform combat data into overall tactical maps [3], [4].

Not surprisingly, the history of IT in its early stages is no different in many other countries, including the United Kingdom, France, Germany and Canada, in which government were early adopters of IT [5], [6].

Nevertheless, over the course of time, the role that IT plays in government has changed quite substantially. From a technology that allows calculations to be performed at great speed, IT has subsequently been used to automate mission critical processes and analyse sensitive information. More recently, IT has been used to improve tax collection and support decision making at different managerial levels [7].

As democratic governments strive to improve the health, education and economic prospects of their citizens, they increasingly look at IT as a strategic tool that allows better decisions to be made. As a result, today IT pervades all branches of government, be they executive, legislative or judicial [8], [9].

Moreover, in each branch IT plays a critical role in the delivery of all kinds of public services. Internal and external security, infectious disease control, weather forecast, tax collection, food safety, driver license issue and patent registration are just a few examples of public services that tend to rely upon IT for punctual delivery [10].

With the advent of the Internet a body of new computerized systems has been developed to make public services more readily available to all, and also to facilitate the interaction among government agencies and between the government and private businesses. The term "E-Government", short for electronic government, has been coined to describe such a body of systems [8]–[10].

Nonetheless, despite all the qualifications and experience that government officials may have gained over the years, investing in IT is still likely to be one of the most challenging undertakings that decision makers in the public sector face today [11].

What makes the whole endeavor so difficult is not solely the potential consequences of such investment decisions, which are far reaching these days. One must also consider the diversity of service providers, packaged solutions, development platforms and new untested technologies one may choose from, together with the myriad of intangible benefits yielded by IT projects, which are difficult to quantify [12].

Hence, IT investment evaluation methods are naturally expected to be able to deal with intangibles in a satisfactory manner. Regardless, many of the methods that have been put forward so far rely upon financial performance indicators that are widely recognized as being inadequate

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to deal with the qualitative aspects of intangibles on their own. The net present value (NPV), return on investment (ROI) and internal rate of return (IIR) are examples of such indicators [13].

Among the IT evaluation methods that do take intangible benefits into consideration, most of them have chosen to ignore that it is frequently the case that IT projects can be split into smaller valuable subprojects, with a high degree of separation of concerns [14].

Furthermore, they completely overlook the fact that most often projects have to be completed within an allocated time frame. Hence, not necessarily all subprojects of an IT projects are implemented. Finally, the choice of the subprojects that are actually going to be implemented, and the order in which they are run, may substantially affect how the benefits are appropriated [15].

This paper presents a method for analysing IT investment in the public sector. It encourages managers and decision makers to maximize the appropriation of the intangible benefits yielded from such investments. However, it does not ignore the fact that the financial aspects of IT investment are also relevant to the appraisal process and should be properly considered. Moreover, the method acknowledges the following in an appropriate manner:

- IT investments are usually comprised of one or more projects, which are frequently split into subprojects;
- Time constraints are likely to prevent the development of all possible subprojects and
- The order in which the subprojects are run may reflect upon the appropriation of both tangible and intangible benefits.

The remainder of this paper is organized as follows. Section II presents a review of the principal concepts and methods used in the subsequent sections. Section III introduces the method presented in this paper. Section IV demonstrates the method with the help of a reasonably complex example. Section V compares the method with other possible alternatives. Section VI presents the conclusions of this paper.

II. Conceptual Framework

A. The underlying example

According to Seneca (5 BC - 65 AD), the revered Roman philosopher and politician: “The path of precept is long, that of example short and effectual” [16]. As a result, the example that follows is used to help make the concepts, methods and techniques presented throughout this paper easier to grasp.

With this goal in mind, consider a city of four million inhabitants such as Houston in the USA, Milan in Italy or Alexandria in Egypt. Allow this particular city to be an international center for technological development and innovation. For the purpose of this paper such a city is referred to as *Innovatus*, which is Latin for the introduction of new ideas.

IT being one of the main sources of innovation these days, the Innovatus’ mayoress wishes to run some innovative IT projects that tackle issues that are important to her citizens. Table I describes these projects.

In line with the democratic spirit, current legislation limits the time that the heads of municipal governments can stay in office. Hence, Innovatus’s mayoress wishes as many of these projects as possible to be completed during her administration. However, as there are many other projects to be run and financial and non-financial resources are currently scarce, only one IT innovative project can be run at any given time. Also, the capital investment required by these projects should be spent efficiently.

B. Intangibles

It is usually accepted that an asset is something of value that can be owned or controlled. Houses, parking spaces, patents, the right to buy shares at a certain price and club memberships are common examples of assets [17].

It should be noted that the value of an asset stems from the benefits that it provides or may provide to its owner or controller. A house, for example, can be sold or rented and the resulting capital can then be used to buy products and services, and also to start or consolidate new ventures. The same line of thinking can be applied to parking spaces, patents, the right to buy shares at a certain price and club memberships [18].

However, some of the benefits stemming from an asset are intangibles, i.e. they stem from subjective perceptions of reality that do not have a physical or financial embodiment. Boosted employee moral, high job satisfaction, enhanced customer loyalty, trust in management and confidence in the future of a company are examples of intangible benefits which usually stemming from good strategy and management [19].

Moreover, it is a well-established phenomena that many decisions that one makes throughout one’s life are at least partly based upon the perceived value of intangible benefits. For instance, when considering an invitation for a business lunch or dinner, one is likely to take into account the opportunities that such an invitation may bring about. In addition, one may also consider the social and professional implications and, perhaps, the reputation of the restaurant where the delicacies are going to be served.

All these considerations are intangibles. Nonetheless, if the opportunities are attractive, the implications are positive and the restaurant is good, there is no logical reason for refusing such an enticing proposition [20].

TABLE I.
PORTFOLIO OF INNOVATIVE IT PROJECTS

Project	Description
PBS	*Parking-space booking system* - broadcasts on the Internet the availability of public and private parking space in the city center, using a network of bidirectional sensor arrays. Once in place, the IT system will allow for a restricted form of parking-space booking, so that drivers know where to park their car in advance
CMS	*Camera monitoring system* - monitors critical areas of the city center with high definition cameras. Face recognition software will be used in conjunction with the cameras, so that known criminal can be easily spotted
MFS	*Motor-vehicle fining system* - Allows police officers to fine drivers who have committed traffic offenses using a tablet-like device with a high resolution camera and licence-plate recognition software

C. Intangibles and Decision Making

According to [21], although intangible benefits are hard to quantify in financial terms, they can be more easily dealt with when compared to each other in pairs. Given a set $B = \{B_1, B_2, \cdots, B_n\}$ of elements that can be compared with each other using a criterion C, Saaty's pairwise comparison strategy leads to the construction of a valuation matrix $V_{n\times n}$ as shown in Table II.

TABLE II.
SAATY'S SQUARED VALUATION MATRIX

$$
\begin{array}{cc}
 & \begin{array}{ccccc} B_1 & B_2 & B_3 & \cdots & B_n \\ \downarrow & \downarrow & \downarrow & & \downarrow \end{array} \\
\begin{array}{c} B_1 \rightarrow \\ B_2 \rightarrow \\ B_3 \rightarrow \\ \vdots \\ B_n \rightarrow \end{array} &
\left[\begin{array}{ccccc}
1 & \frac{1}{v_{2,1}} & \frac{1}{v_{3,1}} & \cdots & \frac{1}{v_{n,1}} \\
v_{2,1} & 1 & \frac{1}{v_{3,2}} & \cdots & \frac{1}{v_{n,2}} \\
v_{3,1} & v_{3,2} & 1 & \cdots & \frac{1}{v_{n,3}} \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
v_{n,1} & v_{n,2} & v_{n,3} & \cdots & 1
\end{array}\right]
\end{array}
$$

Each component $v_{i,j}$ in the Saaty's valuation matrix is the result of a direct comparison between two elements in regard to criterion C, using the scale described in Table III. Therefore, if experience and judgement strongly favour B_2 over B_1 regarding C, then $v_{2,1} = 5$ and, as a consequence, the opposite also holds true, implying that $v_{1,2} = \frac{1}{5}$. On the other hand, if it is B_1 that is strongly favored over B_2 regarding C, then $v_{2,1} = \frac{1}{5}$ and, as a consequence, $v_{1,2} = 5$.

All of this leads to the construction of a matrix in which all of its main diagonal entries are 1s, because when compared to itself every element B_i is always equally relevant. Also, every component $v_{i.j}$ in the off-diagonal lower and upper triangular parts of Saaty's matrix is either drawn from the scale presented in Table III or is the inverse of $v_{i,j}$.

According to [21] the relevance of each element B_i, when compared to the other elements under analysis, is given by the component e_i of the normalized principal eigenvector $E = (e_1, \cdots, e_i, \cdots, e_n)^T$ of the valuation matrix V. By normalized it is meant that $\sum_{i=1}^{n} e_i = 1$. As e_i is actually an indicator of the relevance of B_i, for the remainder of this paper e_i is referred to as the *relevance index* of B_i or $RI(B_i)$. See Poole [22] for a comprehensive introduction to eigenvalues and eigenvetors.

Because Saaty's valuation method frequently relies upon perceptions of reality, it is not unusual that some valuation matrices present inconsistencies. For example, consider that B_i is strongly favored over B_j, which in turn is strongly favored over B_k. Nevertheless, inadvertently let B_k be strongly favored over B_i. As this contradicts the usual notion of transitivity, the previous statement actually introduces an inconsistency in the evaluation of B_i, B_j and B_k.

Inconsistencies in valuation matrices can be detected with the consistency ratio (CR). For a given valuation matrix $V_{n\times n}$ that has λ_{max} as its main eigenvalue

$$CR = \frac{CI}{RI}, \tag{1}$$

where *CI*, the consistency index, is given by $\frac{\lambda_{max}-n}{n-1}$, and RI, the random index, is drawn from Table IV in accordance with n.

TABLE IV.
THE RANDOM INDEX

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

According to [21], if $CR \geq 10\%$, then the inconsistencies should be resolved.

D. An example of the use of Saaty's valuation matrix

Consider the municipal steering committee that has been assigned with the task of evaluating the portfolio of IT projects described in Section II-A. Also, imagine that before making any recommendations the steering committee decided to evaluate the projects in the portfolio in the light of the main benefits that they are expected to

TABLE III.
THE FUNDAMENTAL SCALE OF PAIRWISE COMPARISON

Intensity of Relevance	Definition	Explanation
1	Equal relevance	The two elements are equally relevant when compared to each other
3	Moderate relevance	Experience and judgement slightly favour one element over another
5	Strong relevance	Experience and judgement strongly favour one element over another
7	Very strong	An element is favoured very strongly over another
9	Extreme relevance	The evidence favouring one element over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	Should be used when compromise is needed

TABLE V.
THE MAIN EVALUATION CRITERIA

Project	Definition
IPS	*Intensity of public support* - reflects how supportive citizens are likely to be about the realization of a particular project
VMC	*Volume of media coverage* - indicates the volume of positive media coverage that a project is expected to generate
PIV	*Positive impact on the environment* - shows the potential contribution of a project to ensure a sustainable future

yield. Table V introduces the evaluation criteria devised by the steering committee.

It is important to note that none of the criteria selected by the steering committee has an easily quantifiable financial embodiment. Therefore, the committee decided to follow Saaty's ideas [21] on the valuation of intangibles.

Consistent with the Innovatus current economic, social and political landscape, the steering committee considers that the VMC is moderately more relevant to the well-being of city dwellers than the IPS and PIV. Also, the IPS is slightly more relevant than the PIV.

The Saaty valuation matrix introduced in Table VI captures the steering committee expert opinion on the relevance of each of the benefits that the projects in the IT portfolio may yield.

TABLE VI.
THE INITIAL EVALUATION MATRIX

$$\begin{array}{c} \\ \\ \text{IPS} \rightarrow \\ \text{VMC} \rightarrow \\ \text{PIV} \rightarrow \end{array} \begin{array}{ccc} \text{IPS} & \text{VMC} & \text{PIV} \\ \downarrow & \downarrow & \downarrow \end{array} \quad \begin{array}{c} \text{E(\%)} \\ \downarrow \end{array}$$

$$\begin{array}{l} \text{IPS} \rightarrow \\ \text{VMC} \rightarrow \\ \text{PIV} \rightarrow \end{array} \begin{bmatrix} 1 & \frac{1}{3} & 2 \\ 3 & 1 & 3 \\ \frac{1}{2} & \frac{1}{3} & 1 \end{bmatrix} \begin{bmatrix} 25.2 \\ 58.9 \\ 15.9 \end{bmatrix}$$

CR = 6.1%

Observe that $(25.2\%, 58.9\%, 15.9\%)^T = (0.252, 0.589, 0.159)^T$ is the normalized principal eigenvector of the matrix presented in Table VI, being its contents a measure of the relevance of the criteria under consideration when compared pairwise. Hence, *RI*(IPS), *RI*(VMC) and *RI*(PIV) are respectively 25.2%, 58.9% and 15.9%. Moreover, according to the steering committee point of view, the VMC is $\frac{58.9\%}{25.2\%} = 2.3$ times more relevant than the IPS and $\frac{58.9\%}{15.9\%} = 3.7$ times more relevant than the PIV.

E. Project valuation using Saaty's Valuation Matrix

As projects may perform differently when subjected to distinct evaluation criteria, one has to provide an index that indicates the combined relevance of each project. According to [21], this is accomplished by a *weighted relevance index* or *WRI*, which takes into consideration the performance of a project when subject to each evaluation criterion, together with the relevance of each criterion. For a project P_j, *WRI*(P_j) is given by

$$\sum_{i=1}^{n} RI(B_i) \times RI_{B_i}(P_j), \tag{2}$$

where $RI(B_i)$ is the relevance index of B_i (see Section II-C) and $RI_{B_i}(P_j)$ is the relevance index of P_j when subject to criterion B_i.

For example, consider the IT projects described in Section II-A. Moreover, allow the valuation matrix presented in Tables VII, VIII, and IX to encapsulate the relevance of those projects when subjected to the criteria introduced in Table V.

TABLE VII.

INTENSITY OF PUBLIC SUPPORT GENERATED BY EACH PROJECT

	PBS ↓	CMS ↓	MFS ↓	E(%) ↓
PBS →	1	$\frac{1}{3}$	3	26.0
CMS →	3	1	5	63.3
MFS →	$\frac{1}{3}$	$\frac{1}{5}$	1	10.6

CR = 4.8%

Observe that, according to the information displayed in Table VII, experience and judgement indicates that the project that is likely to generate the highest intensity of public support is the CMS, as $e_3 = 63.3\%$. Moreover, the CMS is also the project that is expected to receive the highest volume of positive media coverage, as $e_3 = 74.8\%$ in Table VIII.

TABLE VIII.

VOLUME OF MEDIA COVERAGE GENERATED BY EACH PROJECT

	PBS ↓	CMS ↓	MFS ↓	E(%) ↓
PBS →	1	$\frac{1}{5}$	3	18.0
CMS →	5	1	9	74.8
MFS →	$\frac{1}{3}$	$\frac{1}{9}$	1	7.1

CR = 4.5%

Nevertheless, the CMS does not perform that well when the positive impact on the environment is considered, as the material that will be used to deploy the system is not environmentally friendly. In this case, the CMS yields one of the worst relevance indexes, as $e_3 = 8.8\%$ in Table IX. Therefore, considering the relevance of each evaluation criterion (See Table VI), the weighted relevance indexes of the projects introduced in Section II-A are presented in Table X.

TABLE IX.

EVALUATION OF THE PROJECTS' POSITIVE IMPACT ON THE ENVIRONMENT

	PBS ↓	CMS ↓	MFS ↓	E(%) ↓
PBS →	1	7	3	66.9
CMS →	$\frac{1}{7}$	1	$\frac{1}{3}$	8.8
MFS →	$\frac{1}{3}$	3	1	24.3

CR = 0.9%

It should be noted that according to the steering committee critirea the CMS is the most relevant project, followed by the PBS. The project that comes last is the MFS.

TABLE X.

THE PROJECTS' WEIGHTED RELEVANCE INDEXES

Project	**WRI (%)**
PBS	$25.2 \times 26.0 + 58.9 \times 18.0 + 15.9 \times 66.9 = 27.8$
CMS	$25.2 \times 63.3 + 58.9 \times 74.8 + 15.9 \times 8.8 = 61.4$
MFS	$25.2 \times 10.6 + 58.9 \times 7.1 + 15.9 \times 24.3 = 10.8$
Total	100.0

F. Subproject valuation

Despite the fact that it can be traced back to the work of Dijkstra (1930-2002) in the 1970s [23], the idea of simplifying understanding, planning and maintenance by breaking IT projects down into smaller subprojects with high degree of separation of concerns is still very much in line with current thinking [24]. Moreover, it is expected that as a whole subprojects yield the same benefits as their respective source project, i.e. the project from which they originate [25]. For example, Table XI presents a partition of the PBS project introduced in Section II-A into a number of subprojects.

TABLE XI.

PARKING-SPACE BOOKING SYSTEM SUBPROJECTS

Sub-proj.	**Description**
PBS_1	Select the remotely-controlled digital parking meters to be used in the parking-space booking system
PBS_2	Develop the parking meter reservation and control system
PBS_3	Acquire enough remotely-controlled digital parking meters to replace the existing mechanical parking metres in the city center. Replace the mechanical parking meters.
PBS_4	Integrate the digital parking meters in the city center into the parking-space booking system
PBS_5	Deploy the parking meter reservation and control system
PBS_6	Integrate privately owned parking spaces in the city center into the parking meter booking system
PBS_7	Allow private both businesses and government agencies to advertise in the parking-space booking system website

Tables XII, XIII and XIV show the evaluation of the relevance of the subprojects comprising the PBS project when subjected to the criteria introduced in Table V.

Table XV presents the WRI off each PBS subproject calculated according to Equation 2. Because, as a whole the PBS project bears a WRI of 27.8% (See Table X), the WRI of its subprojects have to de adjusted accordingly.

TABLE XII.
INTENSITY OF PUBLIC SUPPORT GENERATED BY EACH PBS SUBPROJECT

	PBS_1	PBS_2	PBS_3	PBS_4	PBS_5	PBS_6	PBS_7	E(%)
PBS_1	1	1	3	1	$\frac{1}{5}$	$\frac{1}{7}$	3	7.5
PBS_2	1	1	3	1	$\frac{1}{5}$	$\frac{1}{7}$	3	7.5
PBS_3	$\frac{1}{3}$	$\frac{1}{3}$	1	$\frac{1}{3}$	$\frac{1}{7}$	$\frac{1}{9}$	3	4.1
PBS_4	1	1	3	1	$\frac{1}{5}$	$\frac{1}{7}$	3	7.5
PBS_5	5	5	7	5	1	$\frac{1}{3}$	7	26.2
PBS_6	7	7	9	7	3	1	9	44.4
PBS_7	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{7}$	$\frac{1}{9}$	1	2.8

CR = 7.2%

TABLE XIII.
VOLUME OF MEDIA COVERAGE YIELDED BY EACH PBS SUBPROJECT

	PBS_1	PBS_2	PBS_3	PBS_4	PBS_5	PBS_6	PBS_7	E(%)
PBS_1	1	1	$\frac{1}{3}$	1	$\frac{1}{9}$	$\frac{1}{5}$	$\frac{1}{2}$	5.0
PBS_2	1	1	$\frac{1}{3}$	1	$\frac{1}{9}$	$\frac{1}{5}$	$\frac{1}{2}$	5.0
PBS_3	3	3	1	3	$\frac{1}{2}$	3	1	18.1
PBS_4	1	1	$\frac{1}{3}$	1	$\frac{1}{5}$	$\frac{1}{3}$	$\frac{1}{2}$	5.7
PBS_5	9	9	2	5	1	3	3	37.3
PBS_6	5	5	$\frac{1}{3}$	3	$\frac{1}{3}$	1	$\frac{1}{3}$	13.9
PBS_7	2	2	1	2	$\frac{1}{3}$	3	1	15.0

CR = 7.1%

TABLE XIV.
POSITIVE IMPACT ON THE ENVIRONMENT PROVIDED BY EACH PBS SUBPROJECT

	PBS_1	PBS_2	PBS_3	PBS_4	PBS_5	PBS_6	PBS_7	E(%)
PBS_1	1	1	1	1	$\frac{1}{9}$	$\frac{1}{7}$	1	4.7
PBS_2	1	1	1	1	$\frac{1}{9}$	$\frac{1}{7}$	1	4.7
PBS_3	1	1	1	1	$\frac{1}{9}$	$\frac{1}{7}$	1	4.7
PBS_4	1	1	1	1	$\frac{1}{9}$	$\frac{1}{7}$	1	4.7
PBS_5	9	9	9	9	1	3	9	48.0
PBS_6	7	7	7	7	$\frac{1}{3}$	1	7	28.7
PBS_7	1	1	1	1	$\frac{1}{9}$	$\frac{1}{7}$	1	4.7

CR = 1.9%

In formal terms, the adjusted WRI of a subproject P_i in regard to its source project *P*, or AWRI(P_i), is given by

$$\text{AWRI}(P_i) = \text{WRI}(P_i) \times \text{WRI}(P). \qquad (3)$$

Table XV introduces the AWRI of each PBS subproject.

G. *Subproject's dependency relations*

When an IT project is broken down into subprojects, it is often the case that a dependency relationship will hold true among the comprising subprojects [26]. For example, the diagram presented in Figure 1 describes the dependency relations that hold true among the PBS subprojects.

TABLE XV.
THE PSB SUBPROJECTS' WEIGHTED RELEVANCE INDEX

Project	WRI (%)	AWRI (WRI × 27.8%)
PBS_1	$25.2\times 7.5+58.9\times 5.0+15.9\times 4.7=5.6$	1.6
PBS_2	$25.2\times 7.5+58.9\times 5.0+15.9\times 4.7=5.6$	1.6
PBS_3	$25.2\times 4.1+58.9\times 18.1+15.9\times 4.7=13.0$	3.5
PBS_4	$25.2\times 7.5+58.9\times 5.7+15.9\times 4.7=6.0$	1.7
PBS_5	$25.2\times 26.2+58.9\times 37.3+15.9\times 48.0=34.8$	10.1
PBS_6	$25.2\times 44.4+58.9\times 13.9+15.9\times 28.7=25.5$	6.7
PBS_7	$25.2\times 2.8+58.9\times 15.0+15.9\times 4.7=9.6$	2.9
Total	100.0	27.8

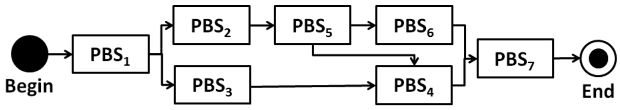

Figure 1. The PBS subprojects' precedence diagram.

In the diagram *Begin* and *End* are dummy subprojects signalling respectively the beginning and end of the project as a whole. In addition, an arrow going from a subproject to another, e.g. $PBS_1 \rightarrow PBS_2$ indicates that the development of the former (PBS_1) must precede the development of the latter (PBS_2).

In these circumstances, PBS_1 is called a predecessor of PBS_2. It should be noted that predecessor is a transitive relation. Therefore, as $PBS_1 \rightarrow PBS_2$ and $PBS_2 \rightarrow PBS_5$, then necessarily $PBS_1 \rightarrow PBS_5$. Frequently transitive relations are not made explicit in precedence diagrams in order to keep them simple.

Note that the benefits yielded by the PBS project can only be fully appropriated if all its subprojects are implemented. If only a subset of the subprojects are implemented, then the appropriation of benefits is partial. For example, consider the following possible, but partial implementation sequence S of the PBS project

$$PBS_1 \rightarrow PBS_2 \rightarrow PBS_3 \rightarrow PBS_5 \rightarrow PBS_4 .$$

In these circumstances, the amount of benefits that one appropriates by using S is given by its adjusted weighted relevance index (See SectionII-F), which is the sum of the weighted relevance index of its components, i.e.

$$\text{AWRI}(PBS_1 \rightarrow PBS_2 \rightarrow PBS_3 \rightarrow PBS_5 \rightarrow PBS_4) =$$

$$\text{AWRI}(PBS_1) + \text{AWRI}(PBS_2) + \text{AWRI}(PBS_3) +$$

$$\text{AWRI}(PBS_5) + \text{AWRI}(PBS_4) =$$

$$1.6 + 1.6 + 3.5 + 10.1 + 1.7 = 18.3 .$$

Hence, S allows for the appropriation of $89.7\% = \frac{18.3}{27.8}$ of the total benefits that the PBS project can yield. Other partial implementations of the PBS project allow for the appropriation of different percentages of the PBS's adjusted weighted relevance index.

H. IT project financing

According to Milton Friedman (1912-2006), the well-known American economist "There's no such thing as a free lunch". Therefore, even public-sector IT projects require capital investment to be run. Nevertheless, some of these projects do provide financial returns that can go towards filling the need for capital investment in other government initiatives [27].

As no project is immune to the effect of change in its surrounding environment, using the financial gains of a project or subproject to run another not only reduces the need for capital investment, but also the risks that every project is naturally exposed to [15].

For example, the PBS project described in Section II-A does generate some financial returns, as it allows the municipal government to tap into the earnings of the private parking space business. In addition, once integrated into the parking-space booking system the remotely-controlled digital parking meters are cheaper to maintain. Also, payment is made easier and less expensive to collect. Therefore, replacing the old mechanical parking meters actually generates some important savings for the municipal government.

As the PBS project generates financial returns, so do some of its subprojects. Table XVI presents the cash-flow elements of each PBS subproject.

TABLE XVI.
THE PBS SUBPROJECT'S CASH-FLOW ELEMENTS

Sub-Proj.	Period							
	1	2	3	4	5	6	···	24
PBS_1	-5	0	0	0	0	0	···	0
PBS_2	-100	-50	0	0	0	0	···	0
PBS_3	-70	0	0	0	0	0	···	0
PBS_4	-50	100	150	150	150	150	···	150
PBS_5	-15	0	0	0	0	0	···	0
PBS_6	-40	50	100	150	200	200	···	200
PBS_7	-10	5	10	40	40	40	···	40

According to the information presented in Table XVI, PBS_4 requires an initial investment of $50,000 (fifty thousand monetary units), or $50K for short. Once its development is completed at the end of the first period, it provides a series of positive returns until the 24^{th} period, when the subproject as a whole becomes obsolete and has to be replaced by a new and more suitable tool. A similar path is followed by PBS_6 and PBS_7. Therefore, these units are *cash-generating subprojects*.

A different path is followed by PBS_2, which requires an investment of $100K in the first period and $50K in the second period. Once its development is completed, it provides no financial returns on its own in respect of the investment required for its development. Hence, PBS_2 is a *pave-the-way subproject*, as it provides the necessary infrastructure for others to thrive upon. PBS_1, PBS_3 and PBS_5 are also pave-the-way subprojects.

The number of periods that cover from the beginning of an IT project until the point at which the project's final product is replaced by a more suitable alternative is often referred to as the project's *window of opportunity*.

It is improper to perform mathematical operations on monetary values without taking into account a discount rate. Therefore, in order to compare the financial value of different subprojects, one has to resort to their discounted cash-flow. The sum of all cash-flow elements of a subproject is its net present value (NPV) [28].

For instance, according to the information presented in Figure 1 and Table XVI, if PBS_4 were developed in the first period, it would yield an NPV of

$$\$3.016\text{K} = \frac{-50\text{K}}{(1+0.8\%)^1} + \frac{100\text{K}}{(1+0.8\%)^2} + \frac{150\text{K}}{(1+0.8\%)^3} + \cdots + \frac{150\text{K}}{(1+0.8\%)^{24}}$$

considering a discount rate of 0.8% per period. On the other hand, if PBS_4 were developed in the second period, it would yield an NPV of $2,869K, in the third, $2,724K and so on.

In order to make matters easier to follow, all the monetary figures presented in this paper are rounded to the nearest integer value. Also, when its use is required the cash-flow discount rate is kept at 0.8% per period.

Clearly, not every subproject can be developed in the very first period. The precedence diagram presented in Figure 1 indicates that only PBS_1 can be developed in that period. If at any given time only one unit can be in its development phase, PBS_4, for example, cannot be developed until the sixth period at best.

Furthermore, each particular implementation sequence of subprojects yields its own NPV. For instance, considering that just one subproject can developed at any given time, the sequence

$$PBS_1 \rightarrow PBS_2 \rightarrow PBS_3 \rightarrow PBS_5 \rightarrow PBS_6 \rightarrow PBS_4$$

yields $4,782K. It is important to note that the NPV of a project unit development sequence is the sum of the NPV of each of its components, considering the period in which they are expected to be built. Therefore,

$$\begin{gathered} \text{NPV}(PBS_1 \rightarrow PBS_2 \rightarrow PBS_3 \rightarrow PBS_5 \rightarrow PBS_6 \rightarrow PBS_4) = \\ \text{NPV}_1(PBS_1) + \text{NPV}_2(PBS_2) + \\ \text{NPV}_4(PBS_3) + \cdots + \text{NPV}_7(PBS_4) = \\ (-5 - 147 + \cdots + 2,152) \times \$\ 1\text{K} = \\ \$\ 4,782\text{K}, \end{gathered}$$

where $\text{NPV}_t(\text{U}_X)$ is the NPV of unit U_X, considering that its development starts in period t.

I. Combining the financial and intangible aspects of IT projects

In democracies the legislative bodies tend to exert considerable pressure upon the executive and judicial branches of government for more and better services on behalf of their constituents. However, in general many public sector projects cannot be implemented due to budget restrictions [29].

As a result, it is not uncommon that many relevant ideas and projects are either put on hold for sometime or only partly implemented [30]. Often this situation persists until enough capital is gathered from taxpayers or borrowed from financial institutions [31].

Moreover, possible changes in the political scenario caused by the proximity of elections, changes in voters' behavior and the action of pressure groups, usually require that projects in the public sector have to be run within an allowed *makespan*, i.e. the number of periods between the start of the first project activity and the conclusion of the last [32].

For example, consider that there is only $280K to be invested in the PBS project and that the allowed makespan is seven periods. Table XVII indicates all of the possible development sequences for the PBS subprojects that comply with these restrictions, together with their respective makespan (MS), adjusted weighted relevance index (AWRI), required capital investment (CI) and return on investment (ROI).

Note that the data presented in Table XVII was obtained according to the following restrictions: (a) the first subproject must be developed in period one, (b) at any given period only one subproject can be in its development stage, (c) once the development of a subproject unit starts it cannot be stopped or paused, (d) there is no delay between the completion of a subproject and the beginning of the development of the next, and (e) not all subprojects are going to be developed within the allowed time frame.

The sequence with the highest AWRI is the logical choice for running the PBS project, as it is the affordable sequence that yields most benefits. There are four sequences in Table XVII that comply with these restrictions, i.e. sequences 1, 2, 3 and 4.

However, if two or more affordable implementation sequences provide the same AWRI, then the sequence with the highest ROI is the logical choice, as it provides the highest return on the investment being made. Therefore, sequence 1, i.e.

$$\mathrm{PBS}_1 \rightarrow \mathrm{PBS}_2 \rightarrow \mathrm{PBS}_5 \rightarrow \mathrm{PBS}_6 \rightarrow \mathrm{PBS}_3 \rightarrow \mathrm{PBS}_4,$$

is the logical choice for implementing the PBS project, as it is the sequence that provides the highest ROI among those that yield the highest AWRI.

It should be noted that PBS_7 is not part of that sequence, as the allowed project makespan prevents its development from taking place. Hence, sequence 1 allows for the appropriation of only $89.7\% = \frac{25.0\%}{27.8\%}$ of the benefits that can be yielded by the PBS project.

III. The Method

Government bodies, organizations and agencies may benefit from using the following steps:

1) Select a portfolio of IT projects that one is considering to run;
2) Establish the appropriate evaluation criteria to which each project is going to be subjected;
3) Use Saaty's valuation matrix to prioritize the evaluation criteria, i.e. to find out the RI of each criterion;
4) Evaluate the WRI of each project;
5) Partition each project in the portfolio into smaller subprojects to facilitate understanding, planning and maintenance;
6) Calculate the AWRI of each subproject;
7) Capture the dependency relations that hold true among the subprojects;
8) Estimate the cost of developing each subproject, together with the returns they are expected to provide;
9) Identify the window of opportunity and allowed makespan;
10) Select the appropriate discount rate and calculate the CI and ROI of each possible implementation sequence;
11) Identify the affordable implementation sequence that provides the highest AWRI within the allowed makespan;
12) If two or more sequences are candidates to be used for the implementation of the projects in the portfolio, select the one that yields the highest ROI. Implement that sequence and appropriate the related benefits.

IV. An Example

Following the ideas of Seneca (5 BC - 65 AD) on the precept of examples [16], this section offers a full illustration of the method introduced in Section III.

Step 1 - Portfolio selection: consider the portfolio of IT projects introduced in Table I.

Step 2- Evaluation Criteria: allow the adoption of the evaluation criteria presented in Table V.

Step 3 - Prioritizing the evaluation criteria: acknowledge the RIs shown in Table VI.

Step 4 - Calculating the relevance of each project: consent to the WRI presented in Table X.

Step 5: Partitioning the projects: Tables XI, XVIII and XIX present a partitioning of the projects introduced in Table I into subprojects.

Step 6 - Calculating the AWRI of each subproject: consider the AWRI presented in Tables XV and XX.

Step 7: Capturing the dependency relations: Figures 1, 2 and 3 present the precedence relations that hold true among the subprojects introduced in Tables XI, XVIII and XIX.

TABLE XVII.
ALL POSSIBLE DEVELOPMENT SEQUENCES FOR THE PBS PROJECT

#	Subproject Implementation Sequences	MS	AWRI	CI ($1K)	ROI (%)
1	$PBS_1 \to PBS_2 \to PBS_5 \to PBS_6 \to PBS_3 \to PBS_4$	7	25.0	224	2,162
2	$PBS_1 \to PBS_2 \to PBS_3 \to PBS_5 \to PBS_6 \to PBS_4$	7	25.0	272	1,708
3	$PBS_1 \to PBS_2 \to PBS_5 \to PBS_3 \to PBS_6 \to PBS_4$	7	25.0	272	1,708
4	$PBS_1 \to PBS_3 \to PBS_2 \to PBS_5 \to PBS_6 \to PBS_4$	7	25.0	272	1,708
⋮	⋮	⋮	⋮	⋮	⋮

TABLE XVIII.
CAMERA MONITORING SYSTEM SUBPROJECTS

Sub-proj.	Description
CMS_1	Select the remotely control cameras to be deployed
CMS_2	Develop the image capturing and identification system
CMS_3	Deploy the image capturing and identification system
CMS_4	Acquire and deploy the selected remotely controlled cameras all over the city center's critical areas.
CMS_5	Integrate the remotely controlled cameras into the image capturing and identification system
CMS_6	Upgrade the system to allow for coordinating action with the local enforcement police force

TABLE XIX.
MOTOR-VEHICLE FINING SYSTEM

Sub-proj.	Description
MFS_1	Select and acquire the image capturing and license plate recognition software
MFS_2	Select the tablet-like device to be used by traffic control officers
MFS_3	Develop the mobile traffic fining system, integrating the image capturing and license plate recognition into the system
MFS_4	Deploy the mobile traffic fining system
MFS_5	Integrate the mobile fining system into the existing traffic fining management system
MFS_6	Acquire the tablet-like devices, loading the mobile finning system application into those devices
MFS_7	Distribute the tablet-like devices, providing traffic control officers with the necessary training

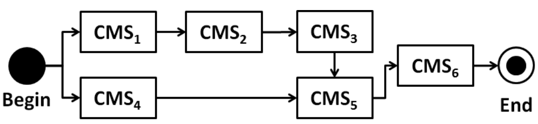

Figure 2. The CMS subproject's precedence diagram.

Step 8 - Estimating the cost of development and returns: Tables XVI and XXI present the cash flow elements of the subprojects introduced in Tables XI, XVIII and XIX.

TABLE XX.
THE CMS AND MFS SUBPROJECT'S AWRI

Sub-proj.	AWRI	Sub-proj.	AWRI
CMS_1	4.6	MFS_1	1.1
CMS_2	4.6	MFS_2	1.1
CMS_3	4.6	MFS_3	1.1
CMS_4	10.5	MFS_4	2.1
CMS_5	4.9	MFS_5	1.1
CMS_6	26.0	MFS_6	2.7
		MFS_7	4.8
Total	55.3		14.0

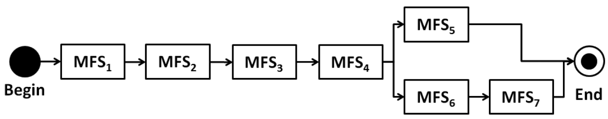

Figure 3. The MFS subproject's precedence diagram.

Step 9: Identifing the window of opportunity and allowed makespan - allow for a 24-period window of opportunity and 14-period portfolio makespan.

Step 10 - Calculating the CI and ROI: Table XXII shows all possible development sequences for the subprojects described in Tables XI, XVIII and XIX that comply with the portfolio window of opportunity and allowed makespan. It also shows the makespan (MS), adjusted weight relevance index (AWRI), required capital investment (CI) and return on investment (ROI) of each implementation sequence.

Step 11 - Identifying the sequences that provide the highest AWRI: There are four sequences in Table XXII that bear the highest AWRI among all possible development sequences.

Step 12 - Identifying the sequence that provides the highest ROI:

Any of the implementation sequences mentioned in the previous step can be chosen to partly implement the portfolio of IT projects, as they yield the same ROI. It should be noted that none of the MFS subprojects are part of these implementation sequences. The MFS

TABLE XXI.
THE CMS AND MFS SUBPROJECTS' CASH-FLOW ELEMENTS

Sub-Proj.	**Period**							
	1	**2**	**3**	**4**	**5**	**6**	···	**24**
CMS_1	-5	0	0	0	0	0	···	0
CMS_2	-140	0	0	0	0	0	···	0
CMS_3	-35	0	0	0	0	0	···	0
CMS_4	-110	0	0	0	0	0	···	0
CMS_5	-20	0	0	0	0	0	···	0
CMS_6	-25	0	0	0	0	0	···	0
MFS_1	-5	-40	0	0	0	0	···	0
MFS_2	-5	0	0	0	0	0	···	0
MFS_3	-70	-60	0	0	0	0	···	0
MFS_4	-35	0	0	0	0	0	···	0
MFS_5	-35	0	0	0	0	0	···	0
MFS_6	-20	0	0	0	0	0	···	0
MFS_7	-20	90	90	120	120	120	···	120

TABLE XXII.
ALL POSSIBLE DEVELOPMENT SEQUENCES FOR THE SUBPROJECTS IN THE PORTFOLIO OF IT PROJECTS

#	**Subproject Implementation Sequences**	**MS**	**AWRI**	**CI ($1K)**	**ROI (%)**
1	$PBS_1 \rightarrow PBS_2 \rightarrow PBS_5 \rightarrow PBS_6 \rightarrow CMS_1 \rightarrow PBS_3 \rightarrow PBS_4 \rightarrow PBS_7 \rightarrow CMS_2 \rightarrow CMS_6 \rightarrow CMS_3 \rightarrow CMS_4 \rightarrow CMS_5$	14	86.0	210	2,385
2	$PBS_1 \rightarrow PBS_2 \rightarrow PBS_5 \rightarrow PBS_6 \rightarrow CMS_1 \rightarrow PBS_3 \rightarrow PBS_4 \rightarrow PBS_7 \rightarrow CMS_6 \rightarrow CMS_4 \rightarrow CMS_2 \rightarrow CMS_3 \rightarrow CMS_5$	14	86.0	210	2,385
3	$PBS_1 \rightarrow PBS_2 \rightarrow PBS_5 \rightarrow PBS_6 \rightarrow CMS_1 \rightarrow PBS_3 \rightarrow PBS_4 \rightarrow PBS_7 \rightarrow CMS_6 \rightarrow CMS_4 \rightarrow CMS_2 \rightarrow CMS_3 \rightarrow CMS_5$	14	86.0	210	2,385
4	$PBS_1 \rightarrow PBS_2 \rightarrow PBS_5 \rightarrow PBS_6 \rightarrow CMS_1 \rightarrow PBS_3 \rightarrow PBS_4 \rightarrow PBS_7 \rightarrow CMS_2 \rightarrow CMS_3 \rightarrow CMS_6 \rightarrow CMS_4 \rightarrow CMS_5$	14	86.0	210	2,385
5	$PBS_1 \rightarrow PBS_2 \rightarrow PBS_5 \rightarrow PBS_6 \rightarrow CMS_1 \rightarrow PBS_3 \rightarrow PBS_4 \rightarrow PBS_7 \rightarrow CMS_2 \rightarrow CMS_4 \rightarrow CMS_3 \rightarrow CMS_6 \rightarrow CMS_5$	14	86.0	210	2,384
⋮	⋮	⋮	⋮	⋮	⋮

project yields the lowest AWRI among the projects in the portfolio and it takes too long to provide financial returns.

V. RELATED WORK AND DISCUSSION

In recent years many interesting proposals have been put forward to advance the coverage and precision of IT-initiative evaluation methods in the public sector. For instance, Raus et al. [33] present an IT investment analysis framework that combines the value-creation perspective from both the public and private sectors. The framework incorporates the different needs and requirements of various stakeholders, enabling the assessment of IT innovations.

Srivastava [34] advocates the use of a framework that integrates eight areas in which IT can yield a positive impact on government initiatives. The framework provides a basis for reasoning about e-government projects and assessing their respective return on investment.

Over [35] proposes the adoption of an IT investment management model as a means of indicating where IT investments should be made and how these investments can be assessed, compared and controlled.

Guclu and Bilgen [36] endorse the use of a model that merges public value, strategic goals, service delivery value chain, performance indicators, continuous monitoring, constant evaluation, and asset management concepts. According to the authors, the model can be used to more easily assess the effectiveness of investments being made in government information system projects.

Neuroni et al. [37] claim that the use of real options can better capture the flexibility that is intrinsic to IT projects in the public sector. Consistent with this view the authors introduce a real option model for the evaluation of e-government projects. The model takes into account the perspective of different stakeholders and considers various dimensions of cost and value creation.

A review of the existing literature on return on investments made in IT in the public sector, and of general approaches to the measurement of such returns is presented in [38].

It should be noted that none of the proposals presented so far take into consideration that IT-projects can frequently be broken down into smaller parts with high degree of separation of concerns [24]. By ignoring this particular aspect of IT-projects, they are unable to acknowledge the fact that the order in which these parts are implemented may quite substantially change the value of IT initiatives [15].

Furthermore, these proposals fail to properly combine both the tangible and the intangibles aspects of IT-initiatives. Therefore, they fall short of allowing intangibles benefits to be appropriated with less capital investment. Finally, they tend to ignore either the initiative's makespan or window of opportunity, or even both.

VI. Conclusions

Among the uncountable changes that society has been going through as a result of the widespread availability of information and communication technologies (ICTs), making government more sensitive to the needs and desires of their citizens is possibly one of the most far reaching in its implications and significance [8]. Not only have ICTs given a stronger voice to citizens in legislative bodies, but also made the executive branch of government more concern about the quality of the services they provide for all of us [39].

As the pressure for new and better public services builds up, so does the number of IT projects that are run by government bodies and agencies. All of this increases the claim for better IT evaluation methods that are able to deal with intangibles in a proper manner [11].

This paper presents a method for the evaluation of IT projects in the public sector. The method, which is based upon the ideas of Thomas L. Saaty on evaluation of intangibles and the fact that IT projects can be often divided into smaller subprojects, allows civil servants to maximize the benefits yielded by IT initiatives, while making a more efficient use of the financial resources they have at their disposal.

The method presented in this paper is superior to other methods that have been put forward so far, as it favors the appropriation of as many intangible benefits as possible within a predefined window of opportunity and project makespan, which are common concerns in government projects and initiatives.

Moreover, the method encourages the use of the financial resources yielded by a subproject to fulfill the need for capital investment of other subprojects. Hence, it allows more benefits to be appropriated with less financial resources. Furthermore, by reducing the need for capital investment, it helps to reduce the financial risk exposure due to changes in the political, economic, and social scenario, which every public-run project is naturally exposed to.

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