# Towards Robust IT Service Portfolio Management

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**Abstract.** ITIL recommends implementing Service Portfolio Management as a way to actively manage IT investments, with transparency in its operations and spending. Selecting which and when projects should be executed is an important but complex task. It is all the more complex if one includes operational costs, which represent a significant component of the IT budget. We investigate techniques to provide decision support in selecting IT investments. We provide a model to link IT investment selection to business value and a method to generate valid portfolios and to guide an IT executive the 'best' portfolio. Finally, we evaluate our method with a case study and report on the feasibility of the method.

**Keywords:** IT Portfolio Management, Business Service Management, Robust Optimisation

## 1 Introduction

While it is true that IT enables and enhances an increasing number of goods and services, too often IT organisations struggle to demonstrate the business value of IT since interactions between business and IT stakeholders are often centred on technical capabilities. The IT Information Library (ITIL) [1] makes a clear distinction between *Business Services* that generate value and take part in business processes and *IT Assets* that underpin other services but have no business context. For instance, a credit rating service delivers value to a bank and is a business service; an infrastructure service, such as a shared database service, is an IT asset since it does not provide any direct business value. Several business services may however depend on the shared database service. Up to now, IT organisations have been focused on operating IT assets (networks, servers, and storage) and have given little attention to business value.

IT executives are increasingly under pressure to justify the costs of IT and need to transform IT assets into business services, with clearly identified costs and business benefits [2]. ITIL recommends implementing Service Portfolio Management [3] as a way to actively manage IT investments, with transparency in its operations and spending. IT investments can be categorised into two categories. *Operational costs* are required to manage and maintain IT assets that are listed in the Service Catalogue, for instance to deal with incidents, problems and changes. IT *projects* are carried out for the development of new services and retiring services that are no longer economically or technically viable.

When doing their yearly planning, IT executives consolidate the demand for IT resources, both for project and operations activities, that emanates from the various business units and from IT, and select how to best allocate budget and resources. It is not unusual to have several hundreds of such demands in large IT organisations. Because of the considerable amounts of resources that are at stake, planning IT investments is an important but complex task. We have identified four reasons that make this decision complex. First, complex inter-dependencies exist between IT assets, and between business services IT assets, making it difficult to link IT investment to strategic business planning. Secondly, because the planning process can happen between one to two years ahead of execution, there is a high level of uncertainty in the input data. For instance, costs, workloads and durations of new IT projects can only be estimated and may be widely variable. Third, the selection of IT investments is subject to multiple constraints, resource constraints, budget constraint, time constraints or interdependency constraints. Finally, there are many criteria to take into account in evaluating a portfolio: a CIO may want to provide the most valuable services while keeping costs low and maintaining high levels of employee satisfaction. In a typical scenario, such objectives are conflicting, so a trade-off must be found.

In this paper, we discuss the requirements of IT service portfolio selection and concentrate on ways to link IT investment selection to business value. We then implement a multi-objective selection method to generate feasible portfolios and guide IT executives in finding the portfolio that best aligns to their preferences. The method addresses issues of information incompleteness and uncertainty.

This paper is organised as follows. Section 2 reviews related work, and section 3 presents the decision problem and the related information model. Section 4 shows the formulation of the optimisation problem, and how the method can be applied interactively to provide decision support. The method is illustrated through a simple example in section 5. Finally, we conclude and present our future work intentions.

## 2 Related Work

This work contributes to the research domain of Business-Driven IT Management (BDIM). BDIM has been defined as "the application of a set of models, practices, techniques and tools to map and to quantitatively evaluate interdependencies between business performance and IT solutions – and using the quantified evaluation – to improve the IT solutions' quality of service and related business results" [4].

The BDIM paradigm has already been applied to several IT domains: in change management, IT changes can be evaluated and scheduled in order to minimise financial losses [5][6], in capacity management, systems configuration can be optimised from a business objective perspective [7][8], in network management, network configurations must align with customer satisfaction and business profitability [9], or in incident management, performance of IT support organisations is evaluated and optimised to meet service levels [10]. The latter example is notable in that it does not address the technology dimension of IT but rather the aspects of people and processes. In line with these approaches, we build a linkage model between an IT decision − whether to select an IT investment or not − and business outcome.

This work also relates to a number of fields of Operations Research and Management Science. The IT investment decision problem is linked with financial investment planning [11][12], but there are significant differences in the problem formulations and in the solution methods. First, the decision variables for IT projects are binary (go/no-go decision) while they are continuous in financial planning (corresponding to an amount of security). Secondly, financial portfolio selection heavily relies on past performance to forecast future performance and understand the interdependencies between different securities. There is much less consistency in the IT domain since very few projects are repeated.  Finally, while investing in a given financial asset affects the portfolio performance, it does not significantly influence the market performance of the asset. The amount of resources invested in an IT project can determine its outcome and the quality of delivered assets.

R&D project selection and resource allocation have received considerable attention over the last three decades. Various models and algorithms have been developed to help a decision maker in selecting R&D projects from a pool of available projects namely: traditional scoring techniques [13], multi-attribute utility theory [14], comparative approaches such as q-sort [15] or analytical hierarchy procedure [16]. Multiple optimization models based on mathematical programming have also been proposed [17]. We refer the reader to [18] for a survey of this diverse set of techniques.

Nevertheless, very few works deal with the requirements presented in the introduction: linking IT assets to business value, dealing with uncertainty, constraints and multiple conflicting objectives. A notable exception is the work of Stummer and Heidenberger [19] which apply multi-objective optimization techniques [20] to the problem of project selection. Combining different evaluation criteria, such as return-on-investment (ROI) or customer satisfaction, into one objective is a difficult task. A decision maker cannot easily assign target regions and relative weights for each criterion, a priori [21]. Rather, she needs to explore the solution space, and participate in the search process. More recently, in [22], the authors keep the principles found in [19] but extend the work by formalising the notion of dominance for project portfolio section and by presenting a scalable algorithm to compute non-dominated portfolios.

Considering that, in most firms, IT projects account for less than 30% of the total IT spend, and that the remaining 70% goes towards maintenance and ongoing operations [2], it is not sufficient to only focus on the selection of IT projects. In this paper, we provide a method for the selection of all IT investments, addressing simultaneously projects and asset operations.

# 3 Conceptual Solution for Service Portfolio Management

We propose a conceptual solution for service portfolio management that takes into account all IT investments, both project activities and on-going maintenance activities. We first describe the information model that is used in the remainder of this paper, then propose a model that links the selection of an IT investment to business objectives, discuss the data uncertainty, and conclude with possible metrics to evaluate IT portfolios.

## 3.1 Information Model

The proposed information model includes the main concepts necessary in service portfolio management. We chose to base the model on ITIL terminology and concepts whenever appropriate. Fig. 1 depicts this information model.

Following the ITIL guideline, we make a distinction between *IT services* that provide business value (*business services*), and internal services whose purpose is to provide infrastructure and necessary underlying functionality with no direct business value (*IT assets*). A *business process* is composed of a number of *business services* and in this paper we only consider business services that are supported by IT. Business services are composed of one or several assets, and assets in turn can depend on other lower- level assets. Because the goal of this work is to guide the selection of IT investments, the intent is not to have a fine grained model of assets, as one would find in a configuration management database (CMDB). The configuration items present in the CMBD are elements of the infrastructure (e.g. servers and routers) and of the software (e.g. operating systems and applications). Here, an IT asset is a coarse-grain representation of an IT service that includes the people operating it (support staffs, possibly from different departments), the underlying technology (configuration items) and processes (IT service management processes such as incident management or change management).

*Metrics* are used to measure the performance, availability, maintainability and regulatory compliance of business services. In this work, we are agnostic as to what the metrics are. They can represent service levels such as Mean Time To Restore (MTTR) or Mean Time Between Failures (MTBF) frequently used to measure the maintainability and availability of services, financial metrics such as cash flow or sales, or performance indicators of IT processes. The Control Objective for Business Information related Technology (COBIT [23]) specifies a large collection of such metrics and high-level performance indicators. We assume that executives have opinions about the objectives they are trying to achieve and have ideas about suitable target regions for each metric. For instance, executives may wish to increase revenue by 10% and improve customer satisfaction (measured by doubling the MTBF of the e-commerce site).

An *IT investment* is an activity that consumes budget and resources. For each investment, a cost profile and a staffing profile are defined. The cost profile defines the cost of the project as a function of time. In the context of this paper, time is discrete and the unit is typically in months or quarters. The staffing profile gives an estimation of the required human resources as a function of time. Because IT resources are highly specialised, staffing profiles are organised per role (e.g. database administrator, level 1 PC support, or Java developer). IT investments are specialised into two categories, operations and projects. An *operations* investment ensures the smooth execution of an asset. Several operations investments can be proposed for each asset and only one will need to be selected. As will be detailed in the following sub-section, different operations investments, hence different levels of budgets and resources, will lead to different levels of business service metrics. A *project* aims at developing a new service, enhancing an existing service or decommissioning a service. Projects can have impact on several metrics. For instance, a project that deploys a new feature on a firm's e-commerce web site may generate additional revenue and improve customer churn rate. Projects may also reduce operating costs, and will have impacts on the cost and resource profiles of assets, with IT consolidation projects being a typical example.

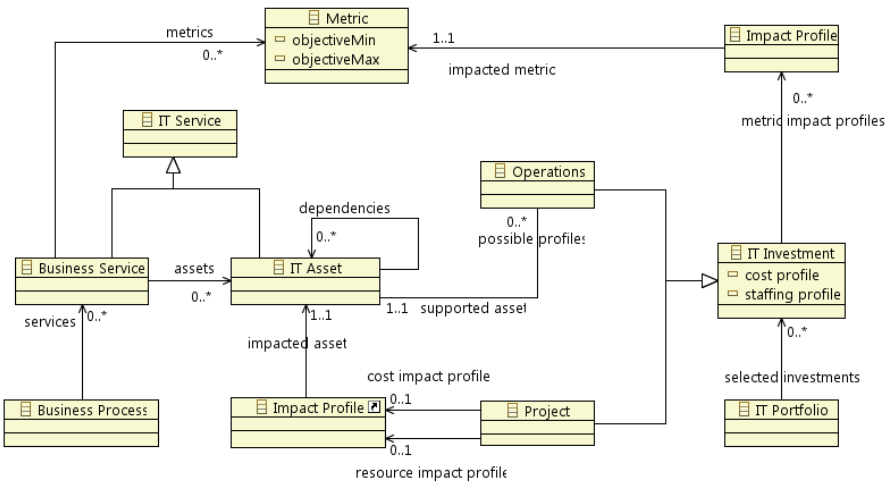


**Fig. 1.** Information model for service portfolio management

### 3.2 Decision Problem

In this sub-section, we introduce some notation and formalise the decision problem we are solving.

Let $S$ be the number of business services and $A$ be the number of assets being considered. Let $A_s$ be the set of assets on which service $s$ depends, i.e. the transitive closure over the dependency relation. Let $M$ be the number of metrics for services. Finally, let $P$ be the number of projects and let $O_a$ be the number of operations investment associated with asset $a$. Throughout this paper, we will use the indices $s$ for services, $a$ for assets, $o$ for operations investments, $p$ for projects, $m$ for metrics and $t$ for time period.

We wish to select the set of investments over a number $T$ of time periods that will lead to the 'best' outcomes. To this end, we define the Boolean decision variables:

- $x_{a,o}, a \in [1, A], o \in [1, O_a]$, such that $x_{o,a} = 1$ if and only if operations investment $o$ is selected for asset $a$;
- $y_{p,t}, p \in [1, P], t \in [1, T]$, such that $y_{p,t} = 1$ if and only if project $p$ is selected and it is scheduled to start at time period $t$.

A solution of the service portfolio selection problem is hence an assignment of the variables $x_{o,a}$ and $y_{p,t}$. The set of feasible portfolios is defined by refining the set of all possible assignments and ensuring that the following types of constraints apply:

- *Operations constraints*: one and only one operations investment must be selected for each asset;
- *Budget constraints*: for each time period, the total spend in projects and operations must not exceed the planned budget;
- *Resource constraints*: for each time period, the total demand for resources must not exceed the planned resource supply;
- *Logical constraints*: rigid interdependencies between projects and operations investment (e.g. follow-up projects and mutually exclusive projects);
- *Positioning constraints* ensure that the portfolio is aligned with strategic requirements and that it well balanced between business unit, functional area, geography, or technology area;
- *Threshold constraints* filter out investments that do not meet minimum acceptable levels (for instance the Net Present Value (NPV) must exceed a given threshold).

These constraints are common in portfolio selection [22] and can be modelled as linear inequalities using the decision variables $x_{o,a}$ and $y_{p,t}$.

## 4 Multi-Criteria Service Portfolio Selection Under Uncertainty

The conceptual solution presented above does not define the criteria that qualify the 'best' portfolio. Moreover, we have not addressed our requirement to deal with the uncertainty in the input data. In this section, we address these issues: we first comment on aspects of uncertainty and risk, define criteria to evaluate service portfolios and propose a solution method.

### 4.1 Uncertainty and Risk

The level and significance of uncertainty differs among specific assets and projects, with the demands for asset operation demands and outcomes being far more predictable than IT projects. Also, the level of uncertainty may not be the same for all projects. Clearly uncertainty will be in its highest when a project is at the proposal stage; however it will continue to exist through its execution and delivery.

We also note that uncertainty comes in many forms in IT service portfolio management. Not only the human and monetary demands of projects and assets cannot be fully known in advance and their outcome is not certain, but unforeseen events may the expected outcomes. For instance technical difficulties may require additional development, quality issues may require additional testing, or supplier delays may postpone the completion of a project.

Sophisticated models that take into account project and asset specific knowledge such as these unforeseen events and risks could be built to represent costs, resource demand and business impact. In this paper, we do not mandate what method is used to build these models. In practice, we believe that confidence intervals may be a simple enough approach that it may be accepted by practitioners, while at the same time capturing more information that a deterministic model. The shapes of the distributions could be either assumed (for instance Beta or triangular distributions are often used in project management), or derived from historical data.

### 4.2 Portfolio Valuation

We now define the criteria that qualify the 'best' portfolio in a way that takes into account the uncertainty of the input data.

**Service Metrics.** We assume that we have available a default forecast of the metrics being considered. This default forecast assumes that no changes are being done, i.e. no projects are selected and the level of budget and resources for operations stays the same. This forecast could be extracted from a domain expert or calculated using forecasting techniques [24]. We define this forecast as a random variable and note $F_{m,t}$ the forecast for metric $m$ at time $t$.

As part of the demand management process, requests for IT resources need to be justified by a business case, and often quantifiable business impact is required by portfolio managers. Hence, we assume that we have estimations of the impact of various investments to the business service metrics. For instance reducing the shared database service support staff by 20% is expected to increase by 30 minutes the MTTR of the two services dependant on the shared database asset. This impact can be estimated by a domain expert or determined through capacity and demand management. Simulation methods have also been successful in modelling IT support organisations and in predicting the performance of the incident management process [10]. For generality in this paper we define the random variable $I_{a,o,m}$ to be the impact on metric $m$ of choosing the operations investment $o$ for asset $a$. In a similar way, we also define $I_{p,m,t}$ for projects. Note that the impact of a project is time dependent, since it requires for a project to be completed, at least partially, to have some impact.

The overall impact of a portfolio selection on metric $m$ is hence composed of the default forecast, the impact of all operations investments on all dependant assets, and the impact of projects:

$$M_{m,t} = F_{m,t} + \sum_{a \in A_S} \sum_{o=1}^{O_a} x_{a,o} . I_{a,o,m} + \sum_{p=1}^{P} \sum_{\tau=1}^{t} y_{p,\tau} . I_{p,m,t-\tau} \qquad (1)$$

**Costs and resources.** Cost and resource usage of projects and operational activities are also assumed to be present. Most IT organisations require this information in order to do portfolio selection. However the quality of estimations can vary significantly. We hence introduce the random variables $C_{a,o,t}$ and $R_{r,a,o,t}$ respectively for costs and resource demands of asset operation investments, and $C_{p,t}$ and $R_{r,p,t}$ for the corresponding demands of projects. Because when a project is submitted it has not been decided when it would start, the time index for $C_{p,t}$ and $R_{r,p,t}$ is relative to the start of the project. The time index for $C_{a,o,t}$ and $R_{r,a,o,t}$ is absolute.

In addition, projects have the possibility of impacting the cost and resource demand of assets, for instance when introducing a new technology, and may have positive or negative consequences. We note $I^{C}_{p,a,t}$ the random variable modelling the impact of project $p$ on the cost of asset $a$ and $I^{R}_{r,p,a,t}$ its impact on resources. Hence the total cost of running asset $a$ is:

$$C_{a,t} = \sum_{o=1}^{O_a} x_{a,o}.C_{a,o,t} + \sum_{p=1}^{P}\sum_{\tau=1}^{t} y_{p,\tau}.I^{C}_{p,a,t-\tau} \quad (2)$$

A similar equation can be written for the resource requirement $R_{r,a,t}$.

**Portfolio Valuation**. We conclude this sub-section by giving the criteria for the service portfolio selection. For each metric $m$, a decision maker can define a suitable target region $[O^{-}_{s,l,t}, O^{+}_{s,l,t}]$. We can measure the likelihood of having $M_{m,t}$ within $[O^{-}_{s,l}, O^{+}_{s,l}]$ by calculating:

$$\lambda_{m,t} = \int_{O^{-}_{s,l}}^{O^{+}_{s,l}} pdf_{M_{m,t}}(x)dx \quad (3)$$

We can calculate in a similar way the likelihood of meeting budget and resource constraints. For simplicity we consider all random variables to be independent and can hence calculate the sum using the convolution of the variables for positive impacts, or the cross-convolution for negative impacts.

When appropriate, one may want to also consider the sum or the average of certain metrics over time before calculating the likelihood. For instance, providing quarterly and yearly predictions for revenue may be valuable to a decision maker.

### 4.3 Generation and Interactive Selection of Service Portfolios

IT executives often have multiple, possibly conflicting, objectives to take into account. We hence propose to model the problem as a multi-objective combinatorial optimisation problem [20] and aim at generating the set of feasible Pareto-efficient portfolios. The variables of the problem are the $x_{a,o}$ and $y_{p,t}$ defined above. The problem consists of maximise the set of objectives:

$$maximise\ \lambda_{m,t} \qquad m \in [1, M_s], t \in [1, T] \quad (4)$$

Because the problem is NP-complex, exact solutions may not be obtained for problems of realistic dimensions. But many meta-heuristics are available to approximate the Pareto-frontier [20].

A drawback of existing model-based optimal portfolio selection is that they use a 'black-box' approach. The solution is generated without leaving the decision makers the opportunity to make adjustments to the solution. Because all information may not have been modelled and because many stakeholders may be involved in the decision process, we believe a portfolio selection tool should be focused on decision support rather than decision making. When dealing with a small number of objective functions, in [19] the authors propose an effective user interface that allows a decision maker to iteratively refine her set of portfolio. As a next step, we will investigate techniques to visually explore the set of feasible and efficient service portfolios, possibly extending the ideas presented in [19] to support a larger set of objectives and to include the notion of likelihood.

## 5 Case Study and Validation

To demonstrate the feasibility of our approach, we apply it to a simple example of an online PC retailer. We first describe the scenario and validate our models and methods by solving the service portfolio selection for the yearly IT planning.

The business depends on $S = 3$ services: sales ($s_1$), shipping ($s_2$) and customer support. ($s_3$). The set of IT assets that each service depends on are depicted in **Fig. 1**Fig. 2. All services are evaluated by 3 metrics. The Revenue is in $1000s. The remaining two metrics evaluate the quality of service, and are averaged over the 3 services. Mean time between failures (MTBF) is measured in days, and mean time to recovery (MTTR) in minutes. For the purpose of this example, we assume a single, homogenous human resource pool, and ignore attributes such as skills, organisation, and geography that must be taken into account in real-life models. Based on market predictions, the expected revenue and standard deviation are forecasted to be $(\mu = 1000, \sigma = 100)$, $(\mu = 1000, \sigma = 120)$, $(\mu = 800, \sigma = 150)$, $(\mu = 1300, \sigma = 200)$ for all 4 quarters. For simplicity, all random variables in this example are assumed to be normally distributed. Based on historical information and if no changes are made to the IT budget, organisation and infrastructure, the MTBF is expected to be identical for all 4 quarters and normally distributed with $(\mu = 14, \sigma = 5)$, and the MTTR is normally distributed with $(\mu = 300, \sigma = 10)$[1].

The IT organisation of this firm has set itself three objectives for the end of the year: (1) to increase its revenue by 10%, (2) to reduce its IT costs by 5% and (3) to improve customer satisfaction (measured by a two-fold improvement in MTBF and a 50% reduction in MTTR).

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[1] The exponential distribution for MTBF and the log-normal distribution for the MTTR would have been better choices. We have settled on the normal distribution here for ease of calculation of the convolution and cross-convolution.

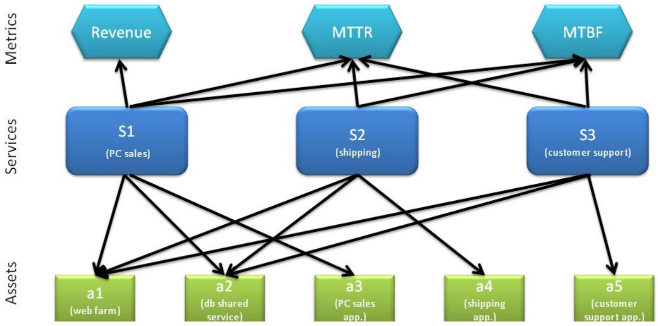


**Fig. 2.** Metrics, services and assets of the online PC retailer

A number of options for the operations of the IT assets have been proposed by the IT managers, in coordination with the business leaders. For each asset $a$, two operation investment options $O_a$ exist: the minimum $o = 1$, and the ideal $o = 2$. To keep this example brief, we assume that operational costs and resource requirements are the same in every budgeting quarter $t$, and we will note them $C_{a,o}$ and $R_{a,o}$. Table 1 presents the investment options for the web farm and the database service.

**Table 1.** Subset of the operations investments

| **Asset** | **Option** | $C_{a,o}$ | $R_{a,o}$ | $I_{a,o,1}$ (revenue) | $I_{a,o,1}$ (MTBF) | $I_{a,o,1}$ (MTTR) |
|---|---|---|---|---|---|---|
| *a=1* | *o=1* | 100 | 40 | $\mu = -50, \sigma = 10$ | $\mu = -3, \sigma = 1$ | $\mu = 10, \sigma = 2$ |
| | *o=2* | 200 | 70 | 0 | $\mu = 3, \sigma = 1$ | 0 |
| *a=2* | *o=1* | 200 | 40 | 0 | 0 | 0 |
| | *o=2* | 250 | 50 | $\mu = 50, \sigma = 10$ | $\mu = 3, \sigma = 1$ | $\mu = -10, \sigma = 2$ |

In addition to the operational investment, one or more projects can be invested in: increasing the shared database service capacity ($p = 1$), upgrading the web farm infrastructure ($p = 2$), implementing a new product search feature in the PC sales application ($p = 3$), implementing a build-your-own PC feature ($p = 4$), implementing an order tracing feature in-house ($p = 5$), and contracting out the order tracing functionality ($p = 6$). The investments in the database and web farm assets have reasonably high initial costs, but low labour requirements and relatively low uncertainty. Labour demands and costs are highly uncertain for the remaining projects that invest in new feature development with the exception of $p = 6$ that proposes to contract out the development and has minimum labour demands. The first two projects have impact mostly on the MTBF and MTTR metrics, as well as on the cost and staffing requirements of the web farm and shared database service assets. All other projects mostly affect the revenue.

Finally, dependencies exist between the projects. If any of $p = 3$ or $p = 4$ is selected, more web capacity needs to be provided ($p = 2$). Two exclusive options ($p = 6$) and ($p = 7$) are also provided for the "order tracking" feature.

We have implemented the proposed solution using the JMetal framework for multi-objective optimisation [25]. Although an exhaustive enumeration algorithm would work on our small example, our goals are to tackle real-world problem of 100s to 1000s of investments. We chose to model the problem using the following variables: 1 binary string of length $P$ used to determine which projects are selected, $P$ integer variables to determine the start time of each project (index $t$), and $A$ integer variable to select operations investment for each asset (index $o$). Since this configuration is not a standard problem type, we have adapted the crossover and mutation operators to fit our data structures.

We defined the target region for each objective to be within 10% of the expected value. When running the algorithm on the online PC retailer example, the algorithm gave a choice of 12 portfolios with 80% likelihood to meet all objectives (out of 131072 possible solutions).

## 6 Conclusion and Further work

We have presented a conceptual solution for IT service portfolio selection, an extension of project portfolio selection that also includes operational costs and resources. We have formalised the problem by presenting an information model and a mathematical formulation. In particular, we have taken into account the uncertainty of the data when defining the objective functions. Finally, we have seen how the model could apply to a small online PC retailer example. We have demonstrated the feasibility of the approach on this small example by generating the Pareto-frontier of efficient portfolios.

This paper gave an insight to the problem of IT service portfolio selection and an indication to the challenging requirements that solutions must meet. While our preliminary results are encouraging, more work needs to be done regarding the validation of the approach. Our immediate next steps are to test the scalability of the solution to understand its limits. Important issues such as the modelling of uncertainty, the nature of underlying distributions, the complexity of assets, services and metrics, are not addressed here and will be the subject of further work. Finally, we will research techniques to visually explore the trade-offs that decision makers have to make. The effectiveness and robustness of the solution will rely on human decision makers so an interactive, real-time, user-friendly solution is necessary.

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