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Value-Driven IT Project Portfolio Management: Tool-Based Scoring, Selection, and Scheduling

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Completed Research

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ABSTRACT

Managing IT project portfolios is a challenge because of IT projects' complexity, dynamics, and uncertainty. Many IT projects exceed resources or time frames and do not reach their value-driven goals. A continuous scoring, selection, and scheduling of IT project proposals is thus essential to build an optimal portfolio. It has a significant impact on value contribution, strategic direction, goal achievement, and competitive advantages. We quantify an IT project's urgency, strategy, efficiency, risk, and complexity as important evaluation and scoring criteria. To support top management decision makers in the IT project portfolio management process, we outline a combination of an evaluation approach with an optimization model. We develop a prototype decision support system to automate and simplify this process and demonstrate its applicability. Our recommendations address both theory and practice, improve IT project portfolio management, support value creation, and goal achievement.

Keywords

IT Project Portfolio Management, IT Project Selection and Scheduling, IT Project Scoring, Decision Support System, Design Science Research

INTRODUCTION

Worldwide, expenditures in Information Technology (IT) increased (Gartner, 2020), and IT became a critical success factor and thus significantly influences long-term performance and competitiveness (Cho and Shaw, 2013; Maruping, Venkatesh, Thong and Zhang, 2019). The evaluation, selection, and management processes of single IT projects to build an optimal portfolio is of high importance and has been addressed by many researchers (e.g., Cho and Shaw, 2013; Kundisch and Meier, 2011; Lee and Kim, 2001). IT project portfolio management (ITPPM) is a very challenging task: IT projects are complex, cross-functional, dynamic, non-routine, and temporary and thus have unknown and uncertain aspects. Also, a large amount of IT budget spending is used for routine operations. There is a need to initiate IT projects to achieve an organization's goals, create value, and stay competitive. Thus, it is crucial to implement the "right" IT projects out of competing proposals. An adequate method to score, select, and schedule IT projects and portfolios is highly essential and a critical business activity. It ensures that selected portfolios optimally create value and support an organization's strategies obeying interdependencies, constraints, and limitations (Chiang and Nunez, 2013; Kester, Griffin, Hultink and Lauche, 2011, Reyck, Grushka-Cockayne, Lockett, Calderini, Moura and Sloper, 2005; Turner and Müller, 2003).

IT project selection is connected with many difficulties, as qualitative and quantitative factors must be considered (Asosheh, Nalchigar and Jamporazmey, 2010). Use of a tool for ITPPM reduces decision times and increases efficiency, quality, transparency, and consistency of portfolio compositions and thus serves as decision support for decision makers. Many multiple criteria decision models to support the portfolio selection process already exist (Mohagheghi, Mousavi and Mojtahedi, 2019). However, no holistic scoring approach combined with an advanced optimization model has been developed and implemented to support decision makers. Thus, we illustrate a combination of an evaluation approach and an advanced optimization model for an IT project portfolio scoring, selection, and scheduling and develop a MATLAB prototype. The integration weakens the limitations of the sole use of scoring approaches as it considers resource restrictions and interdependencies. Further, scoring values do not serve as a key determinant for decisions but as one out of multiple inputs. The MILP solver also enables the scheduling of selected IT projects and a fast derivation of different scenarios depending on changing inputs. We contribute a nascent design theory that combines existing literature on evaluation criteria and optimization models. It provides knowledge to assist IT project portfolio scoring, selection, and scheduling and extends existing approaches in this research area. Our main contribution is the development of an integrated scoring and optimization model for this purpose. Other studies often focus on either scoring or optimization models or only take single projects into account. We integrate both methods and further consider interdependencies. We firstly develop a scoring model to score each IT project proposal uniformly. Afterward, we introduce an optimization model and implement it in a decision support tool. It allows dynamic IT project selections, enables impact analysis of changing input parameters, and increase the objectivity and transparency of ITPPM. Our results address both theory and practice to better understand scoring, selection, and IT project portfolios' scheduling processes. Thus, we support value creation and an organization's goals pursuit. Therefore, we address the following research questions:

RQ 1: How can top management decision makers uniformly score IT project proposals dependent on value creation?

RQ 2: How can top management decision makers be supported to ~~optimally~~ select and schedule an IT project portfolio?

Next, we outline our research background, including our research design and a brief review of ITPPM. Afterward, we develop our scoring model and outline our ITPPM decision support framework. This involves our advanced operations research (OR) optimization model and our MATLAB prototype decision support system (DSS) implementation. Next, we discuss an applicability check and its results. Finally, we generalize our results, discuss implications and limitations, outline conclusions, and an outlook for further research.

RESEARCH BACKGROUND

Research Design

We conduct a Design Science Research (DSR) oriented methodology (Peffers, Tuunanen and Rothenberger, 2007; Peffers, Rothenberger, Tuunanen and Vaezi, 2012). DSR systematically develops new and innovative artifacts and contributes to both Information System (IS) theory and practice (Gregor and Hevner, 2013; Hevner and Chatterjee, 2010). Using this methodology, we can ensure relevance and rigor developing, specifying, and evaluating our IT project scoring, selection, and scheduling models and tool.

Our research is motivated by the increasing importance and spending in IT to gain value, achieve goals, and stay competitive. However, many IT projects still fail and do not reach their goals due to wrong selection decisions (Varajão and Trigo, 2016). To get an overview of relevant literature for ITPPM, we performed a systematic literature review (Templier and Paré, 2015; vom Brocke, Simons, Riemer, Niehaves, Plattfaut and Cleven, 2015; Webster and Watson, 2002). In a first step, we conducted a database search in the journals included in the AIS Senior Scholars Basket of Eight, Project Management Journal, International Journal of Project Management, and Science Direct. We used combinations of IT, project portfolio management, selection criteria combined with scoring and tool based as search terms, and we excluded non-English literature from the review. After identifying key literature, we applied a backward, forward, author, and similarity search using Google Scholar (Webster and Watson, 2002).

Based on the gained knowledge, our goal was to improve both objectivity and quality to score, select, and schedule IT project proposals and enable automatized decision support. We used the examined literature to quantify relevant evaluation criteria, categorized them, and designed our scoring model. We further derived essential requirements and constraints to develop our optimization model. This serves as a basis for our tool to automatize the IT project portfolio composition and scheduling. We repeated the iterations to ensure all scoring, selection, scheduling requirements, scientific methods, and existing expertise. Respective, our decision support model and tool build our artifact. The tool's graphical user interface (GUI) allows to insert IT project data. This includes specifications about resources, interdependencies, and constraints. Once we had developed the software, we extensively tested it and evaluated our tool and model in a subsequent applicability check. From 25 different IT projects with interdependencies and constraints, we selected and scheduled the ones that maximize the total value contribution.

IT Project Portfolio Management

A project portfolio is built of different projects carried out under the management of an organization and both share and compete for the same scarce resources to achieve goals (Archer and Ghasemzadeh, 1999; Linhart, Röglinger and

Stelzl, 2020; PMI, 2013). We define ITPPM as a continuous and dynamic process in which IT project proposals are identified and together with ongoing IT projects (re-)scored, (re-)prioritized, (re-)selected, and (re-)scheduled considering different constraints, interdependencies, resource limitations, and stakeholder interests (Cooper et al. 1999; Kester et al. 2011; Martinsuo and Lehtonen 2007; Pellegrinelli et al. 2015). It assures the strategic goals' meeting, reduces uncertainties, and realizes benefits while controlling the whole portfolio (Daniel, Ward and Franken, 2014; Turner and Müller, 2003).

In the PPM literature, the process of project portfolio selection and scheduling (PPSS) is a main stream ~~since~~ for many years. It is about identifying the "right" projects out of proposals considering limitations, constraints, interdependencies, and scheduling them within the planning periods (Chiang and Nunez, 2013; Zhang, Hipel and Tan, 2019). Following the ITPPM cycle, organizations can set the number of IT projects they can execute simultaneously and prevent an IT project's overload. Resulting, selected IT projects are more likely to be completed successfully (Buchwald and Urbach, 2012). In the literature, there exists a great variety of different approaches and methods for PPSS and PPM. They can be distinguished in financial and non-financial methods (Costantino, Gravio and Nonino, 2015). Here it is possible to differentiate between single criterion analysis, scoring models, and optimization models. The latter includes methods such as integer linear programming, multi-criteria selection, fuzzy programming, MILP, multi-objective programming, non-linear programming, and stochastic programming. Various studies of these approaches and methods can be found in Mohagheghi et al. (2019) and Zhang, Dou, Zhao and Zhao (2017).

	Urgency	Strategy	Efficiency	Risk	Complexity		Urgency	Strategy	Efficiency	Risk	Complexity
Abid and Guermazi (2009)			◑	◑		McLaren et al. (2011)		●	◔	◔	
Archer and Ghasemzadeh (1999)		◑	◑	◑		Raschke and Sen (2013)	◑	◑	◑		
Asosheh et al. (2010)		◔	◔	◔		Reyck et al. (2005)		◑	◑	◑	
Bacon (1992)		◑	◑	◑		Rodgríguez et al. (2016)				●	
Bardhan and Sougstad (2004)			◕	◕		Rosacker and Olson (2008)	◔		◑	◑	
Chen (2002)		◔	◔			Santhanam and Kyparisis (1995)		◑	◑		
Chen et al. (2009)				●		Setterstrom (2016)					◔
Chen et al. (2020)		◑				Serafeimidis and Smithson (2003)		◔	◔	◔	
Chiang and Nunez (2013)	◔	◕	◕	◕	◑	Shang and Seddon (2002)		◕	◕		◑
Cho and Shaw (2013)			◑	◕	◔	Sowlati et al. (2005)			◕		
Irani and Love (2002)		◔	◑			Sweetman and Conboy (2019)	◔	◔	◔		◕
Jiang and Klein (1999)	◑	◑	◑	◑	◔	Thomas et al. (2007)	◑	◑			◑
King (1978)		●				Willcocks (1992)	◔	◔	◕		
Liang and Li (2008)			◑	◑		Xia and Lee (2005)					●
McFarlan (1981)				●		Zhang et al. (2017)		◑	◑	◑	

The fullness of the circles provides information about the degree of focus of the respective evaluation criterion:
◔ : low ◑ : medium ◕ : high ● : very high

Table 1. Overview of Selected IT Project Evaluation Criteria

Independent of the method applied in the PPSS process, there is the need to properly define IT project evaluation criteria as those decisively influence the scoring and selection. Based on our literature review, we categorized the main IT evaluation criteria into the categories urgency, strategy, efficiency, risk, and complexity. Table 1 summarizes the most important literature dealing with these criteria. Here, the fuller the circle, the more emphasis was put on a certain criterion. We used the findings to develop our scoring model and scale after that. However, as criteria are dependent on the environment and thus differ between organizations, a quantification and categorization of all important criteria is impossible (Mohagheghi et al. 2019).

There are also commercially available PPM solutions, ranging from Excel sheet documents to specific PPM software with different functionalities. These include, among other things, data and resource management, portfolio prioritization or simulations, scenario and strategy analysis, scheduling, program management, portfolio summary dashboards, status, bug, and time tracking. While some software offer a wide range of features, others are limited to specific ones with a focus, e.g., on monitoring and tracking. "Microsoft Project & PPM", "Celoxis", "SAP Portfolio and Project Management", "Planview", and "Gensight" are examples for commercial PPM solutions (ERP Desk, n.d.).

DEVELOPMENT OF A SCORING MODEL

Based on our literature analysis and the extracted evaluation criteria, we developed our scoring model. It summarizes the most common selection criteria into one score. This allows a uniform, objective, and transparent evaluation of single IT projects, considering the most common criteria to make reliable results. The quantified evaluation criteria from our literature analysis form the basis for our scoring model. We then divided each of these categories into further sub-categories, again based on the literature. The general mechanism of our scoring model is shown in Equation (1).

$$a_i = \sum_{c=1}^{C} \left(\frac{\left(\sum_{n=1}^{N_c} v_{c_{n,i}} \right)}{\#N_c} w_c \right) \tag{1}$$

Let $v_{c_{n,i}}$ be values of a criteria's sub-criteria with $c \in \{1, \dots, C\}$ being the criteria, e.g., risk, and $n \in \{1, \dots, N_c\}$ their sub-criteria, e.g., probability of occurrence. Parameter w_c denotes the weight, i.e., importance of criterion c with $\sum_{c=1}^{C} w_c = 1$. Top management decision makers must define all weights w_c and values $v_{c_{n,i}}$ for all (sub-)criteria. The individual IT project score a_i of an IT project proposal i is thus the sum of products of the sub-criteria's mean score with the corresponding criterion's weight.

We developed an exemplary scoring table using the quantified (sub-)criteria (cf. Table 2). It defines a scale with specifications a sub-criterion must have to get a certain score. We used a mix of verbal and numerical scales. Decision makers evaluate each IT project proposal accordingly to each sub-criterion and assign a score considering the scale's descriptions. The higher the number, the higher is the score and the IT project's influence. By applying Equation (1), it is possible to use this input to calculate each IT project proposal's individual score. However, the scoring table in Table 2 is very general, and depending on the organization, concrete verbal or numerical values need to be defined precisely.

A first criterion is the operational urgency, which evaluates the consequences of an IT project's rejection. This encompasses the expected consequences of a non-compliance with regulatory requirements, the need for an IT project to modernize or replace existing technical equipment, and the need to keep the daily business running. We further identified the strategy to be a standard evaluation and selection criterion. Here decision makers have to evaluate the positive impact of an IT project's selection on competitive advantages, increase in market shares, and the degree of support to achieve the business goals. Efficiency is another evaluation criterion, and required periods until invested capital recovers are scored. Further, the effects of an IT project's selection on long-term cost savings and growth rates are evaluated.

We identified risk to be an additional, widely used evaluation criterion. It includes the probability of occurrence and its resulting cost as sub-criteria. The experience of an IT project leader in similar finished IT projects is a further risk sub-criterion. Lastly, the degree of both positive and negative influences on other IT projects is evaluated. The sub-criterion of positive (negative) impact describes the percentage of other IT projects being positively (negatively) influenced by an IT project selection. The criterion complexity is composed of two sub-criteria. The first one includes the required number of involved business departments for IT project implementation. The more departments involved, the more complex is the IT project. As employees can only deal with a limited amount of changes in their daily work, we define the degree of deviation from the daily business by the IT project's selection to be a second sub-criterion.

(Sub-) Criterion		Score 1	Score 2	Score 3	Score 4	Score 5
Urgency	Non-compliance with regulatory requirements	non existing	short-term disruptions	considerable disruptions	legal consequences	sanctions
	Need to keep the daily business running	no need	for only a few processes	for several processes	for many processes	for core processes
	Need for modernization	within the next 6+ years	within the next 5 years	within the next 4 years	within the next 3 years	within the next 2 years
Strategy	Competitive advantage	none	barely noticeable	noticeable	considerable	highly significant
	Business goals support	none	barely noticeable	noticeable	considerable	highly significant
	Increase in market share	no effects	barely noticeable	noticeable	considerable	highly significant
Efficiency	Investment recovery (in periods)	> 20	16-20	11-15	5-10	< 4
	Long-term cost savings	no effects	barely noticeable	noticeable	considerable	highly significant
	Impact on growth rate	no effects	barely noticeable	noticeable	considerable	highly significant
Risk	Probability of occurrence	> 15%	11-15%	6-10%	5-2%	< 2%
	Cost (in k €)	> 1,000	300-1,000	100-299	99-20	< 20
	# of similar past IT projects of IT project leader	none	1-2	3-4	5-6	> 6
	Positive impact on other IT projects	none	1-3%	4-6%	7-10%	> 10%
	Negative impact on other IT projects	> 10%	7-10%	4-6%	1-3%	none
Complexity	# of involved business departments	> 13	10-13	7-9	4-6	< 4
	Degree of deviation from daily business	many significant changes	considerable number of changes	effects on isolated processes	minor changes	no changes

Table 2. Exemplary Scoring Table

DECISION SUPPORT FOR ITPPM

Underlying Model

Our MILP optimization model is based on the model of Ghasemzadeh, Archer and Iyogun (1999). An application enables the selection and scheduling of different IT project proposals for an optimal IT project portfolio composition. We decided to use a MILP optimization model and solver as indivisible resources for an IT project initiation are integer. Moreover, binary variables enable selecting IT projects into a portfolio and considering further restrictions like interdependencies. Thus, it is possible to describe an IT project's execution by expressing a decision between an exclusion ($x_i = 0$) or execution ($x_i = 1$) in general or for a specific planning period. In a first step, each IT project is scored according to our scoring model. After that, a maximization of the objective function (2) is possible. It considers different constraints, resource limitations, and a scheduling in a multi-periodic planning horizon, while it is flexible regarding the starting periods. Many other models only consider either one planning period or IT projects that have to start in period one, leading to a non-exhaustion of resources and less selected IT projects (Carazo, Gómez, Molina, Hernández-Díaz, Guerrero and Caballero, 2010). Table 3 expresses the notation for our optimization model.

$P := \{1, 2, \ldots, p_{\lvert P\rvert}\};\ \lvert P\rvert \in \mathbb{N}$	Set of IT projects p_i with $\lvert P\rvert$ defined as the cardinality of P
$A := \{a_1, a_2, \ldots, a_{\lvert P\rvert}\}$	Set of scores a_i of IT project p_i, see Equation (1) and Table 2
$T := \{1, 2, \ldots, \lvert T\rvert\},\ \lvert T\rvert \in \mathbb{N}$	Possible periods t_i for IT projects
$E := \{\{p_{1_1}, p_{2_1}\}, \{p_{1_2}, p_{2_2}\}, \ldots, \{p_{1_{\lvert E\rvert}}, p_{2_{\lvert E\rvert}}\}\}$ $\lvert E\rvert \in \mathbb{N} \cup 0,\ p_{1_l} < p_{2_l}\ \forall\, l = 1, 2, \ldots, \lvert E\rvert;$ $p_{1_l}, p_{2_l} \in P\ \forall\, l = 1, 2, \ldots, \lvert E\rvert$	Set of sets of mutual exclusive IT projects (an empty set is possible)
$M := \{m_1, m_2, \ldots, m_{\lvert M\rvert}\};$ $m_i \in P\ \forall\, i = 1, 2, \ldots, \lvert M\rvert$	Set of mandatory IT projects (an empty set is possible)
$PR := \begin{Bmatrix} pr_{11} & \cdots & pr_{1\lvert P\rvert} \\ \vdots & \ddots & \vdots \\ pr_{\lvert P\rvert 1} & \cdots & pr_{\lvert P\rvert\lvert P\rvert} \end{Bmatrix}$	Matrix of predecessors pr_{ig}, $pr_{ig} = 1$ if IT project p_i is a necessary predecessor of IT project p_g, $pr_{ig} = 0$ else
$R_s := \begin{Bmatrix} rr_{11,s} & \cdots & rr_{1\lvert T\rvert,s} \\ \vdots & \ddots & \vdots \\ rr_{\lvert P\rvert 1,s} & \cdots & rr_{\lvert P\rvert\lvert T\rvert,s} \end{Bmatrix};\ s \in S$ $S := \begin{Bmatrix} \text{internal domain specific,} \\ \text{external, internal resources} \end{Bmatrix}$	Matrix of required resources $rr_{ij,s}$ of kind s to execute IT project p_i in period j
$R_{s\ total} := \{ra_{1,s}, ra_{2,s}, \ldots, ra_{\lvert T\rvert,s}\}$ $S := \begin{Bmatrix} \text{internal domain specific,} \\ \text{external, internal resources} \end{Bmatrix}$	Set of available resources $ra_{j,s}$ of kind s in period j
$X_{ij} := \begin{Bmatrix} x_{11} & \cdots & x_{1\lvert T\rvert} \\ \vdots & \ddots & \vdots \\ x_{\lvert P\rvert 1} & \cdots & x_{\lvert P\rvert\lvert T\rvert} \end{Bmatrix}$	Matrix of binary optimization variables, $x_{ij} = 1$ if IT project i runs in period j, $x_{ij} = 0$ else
VC	Total value contribution for an organization

Table 3. Notations of Parameters and Optimization Variables

To maximize an organization's total value contribution, we have:

$$VC = \max_{x_{ij}} \sum_{i=1}^{|P|} \sum_{j=1}^{|T|} a_i x_{ij} \qquad x_{ij} \in \{0,1\}\ \forall\, i \in P \wedge \forall\, j \in T \qquad (2)$$

with the constraints

$$\sum_{j=1}^{|T|} x_{ij} \leq 1 \qquad \forall\, i = 1, 2, \ldots, |P| \qquad (3)$$

$$\sum_{i=1}^{|P|} x_{ij} rr_{ij,s} \leq ra_{j,s} \qquad \forall\, j \in T;\ \forall\, s \in S \qquad (4)$$

$$\sum_{j=1}^{|T|} x_{i_1 j} + x_{i_2 j} \leq 1 \qquad \forall \{i_1, i_2\} \in E \quad (5)$$

$$\sum_{j=1}^{|T|} x_{ij} - x_{gj} \geq 0 \qquad \forall\, i, g \in P, \text{with } pr_{ig} = 1 \quad (6)$$

$$x_{ij} k - x_{gk} j \geq 0 \qquad \forall\, i, g \in P \text{ with } pr_{ig} = 1;\ \forall\, j, k \in T \text{ with } j < k \quad (7)$$

$$\sum_{j=1}^{|T|} x_{ij} = 1 \qquad \forall\, i \in M \quad (8)$$

The objective function (2) maximizes an organization's total value contribution adding up the individual scores of selected IT projects. Constraint (3) ensures that an IT project can only run once during the time horizon if it is selected. Further, IT project selection is mostly restricted by resource limitations. Constraint (4) prevents an exceedance of such limited resources and must be set for each restricted resource of kind s. IT projects' interdependencies are considered in constraint (5) to (7). The mutual exclusiveness between two IT projects is obeyed with constraint (5). Temporal interdependencies imply that certain IT projects have to be finished (predecessor IT projects) before others can run (successor IT project). Once a successor IT project is selected into the portfolio, all related predecessor IT projects must also be selected (6). The running period of the successor IT project must be sometime after the predecessor IT project's ending period (7). Due to laws and regulations, strategic considerations, or other reasons, mandatory IT projects must be included independent of their score, see Equation (8). Such IT projects are only optimized regarding scheduling and resource consumptions. Predecessor IT projects of such IT projects are set as mandatory IT projects automatically.

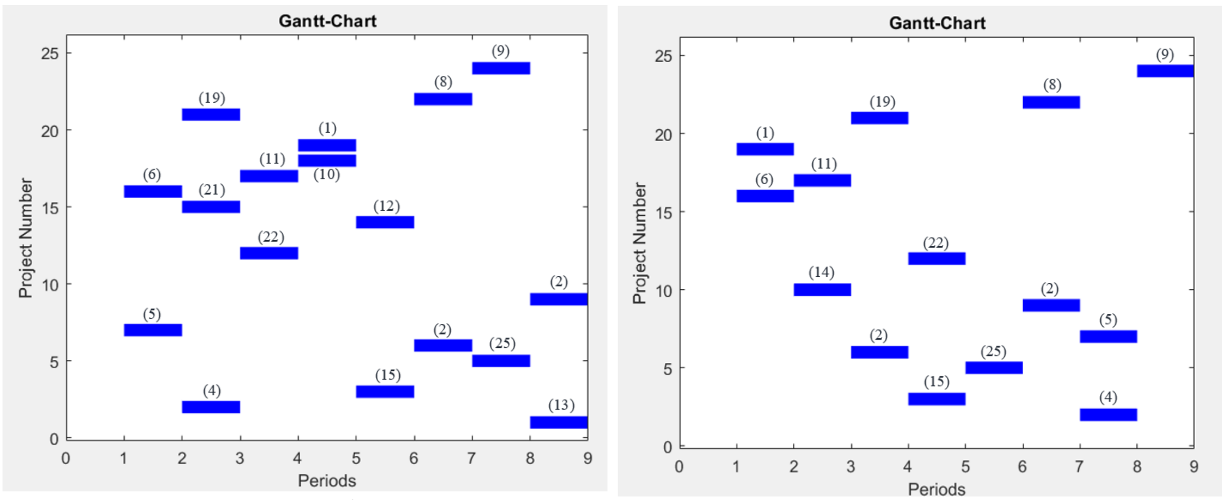
DSS Prototype for an Optimization

To evaluate how our OR optimization model can be applied and how it performs, we programmed a tool using Math Works' software MATLAB Version 9.6. It enables decision support for an IT project portfolio composition and scheduling, which is increasingly important as complexity rises with the number of IT project proposals and periods. It maximizes the total IT project portfolio score by selecting different IT project proposals, taking into account interdependencies and constraints. With the MATLAB App Designer, we generated a GUI for the DSS prototype. Intuitive usability and comprehensive visualization allow top management decision makers to make their inputs for different scenarios. After all specific information is entered, the DSS prototype solves our optimization model with all constraints and illustrates IT projects to select and their corresponding running period. Thus, the decision process is less complex and based on objective and transparent criteria, rather than influenced by subjectivity. A database contains all IT projects' and portfolio's' specific information, for example, a name, number of IT project proposals, planning periods, number of scoring criteria, and corresponding weights. It also contains IT projects' specific scores, interdependencies, constraints, resource availabilities, and requirements. At the end of an optimization process, the total optimized IT portfolio score is given, and the optimal solution with its schedule is illustrated in a Gantt chart. Error messages open in case of contradictions, false or missing inputs, and prevent the optimization process. They are precisely defined to correct inputs easily.

Applicability Check

We provide an applicability check to evaluate our tool and demonstrate its feasibility (Rosemann and Vessey, 2008). We consider two scenarios to show the impact of a decrease in resource availability on the total portfolio value contribution. We use a manually generated and generic IT project portfolio optimization problem for the IT projects' data, including 25 one-periodic IT project proposals and eight planning periods. Based on our scoring model, see Equation (1), and the criteria and scales in Table 2, we evaluate each IT project proposal. The criteria urgency and strategy both get a weight of 0.3, the risk criterion a weight of 0.2, and the efficiency and complexity a weight of 0.1 each. We choose the weights based on the importance of the factors to achieve an organization's goals. We consider three constrained resources: general external-, general internal-, and internal domain-specific resources. The availability throughout every period is given as an input, and top management decision makers set each IT project's consumption. We assume that there are two mandatory IT projects and two pairs of mutually exclusive ones. Temporal interdependencies result from one large IT project that needs to be divided into smaller ones, i.e., four one-periodic IT projects with the need to be finished chronologically. As the three predecessor IT projects do not have a high value contribution without the last successor IT project they are scored very low and the last successor IT project high. This ensures either the selection of all four chained IT projects or none. Figure 1 illustrates the IT project portfolios' optimization results with selected IT projects and schedules in Gantt charts. According to the scoring results, the numbers above the blue bar reflect an IT project's rank, with (1) being the highest-ranked IT project and (25) the lowest. In case of the same scoring value of multiple IT project proposals, they get the same rank.

(1) Schedule for normal resource availabilities (2) Schedule for a 20% decrease in resource availabilities



Numbers in brackets indicate the rank of the IT project according to the scoring results

Figure 1. Optimization Results for the Generic Portfolio

We conduct the calculation on a standard laptop (Intel Core i7-8665U, 1.9 GHz CPU with 16 GB RAM) using MATLAB Version 9.6. Our DSS prototype can find an optimal solution for the IT project portfolio composition and scheduling. In case of normal resource availability, cf. Figure 1 (a), 17 out of 25 possible IT projects are selected into the portfolio with starting periods spread over the complete planning horizon. The maximized total portfolio value is 53.61, compared to a total value contribution of 75.71, if all IT projects are selected without interdependencies, limitations, and constraints.

We then decrease the availability of all three resources by 20% and repeat the optimization. The equal decrease in all resources serves as an example only. In practice, resources' decline mostly differs between resource types. When doing so, only 14 IT projects are selected into the portfolio, with a total value contribution of 44.8. The Gantt chart in Figure 1 (b) illustrates the selected IT projects and their schedule. A decrease of 20% for all resource availabilities thus decreases the maximal total portfolio value by 16.3%. In contrast, a 20% decrease of the external resources and domain-specific resources only reduces the score by 4.4% to 51.25, with 16 IT projects being selected. In our generic example, the decrease in the availability of the general internal resources significantly impacts the IT portfolio's optimal value contribution and must be considered wisely.

DISCUSSION, IMPLICATIONS, AND LIMITATIONS

Top management decision makers' knowledge about IT project evaluation and selection is indispensable to ensure goal achievements and value contributions. With the increasing importance of selecting the "right" IT projects into an IT project portfolio, we adopted a DSR oriented approach to design an artifact. This is our OR optimization model and DSS prototype. Based on relevant ITPPM literature, we developed our scoring model, including an exemplary scale, which serves as an input for our optimization model. This is based on existing models and considers different interdependencies and constraints. We then implemented both models in a tool using MATLAB. It improves objectivity, prevents failures, and uses resources efficiently. Our scoring model and tool both correspond to our research questions. With the relevant evaluation criteria included in our scoring model, it is possible to uniformly score each IT project proposal to create value. Our tool serves as a DSS prototype for ITPPM to optimize IT projects' total value contribution and support the IT project selection and scheduling while further contributing to the existing theoretical body of knowledge. However, it is crucial to consider that it only recommends the best compositions.

The tool's integrated intuitive GUI allows the user to enter IT project-specific data easily. It is possible to determine temporal interdependencies between different IT projects and to specify mutually exclusive ones. Moreover, it allows to define mandatory IT projects and determine resource requirements, availabilities, and scoring of all IT projects according to predefined criteria. It enables to automatize, improve, and justify a strategic optimization of the IT project selection and scheduling process and thus enhances ITPPM quality and efficiency. Our scoring model quantifies important criteria to consider when evaluating IT project proposals. It allows a structured and uniform evaluation process of each IT project, for both, decisions made tool-based or manually. Because of an organization's heterogeneity, sub-criteria can differ and must be defined with specific values. It is crucial always to choose the same criteria within an organization to compare the different IT projects. However, the individual scoring of each IT project with all criteria suffers from high manual effort. There is a trade-off between having enough criteria to evaluate IT project proposals and too many criteria with a high manual effort.

We limited the duration of an IT project to one period, i.e., longer IT projects have to be chained in several one-periodic sub-projects. This leads to an IT project chain with the need for chronological implementation. Although we considered such temporal interdependencies, it still can lead to inefficiencies, as a selection of only some predecessor IT projects without successor IT projects is possible. If the last IT project in the sequence is required for reasonable value addition, it must get a high score whereas predecessor IT projects only get low scores. This increases the likelihood of a selection of either all or none. However, the general steering, controlling, and monitoring are better manageable for one-periodic IT projects and reduce complexity. Deviations from desired goals and resource consumptions can be identified at an early stage. Timely adding, reprioritizing, or terminating IT projects ensure an organization's goals achievement, a meaningful value contribution, and a proper strategy alignment. However, resource or time exceedances are not always rooted in an IT project itself. They can also result from insufficient management support, overloaded employees, or exceedances in other IT projects.

In case of a manual portfolio composition, IT projects can be, e.g., included in the portfolio based on their scoring rank until resources are exceeded. However, with an increasing number of IT project proposals, planning periods, and constraints, this process becomes too complex, making manual decisions too difficult, especially when aiming at increasing the portfolio value. A tool can thus reduce complexity and make decisions more reliable, but "a fool with a tool is still a fool". Our applicability check serves as a small example of how our tool works. It shows that IT projects are selected into the portfolio without strictly following the scoring rank order. This is inter alia due to the consideration of interdependencies, but also as a selection of the highest-ranked IT projects does not necessarily maximize the overall portfolio value. Our underlying example with 25 IT project proposals and eight planning periods shows that, independently of the resource availability, a manual portfolio selection is difficult and potentially would not lead to an optimal portfolio value.

Our tool further enables to perform sensitivity and robustness analyses to assess the impact of changing input parameters, e.g., the inclusion of a particular IT project, and their consequences on the overall portfolio value. Top management decision makers can discuss different scenarios and directly see effects in the total IT project portfolio score. They are able to justify the impact of changes based on realistic values instead of subjective experience. Decisions become more objective, more transparent, and more reliable. However, some selection decisions are not influenced by rationality, but by executives' political decisions or by prestige reasons.

There exists a great variety of commercial PPM software with a wide range of functionalities. However, we could not test the software precisely as we did not have access up to now. Therefore, we could not analyze the underlying models, methods, and assumptions for IT project selections to identify similarities or differences between these and our models. Therefore, our models are based on theoretical considerations and our literature review, limiting our results. IT projects can start in any planning period in our optimization model, but yet it does not consider an a priori defined ending period. Further, our IT project portfolio's total value contribution is summed up by the selected IT project's individual scores. This takes no possible synergies between single IT projects into account. It neglects, for example, that a finished IT project can reduce the required resources of another one or if several low scored IT projects are selected, they together can add more value. Besides, even though the scoring model's application reduces subjective influences and an over- or underestimation of IT project values, it still cannot be avoided. Employees benefiting from an IT project implementation should not evaluate these alone. Instead, it should be done by independent employees to reduce subjective influences. Our applicability check is limited to one manually generated and generic numerical example with only a limited amount of IT project proposals, interdependencies, and constraints. However, our evaluation enables the transferability and generalizability of our models and tool.

CONCLUSIONS AND FURTHER RESEARCH

With increasing spending and relevance of organizational IT and IS, ITPPM today is of great importance to ensure a value contribution, competitive advantages, and goal achievements by optimally selected and scheduled IT projects. We outlined how to uniformly score IT project proposals and how top management decision makers can be supported in their selection and scheduling. Our contribution involves the development of a scoring and optimization model for ITPPM decisions. The scoring model encompasses a systematically structured literature synthesis of relevant IT project evaluation criteria into one scale to score IT project proposals uniformly. The scoring results are then used as an input for further decisions. Our developed mathematical optimization model implemented in the tool provides a DSS prototype for IT project prioritization, selection, and scheduling to compile a portfolio that maximizes the total value contribution over all planning periods. It takes specific constraints, interdependencies, and mandatory IT projects into account and enables a direct comparison and evaluation of different scenarios and results. It enhances efficient resource allocations, reliable decisions with higher transparency, and decreases decision times to increase the total value contribution. Decision makers can define tool-based recommendations as they are based on objectivity rather than only on experience and subjectivity. We tested the tool with a manually generated generic portfolio to show its applicability. It only requires few specifications and the availability of necessary data and information to adopt it in an organization. Our DSS prototype can supplement or replace existing methods to ensure a value contribution by selecting and scheduling the "right" IT projects.

Our scoring and optimization models offer several possibilities to extend the current body of knowledge. Further research should address an extension of the one-periodic durations, include a priori defined ending period, and IT projects' synergies. It should use systematic case study research and expert interviews in focus groups for a strong evaluation. It gives more insights into practical IT project portfolio decisions, and further useful functionalities and constraints can be identified. Experts should also evaluate how our models improve their decision quality and how they simplify the process. Further research should also evaluate our models and tool with real-world data, especially with more IT project proposals, more interdependencies, more constraints, and more planning periods. This provides more evidence for the tool's applicability, and transferability and generalizability have to be shown in detail. Manual effort to make all necessary input in the tool can be further reduced by implementing an interface to upload existing data into the tool. Further research should also analyze existing commercial PPM software in more detail and compare results with our models and tool.

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