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# IT Project Portfolio Management Tools: Towards Taxonomy-based Archetypes

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## Abstract

*To achieve organizational goals and remain competitive, evaluating, selecting, and managing IT projects and proposals to build a value-driven portfolio is a critical activity. IT project portfolio management (ITPPM) tools assist these portfolio-related activities, support strategic decision-makers, and help complete more IT projects successfully. Despite existing research on this topic, knowledge about the characteristics and design elements of ITPPM tools is still limited. We develop a taxonomy based on scientific literature and 60 real-word ITPPM tools with four perspectives, 20 dimensions, and 51 characteristics. Subsequently, we perform a cluster analysis and identify five ITPPM tool archetypes. Our results and findings contribute to the knowledge base and integrate scientific and practical knowledge to build the basis for further research on ITPPM tools. Further, we structure the ITPPM tool market, guide practitioners in selecting an appropriate ITPPM tool and support the development of new solutions or develop existing ones further*.

**Keywords:** IT project portfolio management tools, taxonomy, design elements, cluster analysis, archetypes.

## 1. Introduction

Due to the increasing investments in organizational information technology (IT) (Gartner, 2022) various IT projects arise and a decision on which to select is needed. The evaluation, selection, and planning of these IT projects are critical tasks of IT project portfolio management (ITPPM) and have already been extensively researched (e.g., Trigo & Varajão, 2020). Because of IT projects' rising complexity and importance, there are many commercial tools to support the ITPPM (Kock et al., 2020). However, many organizations only use software solutions for single project management, while those for project portfolio management (PPM) are rarely applied (Besner & Hobbs, 2012). Thereby, they lead to more successful project completions, efficient resource allocations, and less redundant projects. Those implemented in line with organizational needs and goals can support value-driven PPM (Ayyagari & Atoum, 2019). The tools aim to provide an overview of the IT portfolio, display portfolio data, and support decision-makers to prioritize and strategically align the portfolio to ensure value contribution. Thereby, available tools differ in their functionalities (Killen et al., 2020; Kock et al., 2020; Symons, 2009). To meet organizational needs, goals, and purposes, selecting a suitable tool is challenging, given the large number of existing tools. Further, these decisions are often made ad hoc and based on personal perceptions (Ahlemann, 2009; Gerogiannis et al., 2010).

Previous literature has already analyzed several PPM tools, ranked them based on their competitive positioning, analyzed their strengths and weaknesses (Stang et al., 2019; Visitacion & DeGennaro, 2009), identified commonly occurring issues (Ayyagari & Atoum, 2019), and discussed their requirements (Ahlemann, 2009). However, current literature does not provide a holistic and empirically validated analysis of ITPPM tools. Therefore, we classify real-world ITPPM tools and develop a taxonomy that can establish a comprehensive knowledge base of similarities and differences in the field of interest. The taxonomy can set the basis for further theory-building about, e.g., design theories to improve the understanding of ITPPM tools (Kundisch et al., 2021; Muntermann et al., 2015). Based on the taxonomy, we apply a cluster analysis to deduce archetypical patterns in the analyzed tools and evaluate the taxonomy's applicability (Kundisch et al., 2021). These clusters reduce the taxonomy's complexity as they group the objectives and exceed its descriptive character. Thus, our results and findings reduce the complexity of existing software solutions, allow a distinction, and can be beneficial to academics in this field. For practitioners, they provide a structured overview of underlying ITPPM tools, their (non-)functionalities, and can assist the decision process for a specific solution. For already operating organizations and start-ups, our results and findings present the current

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state of ITPPM tools on the market, which allows a comparison of own software solutions and can be used as a basis for new tools and tool extensions. We follow the methodology for taxonomy development by Nickerson et al. (2013) and Kundisch et al. (2021) and address the following research questions (RQ):

RQ1: *What are theoretically grounded and empirically validated elements of ITPPM tools?*

RQ2: *What archetypes can be deduced based on this classification?*

First, we provide the theoretical background of ITPPM and ITPPM tools. Then, we describe our research design, data collection, and research methods. Afterwards, we derive our taxonomy and archetypes and evaluate them with five experts. Finally, we discuss our results and findings, their implications and recommendations, and conclude with limitations, further research opportunities, and conclusions.

## 2. Theoretical background

An IT project portfolio constitutes the management of various IT projects and programs, intending to create value and achieve organizational goals while there is competition for scarce resources (Linhart et al., 2020; PMI, 2017). Within ITPPM, decisions about the evaluation, selection, prioritization, scheduling, and termination of IT projects and programs are continually made. These processes are influenced by constantly changing information, uncertainties, dynamic opportunities, and multiple goals (Mohagheghi et al., 2019). Resource overloads, overlapping projects, unclear roles and responsibilities, and projects deviating from their goals are commonly occurring problems (Too & Weaver, 2014; Trigo & Varajão, 2020). Due to higher IT budgets and more investments, IT has become a critical success factor and significantly influences the achievement of corporate goals (Bezdrob et al., 2020). Therefore, the selection of value-driven IT projects is essential for organizations (Tavana et al., 2019). Nevertheless, many decisions are made ad hoc rather than based on standardized processes and methods. Hence, many IT projects still deviate from their goals, are dropped, or fail (Varajão & Trigo, 2016).

Many ITPPM tools have emerged supporting various ITPPM activities and decisions (Caniëls & Bakens, 2012; Daradkeh et al., 2019; Kock et al., 2020). In general, these tools increase transparency and support decision-makers in the strategic alignment of IT projects, including selecting and prioritizing IT projects, resource allocations, and risk management (Kock et al., 2020). Many factors influence a project manager's use of IS in project management on the individual project level. In particular, increased information quality and high project complexity promote usage. In addition, better system functionality, easy usability, and increased performance have an influence (Caniëls & Bakens, 2012; Ali & Money, 2005). These influencing factors can also be assumed for ITPPM tools.

According to Symons (2009), adopting an ITPPM tool can positively impact organizations. They can reduce failure rates, enable efficient resource assignments, and track and manage various IT projects. Further, ITPPM tools can reduce cost overruns through better project scheduling and increased transparency. Additionally, they can enable shorter project durations, as the projects' status is constantly reported, allowing decision-makers to react quickly to new situations. ITPPM tools can prevent redundant projects with no strategic fit and reduce the time spent on administrative tasks as project data is often maintained in the tools. In practice, ITPPM tools vary significantly regarding their functionalities. Complex all-around tools and rather specialized tools only supporting individual ITPPM activities exist (Daradkeh et al., 2019; Gerogiannis et al., 2010; Kock et al., 2020). Due to the great variety of functionalities and the huge offer of ITPPM tools on the market, overviewing and selecting an ITPPM tool is difficult (Gerogiannis et al., 2010). It thus requires a comprehensive and empirically tested artifact that structures and classifies existing ITPPM tools.

Whereas in literature simple project management tools were often analyzed (Caniëls & Bakens, 2012; Cicibas et al., 2010), only limited research has been done to structure ITPPM tools. Stang et al. (2019) have developed a Magic Quadrant for PPM tools. Here, 17 selected tools that met specific inclusion criteria were classified based on their competitive positioning into the dimensions Leader, Challengers, Visionaries, and Niche Players. Further, individual strengths and weaknesses were evaluated for each PPM tool. Visitacion and DeGennaro (2009) followed a similar approach, selected 14 PPM tools, and used more than 80 evaluation criteria to classify them into the categories Leaders, Strong Performers, Contender, and Risky Bets. In addition to this classification, each PPM tool is presented in a profile that describes its strengths and weaknesses. Ayyagari & Atoum (2019) have developed a taxonomy of PPM tool issues based on 4,775 reviews on ten different PPM tools and identified ten issue categories, e.g., complexity, lack of features, customizing, and service quality. Ahlemann (2009) developed a reference model for project management information systems, including single-project management and PPM tools. Based on an analysis of 28 tools, ten main activities were identified and grouped into the three dimensions of single project management, multi-project management, and PPM. Whereas this study does not provide a structured classification of PPM tools, it highlights the different requirements of PPM software tools compared to single project management tools. Current literature focuses much more on PPM than ITPPM tools, derives requirements, classifies tools into different market segments, analyzes strengths and weaknesses, and common issues of different tools. Therefore, we aim to advance the current knowledge base on ITPPM tools, their characteristics, and (non-)functionalities.

## 3. Research design, data collection, and research methods

To address RQ1, we followed the taxonomy development methodology by Nickerson et al. (2013) and Kundisch et al. (2021). Taxonomies group objects based on common characteristics and support a better understanding and possibility of analyzing complex domains and identifying differences and similarities between objects (Nickerson et al., 2013; Szopinski et al., 2019). They have already been developed in different IS disciples, ranging from classifying virtual assistants (Janssen et al., 2020), blockchain applications (Labazova et al., 2019), to business model taxonomies (Möller et al., 2021). The taxonomy development process starts with a definition of meta-characteristics. They should be defined for the overall purpose of the taxonomy and can be understood as the basis for the selection of further characteristics (Nickerson et al., 2013). Our taxonomy provides a comprehensive overview of existing ITPPM tools to allow a comprehensible differentiation. Thus, we defined the meta-characteristic as "functional and non-functional capabilities in ITPPM tools". In the next step, we defined ending conditions. If they are all met, no further iteration is necessary, and the taxonomy development process can be stopped. Here, we decided to use the objective and subjective ending conditions of Nickerson et al. (2013) without further modification.

Our taxonomy development process started with a conceptual-to-empirical (C2E) approach to include scientific literature on ITPPM tools and identify a first set of relevant dimensions and characteristics. We performed a systematic literature review (vom Brocke et al., 2009, 2015; Webster & Watson, 2002) and searched in the databases AISeL, IEEE Xplore, and ScienceDirect using a keyword search string (("IT project portfolio management") AND ("tool" OR "software" OR "system")). We considered already published and full-text English literature, which led to 269 relevant papers. We screened titles and abstracts and excluded those unrelated to ITPPM tools (n=203). Next, we analyzed the full text in more depth and excluded 45 papers not relevant to identify dimensions and characteristics. We performed a backward, forward, author, and similarity search for the remaining papers and identified six further publications. In the end, we considered 27 scientific publications as relevant for our taxonomy development. Here, we used the defined meta characteristic as a basis to analyze the papers in more detail and to identify and discuss design elements (i.e., named or described (non-)functionalities of ITPPM tools) that contribute to the meta characteristic. For this, we developed a concept matrix (Webster & Watson, 2002) in which we classified all publications and corresponding design elements, see online Appendix 1. We proceeded this way until we analyzed all publications and identified an initial set of 21 design dimensions for a classification of ITPPM tools. These included, for example, portfolio dashboard (e.g., Karrenbauer & Breitner, 2020; Obradovic et al., 2014), resource capacity overview (e.g., Ahlemann, 2009; Stang et al., 2014), what-if scenario analysis (e.g., Karrenbauer & Breitner, 2020; Kock et al., 2020), and time tracking (e.g., Obradovic et al., 2014).

For the next empirical-to-conceptual (E2C) iterations, we relied on the databases Capterra.com, Projectmanagement.com, Projektmagazin.de, and Gartner.com to identify ITPPM tools. We set filters for the category and features of the tools that only PPM tools were displayed and thus identified 533 tools. We removed those for which no further information or web page could be found, that do not exist anymore, have been merged with other tools, or are unrelated to ITPPM, with 256 remaining. We then removed all duplicates, which reduced the set to 157 tools and analyzed those in more detail. Therefore, we visited their websites and removed those that represent pure project management tools without significant ITPPM capabilities or that are only specialized in a particular ITPPM domain. Further, we removed tools that do not provide sufficient freely accessible information. Thus, the final set of ITPPM tools included 60 tools. Based on them, we iteratively performed E2C iterations. We examined and tested available tools or analyzed their website to identify (non-)functionalities. If one was discovered, it was classified into existing dimensions, or we added a new dimension or characteristic. For example, if a tool provided the possibility to create a portfolio status report or described this on their webpage (this dimension was already identified in the C2E iteration), we further looked into it. It was then either classified using the already identified characteristics ($C_{14,1}$ Standard, $C_{14,2}$ Customizable) or a new one was added. After each iteration, we checked and discussed whether all defined objective and subjective ending conditions that Nickerson et al. (2013) suggested were met. In total, we performed four E2C iterations until the taxonomy reached stability, i.e., no further dimension or characteristic was added, removed, or changed, and all ending conditions were met. The overall taxonomy development process is shown in online Appendix 2.

To evaluate our taxonomy, we followed the framework by Szopinski et al. (2019) and focused on the questions "who", "what", and "how". We selected five practitioners with ITPPM tool domain-specific knowledge but without previous contact with the taxonomy (who). With regard to the object of evaluation (what), we specified "ITPPM tools and their (non-)functionalities" as the real-world problem to be investigated. For the evaluation (how), we performed five semi-structured interviews with ITPPM practitioners and questions to discuss the taxonomy's usefulness, comprehensibility, and completeness. All five experts have profound knowledge in the field of ITPPM tools and work in, e.g., the integration, maintenance, support, or improvement of implemented ITPPM tools or are responsible for the overall planning and management of the IT project portfolio. Based on the interviews, we renamed some dimensions but did not merge, split, add, or eliminate further ones.

To address RQ2, evaluate our taxonomy's applicability (Kundisch et al., 2021), and empirically deduce typical archetypes (patterns) of ITPPM tools, we performed the k-means clustering (Punj & Stewart, 1983) with R-Studio based on the developed taxonomy (Oberländer et al., 2019). Cluster analysis aims to identify groups of classified objects (ITPPM tools) to minimize differences within this group and maximize differences with other groups (Kaufman & Rousseeuw, 1990). Archetypes derived from the cluster analysis are useful for adding to the taxonomic knowledge and expanding its descriptive nature (Möller et al., 2021). We applied the "Silhouette" and "Elbow" methods and identified an optimal number of five clusters.

# 4. Results and findings

## 4.1. Taxonomy for ITPPM tools

Our taxonomy-based analysis shows that ITPPM tools can be classified based on four perspectives. Each contains three to eight dimensions (D) and in total 51 mutually exclusive and collectively exhaustive characteristics (see Table 1). The differentiation into four perspectives was adapted from Kock et al. (2020).

**IT portfolio structuring** – The first perspective IT portfolio structuring includes the initial evaluation, prioritization, and selection of IT projects (Kock et al., 2020). Within this perspective, design elements for ITPPM tools can be described based on 20 characteristics and eight dimensions. The *financial project proposal evaluation* $D_1$ indicates how IT projects can be evaluated based on financial criteria (Cho & Shaw, 2013; Purnus & Bodea, 2014). If the functionality is available, most ITPPM tools allow calculating different financial indicators or using a predefined evaluation metric. The *ranking method* $D_2$ determines the method of how IT projects are ranked according to their importance. This dimension was especially important for all interviewed experts. If available, the ranking can be done based on a manual ranking that allows assigning prioritization categories manually or applying a multi-criteria-based scoring model to rank project proposals based on their respective score. The *scoring criteria weighting* $D_3$ specifies how to define a criteria's weighting by determining its importance. It can be done based on a predefined scale or by assigning the individual criteria a weighting percentage. The *portfolio optimization model* $D_4$ indicates whether an ITPPM tool includes optimization models to optimize the IT project portfolio under various constraints and interdependencies. Thus, it can support decision-makers in selecting IT project proposals (Cho & Shaw, 2013; Obradovic et al., 2014). The *what-if scenario analysis* $D_5$ indicates whether an ITPPM tool allows decision-makers to compare the impact of changing constraints on the portfolio and perform different scenario analyses (Kock et al., 2020; Obradovic et al., 2014). The dimension *portfolio Gantt chart* $D_6$ states the possibility of displaying, controlling, and analyzing IT projects' schedules. Therefore, literature often discusses the simplicity of a portfolio Gantt charts (Isac et al., 2020; Purnus & Bodea, 2014). Most of the analyzed ITPPM tools visualize the schedule of all IT projects within the portfolio, whereas some also allow to mark critical interdependencies between individual IT projects. The *project type* $D_7$ states the possibility to assign sub-categories to IT projects within an IT portfolio. All interview partners agreed that this dimension is highly relevant in practice. It can be used to, e.g., specify if an IT project is, e.g., a maintenance or innovative IT project. The *waterline analysis* $D_8$ indicates a list of potential IT projects that can be executed without violating predefined constraints such as budget, resource capacity, or available time. Moving this waterline up or down can simulate the impact of an IT project's addition or deletion onto the portfolio.

**Resource management** – The competition for scarce human resources has been identified as a major challenge for managing IT project portfolios.

**Table 1. Final taxonomy for ITPPM tools (number of tools in brackets)**

| Perspective | Dimension $D_i$ | Characteristics $C_{i,j}$ | | |
|---|---|---|---|---|
| IT portfolio structuring | **$D_1$** Financial project proposal evaluation | $C_{1,1}$ Single option (8) | $C_{1,2}$ Multiple options (25) | $C_{1,3}$ None (27) |
| | **$D_2$** Ranking method | $C_{2,1}$ Manual ranking (16) | $C_{2,2}$ Scoring model (38) | $C_{2,3}$ Not available (6) |
| | **$D_3$** Scoring criteria weighting | $C_{3,1}$ No scoring model (22) | $C_{3,2}$ On a scale (27) | $C_{3,3}$ On percentage (11) |
| | **$D_4$** Portfolio optimization model | $C_{4,1}$ Available (5) | $C_{4,2}$ Not available (55) | |
| | **$D_5$** What-if scenario analysis | $C_{5,1}$ Possible (33) | $C_{5,2}$ Not possible (27) | |
| | **$D_6$** Portfolio Gantt charts | $C_{6,1}$ Dependencies indicated (9) | $C_{6,2}$ Dependencies not indicated (46) | $C_{6,3}$ Not available (5) |
| | **$D_7$** Project type | $C_{7,1}$ Available (33) | $C_{7,2}$ Not available (27) | |
| | **$D_8$** Waterline analysis | $C_{8,1}$ Available (8) | $C_{8,2}$ Not available (52) | |
| Resource management | **$D_9$** Resource capacity vs. demand overview | $C_{9,1}$ Available (53) | $C_{9,2}$ Not available (7) | |
| | **$D_{10}$** Resource assignment process | $C_{10,1}$ Automatic assignment (1) | $C_{10,2}$ Assignment without request (14) | $C_{10,3}$ Resource request on individual level (7) |
| | | $C_{10,4}$ Resource request on individual and group level (38) | | |
| | **$D_{11}$** Time tracking | $C_{11,1}$ Available (52) | $C_{11,2}$ Not available (8) | |
| IT portfolio steering | **$D_{12}$** Portfolio dashboards | $C_{12,1}$ Predefined (11) | $C_{12,2}$ Customizable (45) | $C_{12,3}$ Not available (4) |
| | **$D_{13}$** Portfolio dashboard extraction | $C_{13,1}$ Possible (28) | $C_{13,2}$ Not possible (32) | |
| | **$D_{14}$** Portfolio status reports | $C_{14,1}$ Standard (11) | $C_{14,2}$ Customizable (45) | $C_{14,3}$ Not available (4) |
| | **$D_{15}$** Automated portfolio status report send out | $C_{15,1}$ Possible (11) | $C_{15,2}$ Not possible (49) | |
| Non-functional | **$D_{16}$** Software deployment | $C_{16,1}$ Cloud-based (34) | $C_{16,2}$ Cloud-based and on-premises (26) | |
| | **$D_{17}$** Pricing | $C_{17,1}$ Free version and fee-based version (7) | $C_{17,2}$ Quote based and free trial (6) | $C_{17,3}$ Quote based and no free trial (25) |
| | | $C_{17,4}$ Fixed prices and free trial (17) | $C_{17,5}$ Fixed prices and no free trial (5) | |
| | **$D_{18}$** Integration | $C_{18,1}$ Possible (56) | $C_{18,2}$ Not possible (4) | |
| | **$D_{19}$** Access | $C_{19,1}$ Desktop (24) | $C_{19,2}$ Desktop and mobile (36) | |
| | **$D_{20}$** Customer support option | $C_{20,1}$ Email (8) | $C_{20,2}$ Multiple options (52) | |

Subsequently, ITPPM needs to enable decision-makers to allocate resources efficiently to individual IT projects and identify potential bottlenecks early (De Reyck et al., 2005; Kock et al., 2020). We integrated conceptual and empirical knowledge and identified three dimensions with eight characteristics in this perspective. The *resource capacity vs. demand overview* $D_9$ encompasses whether ITPPM tools have functionalities that allow the review of the resources' availability and requirements (Ahlemann, 2009; Stang et al., 2019). The *resource assignment process* $D_{10}$ designates characteristics to manage the resource demand and, consequently, assign resources to an IT project based on their respective capacity (Kock et al., 2020). Most of the ITPPM tools allow to request individual resources or provide the opportunity to set a resource request at the group level for a specific business role or organizational team, depending on what skills are required for the respective IT project. In some ITPPM tools, individual resources can simply be assigned to specific IT projects without a resource request and approval process. Instead of assigning fixed resources upfront to individual IT projects and project tasks, one ITPPM tool automatically allocates the most appropriate resources to the most critical tasks. According to one expert, this is especially important for rather small IT projects. The *time tracking* $D_{11}$ specifies whether or not an ITPPM tool allows tracking the working hours that individual resources spend on specific IT projects that subsequently need to be approved (Obradovic et al., 2014; Stang et al., 2019).

**IT portfolio steering** – The perspective of IT portfolio steering involves all functionalities related to monitoring the IT portfolio performance (Kock et al., 2020). This perspective can be described using ten characteristics within four dimensions. The *portfolio* *dashboard* $D_{12}$ describes the possibility of an overview of ongoing IT projects. A dashboard summarizes the performance and current status of individual IT projects, supports the monitoring of the portfolio, and thus enables decision-makers to identify destructive performing IT projects (Daradkeh et al., 2019; Karrenbauer & Breitner, 2020; Obradovic et al., 2014). Most ITPPM tools provide highly customizable IT portfolio summary dashboard functionalities that allow to add and delete specific graphs, charts, and KPIs with respect to the individual needs of the respective user. In contrast, others have predefined standardized summary dashboards, in which presented graphs, charts, and KPIs cannot be adjusted, or provide no dashboard at all. The *portfolio dashboard extraction* $D_{13}$ indicates whether it is possible to display the portfolio dashboard directly in the ITPPM tool and extract the most recent summary in a standardized format, e.g., in Microsoft Excel. The *portfolio status reports* $D_{14}$ describes the opportunity to create predefined or customized status reports. Literature discusses it as a mandatory function for ITPPM tools (Obradovic et al., 2014; Stang et al., 2019). The *automated portfolio status report send out* $D_{15}$ specifies the possibility for an automated send-out of the portfolio status report based on predefined schedules.

**Non-functional –** The non-functional perspective encompasses non-functional qualities that are not directly related to ITPPM activities but are critical when evaluating ITPPM tools. This perspective can be classified based on 13 characteristics in five dimensions. The *software deployment* $D_{16}$ describes how the respective ITPPM tool is hosted. The *pricing* $D_{17}$ indicates the pricing policy of ITPPM tools. Some tool vendors offer a free and a fee-based version, or prices need to be requested to get a customer-specific quote with or without a free trial. Others have predefined fixed prices per user with or without a free trial. The *integration* $D_{18}$ specifies whether it is possible to integrate third-party products into an ITPPM tool to expand its capabilities or data sources (Stang et al., 2019). The *access* $D_{19}$ describes the accessibility to an ITPPM tool. Some only provide a desktop version, while others additionally offer mobile access. The *customer support option* $D_{20}$ determines the support option an ITPPM tool offers to allow users to address technical issues or user-specific questions. Some ITPPM tools provide one customer support option in which support requests can only be addressed via email, while others offer multiple customer support options, e.g., help desks or phone numbers.

## 4.2. Archetypes for ITPPM tools

To answer RQ2, we performed a cluster analysis based on our taxonomy. Table 2 shows its results, whereas the last columns each represent a cluster that can be understood as an archetype with varying attributes. The table further indicates the percentage distribution of each characteristic in the five archetypes. Characteristics are color labeled, with 0% in white and 100% in dark gray, e.g., ranking method $D_2$ in Archetype 5 compromises of 56% of manual ranking. Further, the classified ITPPM tool's percentage distribution is shown. All underlying data can be found in online Appendix 3.

**Archetype 1: IT portfolio overview tools with predefined parameters** – This archetype with 13 ITPPM tools (e.g., Portfoleon, Zoho Projects) offers functionalities to overview the IT portfolios' process, status, and resources on predefined parameters. Tools within this archetype allow to manually rank IT projects and show their schedule in a Gantt chart, however, without interdependencies. It is further possible to overview resource capacities and demands, assign resources to IT projects, and track working hours. Available portfolio dashboards and status reports are standardized and a release of the status report is not possible. Integration of third-party products is almost possible for all ITPPM tools within this archetype and they are accessible via desktop and mobile versions.

**Archetype 2: Customizable evaluation and analysis tools with data extraction** – ITPPM tools within this archetype (n=11) allow evaluating, analyzing, displaying, and extracting ITPPM data. Exemplary tools are Clarity PPM, KeyedIn, and Project Insight. Within this archetype, tools allow to evaluate IT projects based on multiple financial criteria and rank them based on a scoring model. Further, all tools within this archetype enable a differentiation in different project types. Regarding resource management, it is possible to get an overview of the capacity and demand, track time, and request resources on the individual and group level. Portfolio dashboards and status reports are customizable to individual needs and the status and can be extracted and automatically send out in most tools. Software deployment is cloud-based and on premise for all tools and integrating other tools is possible.

**Archetype 3: Customizable evaluation and analysis tools without data extraction** – In line with Archetype 2, ITPPM tools within this archetype (n=15) offer possibilities to evaluate, display, and analyze IT projects. However, gathered data remains in the tool and cannot be extracted. As for the ranking method, all tools use a scoring method and define weights on a scale. They further allow an overview of resource capacity and demand, and resources are assigned on individual and group level. Current IT project data is shown in a customizable dashboard and it is possible to generate a customizable status report. It is also common to have quote-based prices and the tools are deployed on a cloud and offer possibilities to integrate third-party software. Meisterplan is one exemplary tool within this archetype.

**Table 2. Cluster analysis results**

| Perspective / Dimension | | Σ n=60 | Characteristics \ Cluster | 1 n=13 | 2 n=11 | 3 n=15 | 4 n=12 | 5 n=9 |
|---|---|---|---|---|---|---|---|---|
| IT portfolio structuring | **$D_1$** Financial project proposal evaluation | 45% | $C_{1,1}$ None | 85% | 18% | 27% | 17% | 89% |
| | | 13% | $C_{1,2}$ Single option | 15% | 9% | 7% | 33% | 0% |
| | | 42% | $C_{1,3}$ Multiple options | 0% | 73% | 67% | 50% | 11% |
| | **$D_2$** Ranking method | 10% | $C_{2,1}$ Not available | 15% | 0% | 0% | 0% | 44% |
| | | 63% | $C_{2,2}$ Scoring model | 0% | 100% | 100% | 100% | 0% |
| | | 27% | $C_{2,3}$ Manual ranking | 85% | 0% | 0% | 0% | 56% |
| | **$D_3$** Scoring criteria weighting | 37% | $C_{3,1}$ No scoring model | 100% | 0% | 0% | 0% | 100% |
| | | 45% | $C_{3,2}$ On a scale | 0% | 64% | 73% | 75% | 0% |
| | | 18% | $C_{3,3}$ On percentage | 0% | 36% | 27% | 25% | 0% |
| | **$D_4$** Portfolio optimization model | 8% | $C_{4,1}$ Available | 0% | 18% | 20% | 0% | 0% |
| | | 92% | $C_{4,2}$ Not available | 100% | 82% | 80% | 100% | 100% |
| | **$D_5$** What-if scenario analysis | 45% | $C_{5,1}$ Not possible | 92% | 0% | 33% | 8% | 100% |
| | | 55% | $C_{5,2}$ Possible | 8% | 100% | 67% | 92% | 0% |
| | **$D_6$** Portfolio Gantt charts | 8% | $C_{7,1}$ Not available | 15% | 0% | 7% | 0% | 22% |
| | | 15% | $C_{7,2}$ Dependencies indicated | 8% | 45% | 20% | 0% | 0% |
| | | 77% | $C_{7,3}$ Dependencies not indicated | 77% | 55% | 73% | 100% | 78% |
| | **$D_7$** Project type | 55% | $C_{8,1}$ Available | 15% | 100% | 67% | 67% | 22% |
| | | 45% | $C_{8,2}$ Not available | 85% | 0% | 33% | 33% | 78% |
| | **$D_8$** Waterline analysis | 13% | $C_{6,1}$ Available | 0% | 45% | 13% | 8% | 0% |
| | | 87% | $C_{6,2}$ Not available | 100% | 55% | 87% | 92% | 100% |
| Resource management | **$D_9$** Resource capacity vs. demand overview | 88% | $C_{9,1}$ Available | 69% | 100% | 93% | 100% | 78% |
| | | 12% | $C_{9,2}$ Not available | 31% | 0% | 7% | 0% | 22% |
| | **$D_{10}$** Resource assignment process | 2% | $C_{10,1}$ Automatic assignment | 0% | 0% | 7% | 0% | 0% |
| | | 23% | $C_{10,2}$ Assignment without request | 62% | 0% | 0% | 0% | 67% |
| | | 12% | $C_{10,3}$ Resource request on individual level | 15% | 18% | 13% | 0% | 11% |
| | | 63% | $C_{10,4}$ Resource request on individual & group level | 23% | 82% | 80% | 100% | 22% |
| | **$D_{11}$** Time tracking | 87% | $C_{11,1}$ Available | 92% | 100% | 73% | 92% | 78% |
| | | 13% | $C_{11,2}$ Not available | 8% | 0% | 27% | 8% | 22% |
| IT portfolio steering | **$D_{12}$** Portfolio dashboard | 7% | $C_{12,1}$ Not available | 23% | 0% | 7% | 0% | 0% |
| | | 18% | $C_{12,2}$ Predefined | 77% | 9% | 0% | 0% | 0% |
| | | 75% | $C_{12,3}$ Customizable | 0% | 91% | 93% | 100% | 100% |
| | **$D_{13}$** Portfolio dashboard extraction | 47% | $C_{13,1}$ Possible | 15% | 91% | 0% | 92% | 56% |
| | | 53% | $C_{13,2}$ Not possible | 85% | 9% | 100% | 8% | 44% |
| | **$D_{14}$** Portfolio status reports | 7% | $C_{14,1}$ Not available | 23% | 0% | 0% | 0% | 11% |
| | | 18% | $C_{14,2}$ Standard | 62% | 9% | 7% | 8% | 0% |
| | | 75% | $C_{14,3}$ Customizable | 15% | 91% | 93% | 92% | 89% |
| | **$D_{15}$** Automated portfolio status report send out | 18% | $C_{15,1}$ Possible | 0% | 55% | 0% | 33% | 11% |
| | | 82% | $C_{15,2}$ Not possible | 100% | 45% | 100% | 67% | 89% |
| Non-functional | **$D_{16}$** Software deployment | 57% | $C_{16,1}$ Cloud-based | 54% | 0% | 47% | 100% | 89% |
| | | 43% | $C_{16,2}$ Cloud-based and on-premises | 46% | 100% | 53% | 0% | 11% |
| | **$D_{17}$** Pricing | 12% | $C_{17,1}$ Free Version and fee-based version | 31% | 9% | 0% | 0% | 22% |
| | | 10% | $C_{17,2}$ Quote based and free trial | 15% | 18% | 0% | 8% | 11% |
| | | 42% | $C_{17,3}$ Quote based and no free trial | 8% | 45% | 60% | 83% | 0% |
| | | 28% | $C_{17,4}$ Fixed prices and free trial | 46% | 18% | 20% | 0% | 67% |
| | | 8% | $C_{17,5}$ Fixed prices and no free trial | 0% | 9% | 20% | 8% | 0% |
| | **$D_{18}$** Integration | 93% | $C_{18,1}$ Possible | 92% | 100% | 80% | 100% | 100% |
| | | 7% | $C_{18,2}$ Not possible | 8% | 0% | 20% | 0% | 0% |
| | **$D_{19}$** Access | 40% | $C_{19,1}$ Desktop | 23% | 18% | 60% | 67% | 22% |
| | | 60% | $C_{19,2}$ Desktop and mobile | 77% | 82% | 40% | 33% | 78% |
| | **$D_{20}$** Customer support option | 13% | $C_{20,1}$ Single option | 15% | 0% | 33% | 0% | 11% |
| | | 87% | $C_{20,2}$ Multiple options | 85% | 100% | 67% | 100% | 89% |

**Archetype 4: "In-between" IT portfolio evaluation and analysis tools –** Archetype 4 consists of 12 ITPPM tools, for instance, Blue Ant and Workfront. All tools allow to rank IT projects based on scoring methods, display their schedule in a Gantt chart, and assign resources on individual and group levels. It is further possible to customize dashboards, mostly extract them, and compose a customized status report. ITPPM tools within this archetype are cloud-based, allow multiple customer support options, and third-party

product integration. While some tools are quote based with a free trial or fixed-priced without a free trial, the largest share is quote-based with no free trial.

**Archetype 5: IT portfolio overview tools with customizable parameters** – The smallest archetype (n=9) provides an overview of selected IT projects, their schedule, and enables to adapt parameters. Here, ITPPM tools (e.g., Asana, Inflectra, Smartsheet). rather focus on resource management and IT portfolio steering with few functions for IT portfolio structuring. A Gantt chart provides an overview of the schedule and a customizable dashboard to overview ongoing IT projects. Slightly more than half of the tools allow a dashboard extraction. A status report can also be generated automatically based on current data. Tools within this archetype also enable time tracking and present the actual and planned value of resource consumptions and requirements. Regarding the non-functional capabilities, tools are mostly available at fixed prices but offer a free trial. Further, they are primarily cloud-based, accessible mobile and by desktop, and allow to integrate third-party products.

## 5. Discussion, implications, and recommendations

Based on scientific literature and empirical data, we developed a taxonomy that enables to classify ITPPM tools in 20 dimensions and 51 characteristics within four perspectives. So far, other researchers have focused on an ITPPM tool's strengths, weaknesses, requirements, and competitive ranking (Ahlemann, 2009; Ayyagari & Atoum, 2019; Visitacion & DeGennaro, 2009). We extend this by classifying current literature and real-world ITPPM tools and derive archetypes. In our taxonomy, there are differences in the distribution of the characteristics within a dimension (cf. Table 2). This represents the current state of technology of ITPPM tools. For researchers, it enables to identify trends and research gaps. For practitioners, it can support to identify design elements and make decisions for an individual tool implementation. Nevertheless, the best combination of design elements is organization-specific. Therefore, there is no one-size-fits-all approach for ITPPM tool development or implementation, but our results and findings provide a starting point to show possible options and support and simplify decisions. Another important aspect influencing ITPPM tool adoption and functions is IT maturity. According to Kock et al. (2020) benefits of IS in PPM emerge with higher IT maturity.

Our literature review showed that many design elements were identified as important early on and remained essential over the years, e.g., the resource capacity vs. demand overview and ranking method. Nevertheless, there are still differences. While graphical representations of the IT portfolio through Gantt charts or dashboards were increasingly discussed as a requirement from 2014 onwards, e.g., integration has increased in importance in 2019. As Gerogiannis et al. (2010), we observed a change from rather simple ITPPM tools to more complex ones. In general, we already identified many dimensions and characteristics in the first E2C iteration and adapted, deleted, or added new ones based on the following C2E iterations. It illustrates that there is already much literature on ITPPM tools and that these topics are also reflected in practical ITPPM tools. However, there are also differences between some identified design elements in literature and practice. While there is much research on dependencies between IT projects in literature (e.g., Bathallath et al. 2016), these are less captured in existing tools. Further, even though the dimension portfolio status report is discussed as mandatory in literature (Obradovic et al., 2014; Stang et al., 2019), still seven percent of the tools do not include it. Also, mathematical optimization models to build an IT portfolio are more present in literature (e.g., Cho & Shaw, 2013; Karrenbauer & Breitner, 2021; Linhart et al., 2020) than in practice. Here, the experts highlighted that mathematical optimization models are complicated to apply. The amount of data to maintain in an ITPPM tool to run an optimization is the biggest challenge that makes them hard to realize. One expert added that an ITPPM tool's customers often request such a mathematical optimization model. However, they rarely consider soft factors, e.g., political aspects and the decision power of individual people within an organization or IT department. The dimensions access and the possibility to create reports and export project data from the tool are increasingly identified in applied tools. Especially the top management often prefers to receive an overview of the ongoing IT project portfolio in, e.g., Microsoft PowerPoint or other formats. The function of an ITPPM tool to extract the most recent portfolio summary dashboard, which subsequently can be used for the discussion at the top management level, is a critical functionality according to the experts. However, once the data is extracted, it represents the status at a certain time, whereas the dashboard always represents the most current status. This means that data can already be outdated at the time of presentation.

We make several theoretical and practical contributions. The taxonomy provides a comprehensive overview of how ITPPM tools can be classified, thus providing researchers a knowledge base. According to Muntermann et al. (2015) and Kundisch et al. (2021), taxonomies can provide a useful starting point and meaningful knowledge base for theory building, e.g., design theories. The performed cluster analysis allows to identify further information, similarities, and differences between the different ITPPM tools. A taxonomy alone cannot provide this information due to its descriptive character (Möller et al., 2021). Thus, it was possible to identify five different archetypes. Besides the evaluation with five experts, we were also able to evaluate the identified design elements within the taxonomy through the archetype analysis (Kundisch et al., 2021). The archetypes can be used to identify critical (non-)functionalities and their relation to each other. Researchers can build on our theoretical contributions, both the taxonomy and archetypes, to advance the knowledge base of ITPPM tools further, e.g., it is possible to develop a maturity model or decision tree to support organizations in selecting an appropriate tool. For practitioners, the taxonomy and archetypes provide an overview of ITPPM tools and their (non-)functionalities. For ITPPM tool developers and vendors, it shows the current state of the market and enables a comparison of products. Thus, it is possible to extend or develop new ITPPM tools and discover new potentials. For organizations that want to introduce an ITPPM tool, our classification and archetypes offer a checklist for the selection and can support this decision. Organizations can define requirements for an ITPPM tool and use the taxonomy and clusters to limit the offer of potential tools in line with their requirements.

## 6. Limitations, further research, and conclusions

Our literature review and expert evaluations have established the taxonomy's wording, completeness, and scope. However, data collection for our taxonomy took place in 2021. Thus, we present a time-bound snapshot that needs to be continuously updated to delete and add new dimensions and characteristics. Due to a taxonomy's extendable nature, extensions to the current version are possible anytime (Nickerson et al., 2013). The addition or deletion can then lead to new or changed archetypes. During the ITPPM tool analysis, we tried to get direct access to as many tools as possible. However, this was not possible for all tools. Those were analyzed based on the information provided on their respective website, demo videos, brochures, and information sheets provided by the vendors. If (non-)functionalities go beyond this public information, we could not consider them in the classification. Many classified tools differ in terms of the depth and scope of the individual functionalities. Therefore, future research can classify existing solutions based on their maturity and develop a maturity model for ITPPM tools based on our taxonomy. In addition, we have not evaluated the usefulness and completeness of our five identified archetypes. Further research can evaluate them with expert interviews and applicability checks. It is further possible to develop a decision tree to support ITPPM tool selections based on the identified clusters.

Following the proposed methods of Nickerson et al. (2013) and Kundisch et al. (2021), we performed five C2E and E2C iterations and developed a taxonomy with four perspectives, 20 dimensions, and 51 characteristics. We evaluated it with five domain experts and confirmed the taxonomy's usefulness, completeness, and comprehensibility. We further evaluated the taxonomy and checked its applicability with the cluster analysis to identify archetypes (Kundisch et al., 2021). Our results provide knowledge for future theory building and guide practitioners to design and select ITPPM tools.

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