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Validation of support tools for project management: Case of COPPMAN

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Abstract

Project managers have started to draw support from IT solutions to handle projects, which are more complex than before. Therefore, most of the companies have been generating solutions specific to their need in addition to available software for general use. Any designed product/software requires a testing process not only to check that it is correctly working (verification), but also to secure that it is successfully serving for the intended purpose (validation). To ensure validity, new trend in software development has become early interaction of the possible users of the software to the development process to improve product quality. Early evaluations of the users provide detailed probing of the need that supports structuring the design, whereas latter evaluations serve as behavioral analysis of the developed software. Thus, user interaction for validation of software can be integrated to design process life cycle at any level of the process with different purposes and detail of evaluation. This study exemplifies validation study of a construction project portfolio management tool (COPPMAN), which is developed to support construction companies in adopting project portfolio centered management perspectives. Within evaluation studies of COPPMAN, three professionals from a construction company were assigned as a focus group and their evaluations were obtained through discussions and interviews at three main levels of the development process as; needs analysis, model generation, and beta testing. The current study mainly handles the beta testing process, where actual utilization of COPPMAN was made with a sample of nine real construction projects of the company. Evaluations made during and at the end of the process appreciate the potential value of COPPMAN in decision-making at top management level with its expected benefits in "strategic planning", "business development", "organizational learning" and "knowledge management". Suggestions for improvement of COPPMAN were also obtained as possible considerations for the forthcoming update. This validation process acts as a successful complementary to other validation testing processes undertaken in the development cycle (expert evaluation, pilot testing and usability testing) by providing a real environment(/in-house) evaluation as a trial of actual utilization of COPPMAN.

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Keywords: construction industry; decision support system; project portfolio management; software testing; validation.

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1. Introduction

Challenge with managing projects have been growing with the recent developments in project-based industries. As a respond to this need, various project management software have been generated to address common or specific needs of project managers. Specifically, this study handles the sample process undertaken to generate a software/tool for construction project portfolio management (COPPMAN). Responding to the need of customer, namely direct users of a software, has been the major issue in software development to propose a product to be efficiently used in the long term. Design quality should be ensured in every aspects of a product considering its appearance, feature set and the interaction scheme (/interface), all of which should be in the context and fit with the purpose to ensure features that are not only responsive to accomplish intended tasks but also fully comprehensible and easily achievable [1]. Once the need is identified, it can be structured through devise ways ending with different products in each. Since there has been lack of a standardized method for the development of software products, checking quality of the product is required, which makes software testing a main concern in software development [2]. Testing is mainly analysing the difference between the actual and the required/expected results with the product. This evaluation can be made through two major aims as "verifying" and "validating" a software program to ensure that it meets technical and functional requirements respectively [3]. Thus, the undertaken methodology would be the leading contributor to the followed design process and the launched product [4]. Therefore, the focus should be structuring the product in the best way (serving for its users) for ensuring a level of success and intended quality with the product [2]. Since software is to be designed as a response to a problem in practice, exploration of the problem in practice (/in its field) is required as well as continuous contact with its potential users in the course of design [5]. The main consideration should be devising the input from its users at early stages and throughout its development in addition to preserving capabilities with the technical support provided [6,7]. Therefore, an iterative design process where validation testing is integrated plays a crucial role in improvement of a software product [4,8]. In the light of the provided information, this study mainly demonstrates the validation process undertaken throughout development of COPPMAN. It was delivered in a granted research project with the aim of supporting construction companies in adoption of portfolio management principles. A practical tool can meet their current need for transforming the traditional project-focused management perspectives to portfolio-focused initiatives by supporting comprehensive evaluation and decision-making processes. Successful management of portfolios may enable construction companies to gain competitive advantage through effective management of multi-projects in the light of the intended strategy by consideration of available resources and capabilities. The following sections summarize the steps undertaken to make COPPMAN serve for the intended purpose.

2. Validation in development of COPPMAN

Validation has been a continuous concern in each main step in the followed methodology for development of COPPMAN (Fig. 1). Following identification of the need, model as laying the foundations was generated as a response to this need and the software was generated in sprints ending up with two main versions as the "alpha" and "beta" versions that provide evaluation with different aims. "Alpha version" provides a more "feature functionality" oriented representation of the solution to ensure tuning in the design while "beta version" represents the "complete product functionality" as the most improved and ready-to-use version [9]. Each validation process provided assessment of the current development and the considerations required in the following step as the main drivers of the construction of COPPMAN. Main support has been drawn from the "focus group" consisting of three professionals from a construction company as supervisors of the overall process where additional evaluations were provided from other construction professionals in different stages to ensure triangulation to eliminate problems with existence, generality and quantification of the solution [5].

2.1. Needs analysis

"Focus group" study has been a successful method in generation of the preliminary concepts in the very early stages of a design project as the evaluations obtained from its representative users [4]. Thus, evaluation of the focus group was obtained in needs analysis to enable early and continuous feedback on development of the tool. Face-to-face

interview with the focus group provided in depth investigation of the need in its field in addition to the general requirements identified through literature review. Literature review provided identification of the need in a more "project portfolio management (PPM)" oriented fashion in terms of the main principles and the tools available while interview reformed the need to be structured with specific needs of construction industry through data obtained as attitudes, behaviours and opinions for setting out the requirements. Investigation was focused mainly on their PPM perspective and current practices, limitations/rooms for improvement, details of required PPM system/framework and potential functions of a PPM tool. As a result of this dual investigation, the identified overall points of the need was validated by focus group where they ranked the complete list of the initial requirements as notable points to be considered as follows (Table 1). This list may serve as original considerations in generation of any study that may be addressing portfolio management initiatives in the construction industry while reinforcing the remark on its need in the industry. The list underlines the need of a "dynamic", "intelligent" and "visual" tool that would integrate "knowledge", "risk" and "strategic" management processes while addressing "resource" issues and taking into consideration "dependencies" between projects.

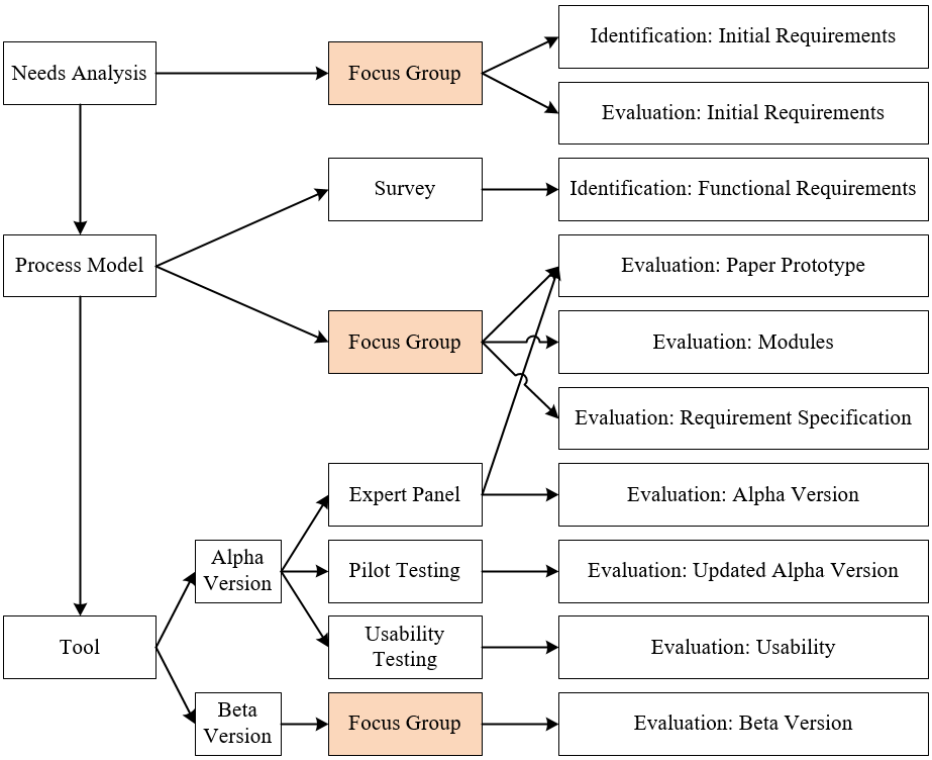

Fig. 1. Validation processes within methodology.

2.2. Model

The findings of needs analysis motivated/directed the research team to structure a "process model" that would encapsulate these through generation of the conceptual model, initial definition of its elements and a supportive algorithm that establishes the links between these elements within the process model. Data collected through a questionnaire survey, which was replied by 108 Turkish company professionals acting in the international market, supported the decisions and functional data to be used in algorithm of the tool as default figures. The identified system and its elements were materialized and improved through generating a "paper prototype" as complete depiction of the model. This numerical exemplification of the system by a hypothetical case (with 25 projects) was evaluated by the focus group and its potential success in responding to identified need was appreciated. Following that, the structured system was elaborated by the research team under five main "modules" handling different groups of the requirements each of which are acting as a building block of the overall system:

- System management module: provides the ability to identify/update company/industry specific concerns/requirements/preferences (e.g., editing default figures and ready-to-use inputs, establishing user management system, i.e. access and authorization issues, etc.).
- Knowledge management module: handles all project information and provides their utilization in the analysis through different data retrieval options and statistical data while supporting corporate learning as well (e.g., issues with post project appraisal, lessons learned, predictions, learning potentials, similar projects, etc.).
- Risk assessment module: enables project level analysis and presents portfolio level risk by integrating project dependencies (e.g., utilizing customizable project risk evaluation forms and investigating evaluation histories).
- Strategic assessment module: enables project level analysis and strategic prioritization at portfolio level (includes similar process with risk assessment module).
- Portfolio analysis module: establishes portfolios, supports decision-making through warnings (where resource sharing issues are also handled) and visualization by project/portfolio level measures/properties.

Table 1. Importance of initial requirements.

Requirement	Rating*
The established system needs to be IT supported.	7.00
Portfolio management tool for construction projects should support strategic choices.	7.00
Portfolio management tool for construction projects should support resource allocation decisions.	7.00
Portfolio management tool for construction projects should support balancing the projects and resources/capabilities.	7.00
Portfolio management tool for construction projects should incorporate past project data into portfolio analysis.	7.00
Portfolio management tool for construction projects should incorporate risk assessment into portfolio analysis.	7.00
Portfolio management tool for construction projects should handle dependencies between projects.	6.67
Portfolio management tool for construction projects should support project selection decisions.	6.67
Portfolio management tool for construction projects should enable visualization of portfolios.	6.67
Portfolio management tool for construction projects should be flexible and dynamic.	6.67
Portfolio management for construction projects should be intelligent and should provide advice/warnings about portfolio decisions.	6.67
Development of a portfolio management tool for construction organizations is required.	6.33
There is lack of an appropriate portfolio management framework and tools in construction companies.	6.33
Portfolio management process needs to be established/re-engineered	6.00
*Seven-Point Likert Scale ranging from "strongly disagree (1)" to "strongly agree (7)"	

The feedback obtained by the focus group demonstrates that the proposed modules were successful to ensure the intended system with notable success in "knowledge management" and "portfolio analysis" modules through the evaluation provided as in Table 2.

Table 2. Success of modules of COPPMAN.

Modules of COPPMAN	Rating*
The structure of the "knowledge management module" is adequate for a construction project portfolio management tool.	6.33
The structure of the "portfolio analysis module" is adequate for a construction project portfolio management tool.	6.00
The structure of the "strategic assessment module" is adequate for a construction project portfolio management tool.	5.67
The structure of the "risk assessment module" is adequate for a construction project portfolio management tool.	5.33
The structure of the "system management module" is adequate for a construction project portfolio management tool.	5.00
*Seven-Point Likert Scale ranging from "strongly disagree (1)" to "strongly agree (7)"	

The generated system and its modules based the decisions on "requirements specification", which is the more definite and technically oriented form of the initial requirements, as translation of principles to features. Focus group also

evaluated the structured requirements as in Table 3 where knowledge management centred requirements were identified as the most critical ones and substantial importance were obtained for the others as well.

Table 3. Importance of requirements.

Requirement	Rating*
Menu for entry of lessons learned, together with view and query options is an important feature	7.00
Calculation of dependencies between projects and visualization of dependencies with a dependency map is an important feature	7.00
Calculation and presentation of predictions for the on-going and potential projects through use of information of completed projects is an important feature	6.67
Tagging system for entry of lessons learned, including editing options for the tag tree and tag-based query is an important feature	6.67
Establishment of project similarity based search and calculation capabilities is an important feature	6.67
Menu for evaluation of risk and strategic fit factors, including editing of the factors and calculation of scores is an important feature	6.67
Establishment of filtering based search and calculation capabilities is an important feature	6.33
Calculation of portfolio attributes and depiction of results through tables, bubble diagrams and bar charts is an important feature	6.33
Menu for entry of different types of projects, together with view and query options is an important feature	6.33
Identification of different users in tool with different accessibility options to the tool menu/operations is an important feature	6.00
Automatic formation of the portfolio alternatives through addition of potential project combinations to on-going projects is an important feature	6.00
Establishment of an automatic warning system for current portfolios is an important feature	6.00
Identification of ready-to-use project inputs is an important feature	5.67
Development of a project representation to be used in visualizations is an important feature	5.67
Calculation and presentation of learning potentials for the on-going and potential projects is an important feature	5.33

*Seven-Point Likert Scale ranging from "strongly disagree (1)" to "strongly agree (7)"

2.3. Tool

The finalized requirements leaded generation of the first version (alpha version) of the tool, which was generated by a developer company through further discussions when required and the possibilities appeared with the advances of technology. The basic version was mainly capable of capturing and utilizing project knowledge and conducting portfolio analysis through considering interdependencies, risks and strategic objectives while enabling selection of the best portfolio by facilitating decision-making through warnings and visual representations of alternative scenarios in terms of project/portfolio level measures. Evaluations of the alpha version generally become "formative" by adding more to design and functions of the tool, so hold promise to make significant advance in the tool through revealing anticipated as well as unanticipated consequences. Whereas, evaluations of the beta version become more "summative" by focusing mainly on the product by assessing its value and utility outcomes [10]. Therefore, validation at both levels of the design with different participants was held to secure the improvement to be in line with the purpose by ensuring variability of the feedback obtained. Validations through "alpha testing" are generally done in a simulated use environment (development organization) while "beta testing" is the process of testing in the end-user site as the first "live operational test" of the software [3].

Regarding evaluation of the alpha version, an "expert panel" consisting of two academicians and two company professionals with no previous involvement in the study was set up for ensuring validity of the tool and the methodology undertaken. Expert panel provides investigation of reliability of the approach and the results while testing whether the important concepts in the domain are covered adequately or not [5]. The experts were selected considering their capabilities in both "portfolio management" and "information technologies" since expert evaluation provides an opportunity of external review considering the target user of the product by raising awareness in both usability heuristics and domain in question [4]. They were allowed to access and navigate within the tool where the sample case in prototype was analysed as the base model to reflect the "mental image" of the model. The panel provided a dual evaluation of the paper prototype (so the model) and the alpha version to benchmark the expected/intended purpose

with the actual purpose. This process provided both "functional" and "operational" testing of COPPMAN through positive results obtained in questionnaires by open-ended questions and ratings on "completeness/coverage", "suitability/accuracy", "usefulness", "usability", "receptiveness", and "overall". This testing ended with an update in the alpha version addressing revision in its functionality as improvement in the visual and searching capabilities of the tool.

The new version was tested through "pilot testing" where the tool was directly used by two different company professionals with their own portfolio samples as the case studies consisting of hypothetical set of real projects under supervision of the research team. The pilot testing provided a transition between the current evaluations as expectations/feedbacks obtained according to presentation of the development and the evaluations that would be made by its direct utilization. The "pilot testing" acted as evaluation of the tool as well as validation of the initial test results and testing materials (i.e. questionnaires to be used in further testing). It provided "operational" and an implicit "usability" testing with extended list of usability centred attributes differently from expert panel study. This evaluation validated the current version of the tool as the first trial of its utilization and its readiness to further testing. Obtained feedback provided final tuning in some of the sections as the final update in terms of aesthetic changes in some buttons, tables, etc.

As a complementary to these processes, testing with major focus on behavioural analysis of the tool was required to assess its practicality, capability and possible benefits. The forthcoming testing was more focused on its usability where the success of the tool considering its interaction with its user was tested in laboratory setting (Human-Computer Interaction Research and Application Laboratory, Middle East Technical University (METU)). "Usability testing" provides consideration of several aspects such as how easily the users learn the system, how efficiently they use the system once they learn how to use it, and how much they are pleasant to use it. The criticality and frequency of errors during the testing process constitute supportive data for consideration of overall usability and possible areas of further improvement in design. Six participants, research assistants from Civil Engineering Department METU, as representative users were tested through "14" pre-defined realistic task scenarios ("pieces of real work") for deeply monitoring the trial of its utilization [11]. Advances of eye-tracking technology and the analysis software provide analysis of the performance data through analysing the micro-level behaviours of the users that may be indicator of the problems, which would not be detected otherwise [4]. Participants successfully undertook the scenarios with indication of minor problems due to its first use. It provided more interface-oriented diagnosis through analysis of both "performance data" (as task completion success rates, time on tasks/fixation durations, mouse click counts, visual outputs as heatmaps, gazeplots, clusters) and "preference data" (through questionnaires including open ended questions and ratings all addressing measures on ease of "use/efficiency", "effectiveness", "satisfaction", "consistency", "learnability", "user guidance", "overall", and some further measures on its "usefulness"). This testing appreciated the current flow of the process and design of the tool, thus ended with no critical update in the current version. Therefore, usability testing turned the latest alpha version to serve as the beta version as well, for its further testing in its real environment as trial of its actual utilization through beta testing.

3. Beta testing

As the last step of evaluation, "actual implementation" with the beta version of tool was made by the "focus group" in their company as the first implementation in the "real setting". The company professionals conducted analysis on the created "real set of portfolio" to evaluate the first real experience with COPPMAN.

3.1. The company

The company was selected due to its place in the international market and their current attempts in establishing portfolio management initiatives. It holds turnkey power generation projects as the Engineering, Procurement and Construction (EPC) contracting arm of a holding, which owns several companies that all serve for construction of power plants, refinery, cement, petro-chemical and gas plants, factories, high-rise buildings, water treatment plants and transmission

lines, bridges and other infrastructural constructions including various energy investments. The power systems company undertakes power plant EPC contracts particularly in the gas combined cycle power plant arena and provides combined services of engineering, procurement, construction, commissioning, start-up, warranty and spare parts services for almost all types of power plants. Therefore, the company is the correct choice for beta testing with their broad range of projects in the international market, mainly in Middle East, Turkey, Africa and Commonwealth of Independent States (CIS). The same professionals (focus group) from the units of "business development", "business control and risk management", and "enterprise systems" participated in testing since their contribution was considered to be important due to their know-how in the issue and the development process of COPPMAN as well.

3.2. The case/portfolio

A sample portfolio was created including somewhat similar projects (i.e., "combined cycle power plant projects" in majority) to make the outputs of COPPMAN representative of typical considerations required in the analysis with minimum information entry. Five "completed project" information with five crucial "lessons learned" in these projects were entered together with two "on-going projects" and two "potential projects". Following establishment of the portfolio, the focus group followed typical analysis process in COPPMAN where they shared live feedback through their experience in each process in terms of sufficient/useful properties and further improvements:

- Data entry: included identification of project inputs and preferences as the initial setting for entry of project information and related lessons learned. This process revealed possible improvement in export/import capability for data transfer, extent and entry type of some captured information, and inclusion of more information as "free-text area for project notes", "project significance", "critical milestones", and "checkpoint" as integration of "change management" initiatives in addition to currently provided information (i.e., "general project information", "critical resources", "partnership information", "duration, financial, project dependency and technology information", "post project appraisal information" and "lessons learned").
- Data analysis: was focused on investigation of "supportive information", namely the data retrieved for "on-going" and "potential" projects based on information of "completed projects", assessment of "risk" and "strategic fit" for these projects based on the obtained information. The analysed information as "similar projects", retrieved "lessons learned", obtained "predictions" and "learning potentials" together with the "retrieval options" were found successful for benchmarking the project at hand prior to analysis of "risk" and "strategy". Final tuning in some calculations was advised as inclusion of more "project attributes" or provision of more flexibility in calculation options.
- Data output: provided analysis of the overall portfolio alternatives, investigation of portfolio and project specific outputs, and performing portfolio selection accordingly. Visual/numerical outputs and the warnings were found helpful in supporting decision maker; however, integration of more flexible "reporting mechanism" addressing unique needs of different users with special focus on some specific points was advised for increasing the success and usefulness of the outputs. Additionally, some minor aesthetic changes in graphs were advised for making some points more visible and attractive for the user where some expressions were to be improved. Flexibility was advised to be increased in some of the calculations, in addition to corrections needed considering outlier data, which further required identification of "exceptional projects" and adjustment in calculations and presented "warnings". As a final remark on analysis of portfolios, integration of a dashboard as "geographic map" that unifies all project figures and representative information on the filtered projects was advised to be more beneficial to "see the big picture" and analyse the overall portfolio or specific portfolio alternatives. Regarding portfolio selection, identification of "strategic hold points" to automate elimination of portfolios that would not be in the stated limits was suggested to be useful.

3.3. Findings

In addition to live feedback through utilization of the sample case, focus group provided an overall evaluation on COPPMAN at the end of the analysis, which are provided below in main sections of "strengths", "shortcomings/improvements", "possible benefits", "possible barriers", and "overall rating":

- Strengths: COPPMAN has the potential to unify different departments on the same portal since it encapsulates several systems required for portfolio analysis and builds a link to projects while establishing a bridge between past and current projects. Knowledge retrieval mechanisms with possibility of successful benchmarking and numerical forecasting ability (i.e. "predictions") constitute the main strengths of COPPMAN. Especially integration of lesson learned management system (which was generated and released as a separate tool (LinCTool) in a complementary study held by Eken et al. [12] with its potential to be used irrespective of portfolio management issues) is quite successful within the system. Support of numerical outputs in addition to visualization abilities are also helpful in addition to warnings as reminder of the points to be noticed.
- Shortcomings/improvements: may be the considerations on the points identified throughout its use as improvements regarding "extent of information", "addition of context", "eased information entry", "flexibility in calculations", and "reporting abilities" (which are outlined in the previous section "the case/portfolio").
- Possible benefits: COPPMAN would be important at holding level and support decision-making for companies working with different type of projects in their portfolio. It can also be valuable for the companies that are working with similar kind of projects in their portfolios due to possible benefits in facilitation of "strategic planning", "business development", "organizational learning" and "knowledge management". It would help to present the company know-how and experience in a single visual platform, which may be highly advantageous during potential project/portfolio selection with the supported analysis.
- Possible barriers: Strong coordination between different divisions is needed since they would work on the same platform where data collection and refining issues would be under control of a unique department/professional, which may be possible barrier to fully utilization of COPPMAN.
- Overall rating: In addition to the preference data obtained through open-ended questions, an overall rating was obtained as presented in Table 4. The focus group was satisfied with overall "implementation" process and COPPMAN was evaluated as "effective" in portfolio management and appreciated for its "support in decision-making" with its adequate "features/components" and "user-friendly" structure. The tool is stated to be "implementable" in the company of investigation and also in similar construction companies through its appreciated abilities of "better visualization of the portfolios", "effective reporting and documentation" and its support in "strategic evaluation", "selection of the right projects", "portfolio risk evaluation", and "short term and long term planning". Regarding the additional checklist for "possible benefits" of utilization of COPPMAN, all the respondents achieved consensus on the benefits in "strategic planning and strategic achievement", "project selection and portfolio optimization", "knowledge management and organizational learning", and improvements in "communication, documentation and reporting" where further possible benefits were selected as advances in "risk minimization" and "long term profitability" by one respondent.

3.4. Result

Real application addressed "operational" testing (i.e. usefulness) of the tool for measuring its potential benefits as well as further evaluation of its "usability". Direct utilization of the tool revealed some additional considerations that might be structured upon current capabilities provided with the help of technology. At the end of beta testing the current version of the tool was appreciated to be sufficient to serve for the expected purpose with its potential benefits for construction companies. In the light of the feedback obtained, a final update on COPPMAN has been performed as the update on the accepted version based on improvements in the current functionality of the tool. The update addressed mainly a general improvement in the structure of COPPMAN, integration of "geographic map" and improvement of

"reporting" abilities while facilitating the information control through a common "project layer" and increasing flexibility in "calculations".

Table 4. Overall evaluation on COPPMAN.

Statement	Rating*
COPPMAN tool facilitates decision-making for managers.	7.00
We are satisfied with the features/components of COPPMAN tool.	6.33
COPPMAN tool supports effective reporting and documentation.	6.33
COPPMAN tool facilitates visualization of the portfolios.	6.33
COPPMAN tool provides an effective portfolio management.	6.00
COPPMAN tool facilitates strategic evaluation of the portfolio.	6.00
COPPMAN tool eases selection of the right projects.	6.00
We are satisfied with the COPPMAN implementation.	5.67
COPPMAN tool is useful for portfolio risk evaluation.	5.67
COPPMAN tool provides support for short and long term planning.	5.67
COPPMAN tool is user-friendly.	5.67
COPPMAN tool would be implementable in similar construction organizations.	5.67
COPPMAN tool provides adequate warnings regarding the portfolios.	5.33
COPPMAN tool would be implementable in our organization.	5.00
COPPMAN tool is useful for organizational learning.	4.67
COPPMAN tool does not require extra burden (additional cost / workload or legal issues) for implementation.	4.00

*Seven-Point Likert Scale ranging from "strongly disagree (1)" to "strongly agree (7)"

4. Discussion and conclusion

Phased validation of COPPMAN maintained the complete support in development of the tool to make the process be in a more user oriented fashion. Early integration of the potential users led reshaping the design through feedback obtained on the materialized sections of the product, which provided the direct demonstration of the status and structuring its further development properly. Needs analysis provided setting up the context and crucial points, model development enabled formalization of concepts in a framework as features of the system, and evaluations on tool provided better demonstration and revealing further points to be considered through the opportunities provided with technology. Especially, the beta testing process served for evaluation of direct experience of the user with COPPMAN, appreciation of its possible benefits and points to be considered in a possible update. This methodology has provided a way for generation of a software that would be applicable by its users in the light of the first signals obtained on its potential success. However, actual benefits are to be only observed in case of its adoption and utilization by construction companies. The main contribution of this study lies in framing the need by joint effort obtained through literature and field studies, which can be deemed as an essential start required for any research in this field. Overall methodology undertaken in this study exemplifies a user-oriented software development process whose findings may serve for further studies undertaken in construction project portfolio management literature and for PPM studies in other project-based industries as well.

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