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Abstract
A company's product strategy and its management of the product development process have been found to be key factors for a product's success on the market [1]. Project managers of development projects need support to make process decisions and defining goals that are consistent with the business's goals while bearing in mind the ability of the development team to deliver a product to the market that satisfies the customer's expectations and needs [2].

Uncertainty is a part of the product development project's nature, which according to Simon [3] is ill-structured, explorative and pragmatic. In product development projects it is desirable to reduce the level of uncertainty in order to make decisions without having to redo them later in the project resulting in longer lead time and higher costs. It is the project manager's responsibility to manage this uncertainty in a complex ever-changing project environment. However, this research shows that there is unnecessary uncertainty in planning and controlling decisions when project changes occur. The uncertainty is manifested in not considering performance aspects of the project and the product in a wider organisational context. Visualization and clarification of decision situations and consequences is rarely used in practice and structured reasoning about project and product performance when making decisions is also rare. In order to enhance the project managers' understanding of decision-making in product development projects, the objective of this paper is to propose a mindset for clarification of decision situations when changes has occurred. The proposed mindset is supposed to aid project managers when handling project changes by reducing complexity in project planning and supporting the articulation of uncertainties.

Keywords: decision-making, mindset, engineering design, project management.

1 Introduction
A project manager of a product development project is facing a complex task: manning, where to put efforts, when to perform activities, how to perform activities, all within given resources, costs, time limits as well as to monitor for deviations, and revise the plan.

In the literature we find methods and tools to support decision-making on different levels of the project organisation. Accordingly to the VDI-guideline 2221 [4] the engineer (expert level) has at his/her disposal different methods to support clarification and structuring of the design tasks within a range of design stages in order to make decisions. Examples of design

methods are; Brainstorming, Cost-benefit analysis, Use-value analysis, Decision-tree analysis, and the Decision criteria matrix. The project manager has mostly methods for structuring activities and the management of project stakeholders, resources, and costs, e.g. Stage-gate process [5], Deficiency Report (resource management and analysis) [6], Enterprise Resource Planning (cross-functional resource management) [7], Interface chart (stakeholder analysis and planning) [8], and Recovery-Wave Planning (incremental project planning). There are exceptions to the generic methods, such as the Critical Chain Concept which focuses on project performance and decision-making [9]. The problem is that the project manager's task is complex and existing methods and tools are often too generic in their nature. Also, there are few or no existing methods that support clarification of decision situations on a practical level, leaving the project manager on his/her own when confronted with decision situations that need to be managed due to either the project deviating from its path or changes in the project environment.

It is our hypothesis/idea that a mindset, i.e. a frame of reference for decision-making, could help the project manager in recognising the type of decision-making situation he/she is facing and help with the clarification of the decision situation when a change has occurred. We focus upon essential aspects to consider for clarification and planning of decision activities. Our aim is to propose a mindset for project managers in order to reduce complexity in project planning and to support the articulation of uncertainties when a change has occurred. This paper and the case study are focused on collocated design teams.

Research questions:

1. *What does a model of a mindset contain in order to decrease complexity in planning and to support the articulation of uncertainties during decision-making in practice?*
2. *How should this model be designed to support clarification and the articulation of uncertainties of decision situations after a change of the project has occurred and thereby decrease complexity in planning activities?*

The paper first describes the background of the research, the research methodology and methods used. An industrial case study is described and the results discussed, followed by relevant literature. The requirements for a mindset of decision-making are described and a model of a project manager's mindset is proposed, followed by discussion and conclusions.

Research Methodology

Blessing and Chakrabarti's [10] Design Research Methodology (DRM) is the chosen research methodology for this research, and this paper is a result within the DRM's prescriptive stage.

Research method

In this research work we have carried through an industrial research study and a study of the literature. The industrial research case study at a mid-size Swedish company was performed between 2006 and 2008. The case study was initiated by a workshop with 9 people from different departments in order to create an overall understanding of their product development process including communication, areas of responsibilities, and decision-making. A total of 12 interviews followed and were held with people from the board of directors, market management, project management, engineering design, logistics, and production. The aim of the case study was to map the company's management of their product development projects. Two projects were investigated, one successful and one not successful (according to the Company). The interviewees also commented upon a second unsuccessful project during the interviews to illustrate some of their points. We have studied literature on decision-making in

the area of engineering design methodology and project management in order to identify contributions to our understanding of decision-making within project management and to identify contributions to a mindset.

2 Industrial Research Case Study

The case company's core competence is within heavy machinery development. No machinery components are produced by the company but are instead delivered by sub-deliverers and assembled, tested, and shipped to retailers as a whole product. The company is successful which is shown by the presence on the 2003 list for largely growing businesses in Sweden, which means they have grown by 25% per year for at least five years in a row. The company employs 66 persons in Sweden and 16 in Canada with a turnover of 20 million € per year. They sell approximately 300 products per year on the global market which all are individually configured, with regard to mechanics and electronics, for individual customer needs.

The result of the case study were divided into 4 sections, related to project management decision-making, and are described below.

1. The Company's shared overall view of their process.

The Company have a formal description of their product development process including critical decision points, but did not follow it in practice. They skip some gate decision points (market verification of design and field test review before production) because after committing to the project at an early stage, their notion is that they freeze the specification in order to get the product to the market fast. This means that the specification should not be altered during the project, when in fact it is which can be seen by that there are different versions which differ between finalized designs to start of production.

> *"When the design work is initiated it is a matter of getting the product to the market within our timeframe. After that (finalized design) it is about feeling content with what we got." (Statement of a designer)*

The project managers tend to not communicate the state and plans of the overall project in an appropriate way. This was commented by a designer:

> *"...the overall state of the project is not discussed in general during the project."*

By not communicating overall state of the project the experts have a hard time to keep a whole picture of the project in mind and to reason about priorities for overall progress.

At a strategic level it was stated that the priorities was: cost, quality and time for the projects, but when looking at the focus of decisions made it tended to be quality (functionality) early on in the process, cost in the end, and time afterwards.

2. The decision situations of most value to project management.

The decision situations that the project managers considered most important in order to communicate, plan, and reason about performance were the different planning and review meetings during the projects. The review meetings can best be described as the control function of project management as described by Haffey [2]. Three organisational levels were involved during these meetings: a member of the project reference group, the project manager, and relevant experts. The planning meetings were few during the projects and were about directing and organising activities and resources. The review meeting were where different relevant competences gathered and discussed activities, plans, project and product changes, and product performance. The aim of the review meetings can be seen as the monitoring of the progress and deviations in order to control the satisfaction of goals. The

weekly review meeting tended to be task focused and were considered most significant in order to manage the communication, information, and progress of the project.

> *"The weekly review meetings are important in order to review and secure progress of the work." (Statement of a project manager)*

3. The responsibility of project and design decisions?
The project manager is a part of the reference group and has to a large extent been a part of setting the culture for decision-making in projects. Management does not focus on efficiency of projects so projects are managed without focusing on efficiency as well. Team members rely heavily on the manager to manage the whole of the project. A designer stated:

> *"One hopes for having an overall view when looking at consequences, but if someone does, it is the project manager."*

When studying their decision-making and project success, with that statement in mind, it is clear that they tend to focus on the effectiveness and overlook the efficiency of projects. The project manager for the project acts as responsible for the quality of the design and overlooks the success of the project as a whole. Management of a successful project demands management of both the progress of the project as well as the final product.

4. The behaviour when making decisions in design projects.
The authors expected to see usage of support tools such as the ones described in section 1 but there was no evidence of use of support tools for clarification of decision situations. Decision-making on an expert level is seen as an individual cognitive activity to a large extent within the company. On a project management level, decision-making is seen as product quality, cost and functionality control. When interviewing a designer it was shown that design decisions were made individually and between review meetings.

> *"We discuss something on one meeting, solve it between, and nail it down on the next meeting. I do not think we make any detailed decisions on the short time during the meetings..."*

The expert prepares a suggestion for a solution to a problem between meetings which is reviewed in a review meeting and decided upon, or the expert is asked to revise the suggestion, and by doing so they plan for upcoming activities in a rather sequential manner.

It seems that project management decisions were about: overall product design (product structure, alternatives/optimization of design), timing of activities (what to do next), and progress (go/no go or revise), and was made in the planning and review meetings. These decisions were responses to the need of the project team at that specific time. Decision-making in the review meetings was a response to changes that occurred between review meetings. Decisions made by the manager between meetings were of a more technical nature (participating in design decisions) which had the same characteristics as of decisions made by designers.

Discussion of the case study
Decision situations that occurred with the project manager and the group present were planning (directing and organising) and reviewing (control). The planning meetings were few during the projects and were about timing of activities (what to do next), and progress (go/no go or revise decisions). The review decisions were where different relevant competences gathered and discussed progress, project and product deviations, and product performance. Design decisions were made mostly individually by experts and between review meetings about alternatives and optimisation of design solutions.

The Company have a decision-making culture which did not support clarification of relevant aspects and articulation of uncertainties when making decisions. This culture may be explained by that the company reuses a large amount of technical solutions and has been doing so for a long time, resulting in that they rely too heavily on experience and routines when making decisions. It means that when they are forced to be more innovative in their development process, the project suffers from high costs and long development time due to a lack of consideration of the complex nature of product development projects, consequences, and project performance aspects when making decisions.

The notion within management is that after concept development the specification is frozen and no major changes occur, when in reality major changes do in fact occur and most likely impact the result. Early thoughts and estimations of the project and product as a whole is changed during development due to e.g. misinterpretation of market input or not functioning solution options of design. The notion of a non-changing project environment results in difficulties in managing changes during development due to a lack of consideration of essential aspects of the changed situation and its consequences, impacting planning and execution of activities.

The high level of unnecessary uncertainty when making decisions affected project cost, product cost, and project time. Product performance and quality were the main focus when making decisions in the projects and resulted in high quality products. The project managers did not consider the properties of project decision-making, i.e. project effectiveness and project efficiency. Nor did they reason about the responsibility of delivering a product that meets the stated requirement within time and budget, and therefore did not approach project planning and reviewing of decisions accordingly.

4 Theoretical contributions to decision-making

A project manager in product development is responsible for guiding an expert team in their process over the duration of the project. This put great demand on the project manager to have an understanding of how design decisions are made and best supported. López-Mesa and Chakrabarti [11] illustrate in a clear way how conceptual design decisions are made in practise and shows how designing is about synthesis controlled by tentative decisions and validation. Hansen and Andreasen [12] described that the engineering designer do not see a clear line of explicitly made decisions, but as a result of other decisions being made and clarification obtained.

In order for the experts in a project team to make suggestions for solutions and to verify them in an effective and efficient way with regard to overall project and product performance, they need to be aware of uncertainties of the project as well as the artefacts they are designing. The complexity of product development presents a great challenge for team members in understanding and communicating the uncertainties inherited in decision situations.

Uncertainty in decision-making

In product development projects it is desirable to reduce the level of uncertainty in order to make decisions without having to redo them later in the project resulting in longer lead time and higher costs. It is the project manager’s responsibility to manage the uncertainties witin a complex ever-changing project environment. Uncertainty is a part of the problem solving nature within product development projects, which according to Simon [3] is ill-structured, explorative and pragmatic. Also, many of the difficult aspects of uncertainties in product development projects origins from the complexity associated with large project teams. People

making decisions in product development teams are dependent on the communication of uncertainties of the project and the performance of artefacts, and is a complex task when the understandings of uncertainties are spread among many project participants [13].

Uncertainty can lead to unwanted consequences, impacting project and product performance. We cannot know everything about the uncertainties and consequences of project activities when planning for them, but we can try. Haffey [2] comments upon the managers' responsibility of consequences:

> *"They must also recognise unnecessary and undesired consequences on other related activities and groups, and their ability to perform and contribute to organisational performance."*

Uncertainty in decision-making practice plays a crucial role due to the implications of incomplete, inconsistent and evolving information resulting in a need to manage decision-making by clarifying the essential aspects of decision situations, including its consequences of the chosen course of action [14].

Complexity in decision-making

Complexity is a matter of *level* of complexity and Snowden and Boone [15] divide it into: simple, complicated, complex, and chaotic. In a complex context a right answer does exist but cannot be found due to too many and too rapid changes in the context. Decision-making in organisations are often imposed by major changes which introduce unpredictability. It is the area of *"unknown unknowns"* and is the context to which most of the contemporary business has shifted to. A decision situation in a complex context can be managed by introducing experiments that is safe to fail [15], e.g. a mock-up. However, it is also important to clarify that level of complexity is the perceived level of complexity in the mind of the person conducting e.g. a design task or a project manager planning a design task.

Project-based management is frequently associated with the management of complexity [16] and in product development the complexity of projects has increased due to e.g. multi-disciplinary cooperation and concurrent execution of tasks in different departments [13]. As Baccarini [16] suggests, in the definition of project complexity it is important to clearly state what kind of complexity is being dealt with, and in this paper it is the complexity of planning and controlling project activities in order to support the experts in a product development team.

Planning in a complex world, where order is circumstantial, is rather pointless and at the same time of great importance. Cuhna and Cuhna [17] explains by stating that management's discussions of possible future scenarios creates the opportunity to meet unfolding circumstances with prepared actions, a shared knowledge of plans enables individual improvisation, plans can be set while actions unfold, and planning can enable organisational learning. If plans are viewed as resources and planning as a coordination mechanism, organisations would be able to integrate effectiveness and efficiency by conceiving actions as it unfolds, i.e., by improvisation [17].

A mindset for design decision-making

In 2000 Hansen [18] proposed a mindset for design decision-making which is intended to form a sound basis for the engineering designer's understanding of decision-making, and explain all relevant phenomena related to design decision-making. In 2004 Hansen and Andreasen [12] presented a model of an evaluation and decision-making activity called "The

decision node". It explains in a generic way a decision episode of an engineering designer. A second model, called "The decision map", was also introduced and explains what is synthesised during the design process. It shows the three artefacts which are designed during a product development project: the product, the life phase systems, and the meetings between the product, operator, and the life phase system. A third model was introduced called "The decision score", which explains the five dimensions that design decisions' consequences impact: the use process, project tractability, the product, the business, and the product life cycle. The mindset proposed by Hansen and Andreasen [12] aims at supporting design decision-making and has common objects of interest with project management decision-making, such as the progression of the project, specifications, the product life cycle, and business, but do not cover all essential objects of consideration for planning activities. It is therefore interesting to explore a mindset of a project manager and compare it with Hansen and Andreasen's in order to see common points of interests between a project manager and the experts in a project team when planning after a change has occurred in a project.

A Model for decision-making in project management

Gidel et al. [19] provide a mindset for increased problem solving capacities in complex decision situations. The purpose of the mindset is to organise the decision-making process in an acceptable way in order to make increasingly effective decisions. By looking at influencing factors, and which could be managed, Gidel et al. presents a framework which could create a favourable context for effective decision-making in all levels of the design process. Gidel et al. draw inspiration from quality principles and systematic modelling of decision-making processes in design. The quality principles used are: controlled decision-making (a logical and intuitive approach), staff involvement (communication), and prevention (of unwanted consequences). The modelling of decision-making processes in design contributes to the mindset by providing clarification and classification of influencing factors in order to amplify the decision-making capacities. However, the model is aimed at setting up and planning projects on a generic level and does not support clarification of decision situations on a practical level after a change has occurred during execution of a project.

5 A proposal for a mindset

Requirements and content of a mindset for decision-making

The model should be an initial visualisation of essential aspects for a project manager to communicate, consider and discuss in a group setting when a project change has occurred in order to create revised common goals and a shared understanding of the decision situation. The clarification of the situation should reduce complexity of planning and support the articulation of uncertainties.

Project management activities can be described as planning and reviewing and are two different kinds of decision situations which is relevant to the project manager to influence and manage in a group setting. The planning decisions involve arranging activities in time and their dependencies, assigning resources, and manning. Reviewing involves the assessment of the current state of the project progression and cost related to the delivery, and the product state related to the specification. The two different decision situations can both be considered to be project management planning activities because they both relates to the current state of the project and the planning of upcoming project activities. We therefore categorise them into planning. Characteristics of planning can be described as: *review*, i.e. clarification of decision situation, assessment of consequences, and revision of plans; *task*, i.e. sequence of tasks, timing of tasks, and dead-lines; *manning*, i.e. allocation of people; and *allocation of*

resources, i.e. cost management. Project properties which are important to consider during a project can be described as project performance, i.e. effectiveness and efficiency, and are related to project delivery and project progress. The level of unnecessary uncertainty may affect the delivery by not being able to achieve the desired specification, and uncertainty also effects the progression of the project due to rework when decisions need to be reconsidered after changes. Project influences which leads to changes may be simplified into two contexts: internal or external the development group. The changes we intend to consider in this research work are changes due to influences external the development group, e.g. change of project scope imposed by a management group. This leads to a complex planning situation where project and product performance needs to be considered as a whole by the project manager in cooperation with the experts in the development group in order to consider specific issues of the product as well as the overall issues of the project. The imposed change may lead to a revised project plan as well as revised specifications.

The proposal for a project manager's mindset

In this section we introduce a model of project decision-making which is based on empirical findings and literature reviews. The illustration of the model in this paper is called "The decision map" and is inspired by, and builds upon, Hansen and Andreasen's [12] earlier work of a mindset of design decision-making. The model was developed by stating three questions to support clarification of project management decision-making:

Who are included in the decision-making process of a project manager?

The communication that enables a project manager to plan and review a decision situation after a change has occurred can be simplified to four parties: a project reference group, the project manager, the experts in the team, and external experts. A change can be initiated by all four parties. There are three scenarios related to the most common initiations of change, found during the empirical study, and are: external request, expert request, and reference group request. An external request is often directed to an expert in the team which is then brought to the project manager's attention. The requested change is evaluated and a decision is made about acceptance or denial of the request. If the change is accepted the development team suggests a plan of actions to manage the change. Depending on the size of the intended actions, the project reference group may be consulted and asked to approve the plan of actions. An expert request is when an expert in the team requests a change. The team evaluates the request and a decision is made about acceptance or denial of the request. The size of the change determines if the reference group should be consulted. A reference group request for a change is often an imposed change and may not be open for discussion. The project manager discuss the change with the reference group, if possible, and evaluates and plan the change with the team in order to determine the impact on different expert areas and the project as a whole.

What do project managers decide about in planning and reviewing situations?

No matter where a change is initiated from, within the group or external the group, the group members need to consider the impact on expert areas as well as the project as a whole in order to plan and execute activities with regard to project and product performance. A suggestion of actions to meet the change needs to be formulated to provide basis for future decisions in the project. This suggestion of actions needs to be validated within the group and sometimes with the project reference group too, depending on the impact of the change on the project. The decisions made during planning and reviewing are aimed at adapting to a change and still being able to deliver a project and a product that satisfies the specifications within time and budget. What a project manager decides about in planning and reviewing situations are

progression of the project, budget and cost allocation, manning during different project stages, and acceptance or modification of suggestions of actions to meet changes in a project. Figure 1 shows the input to planning and reviewing activities and what the output is, i.e. the essential impact of decisions made.

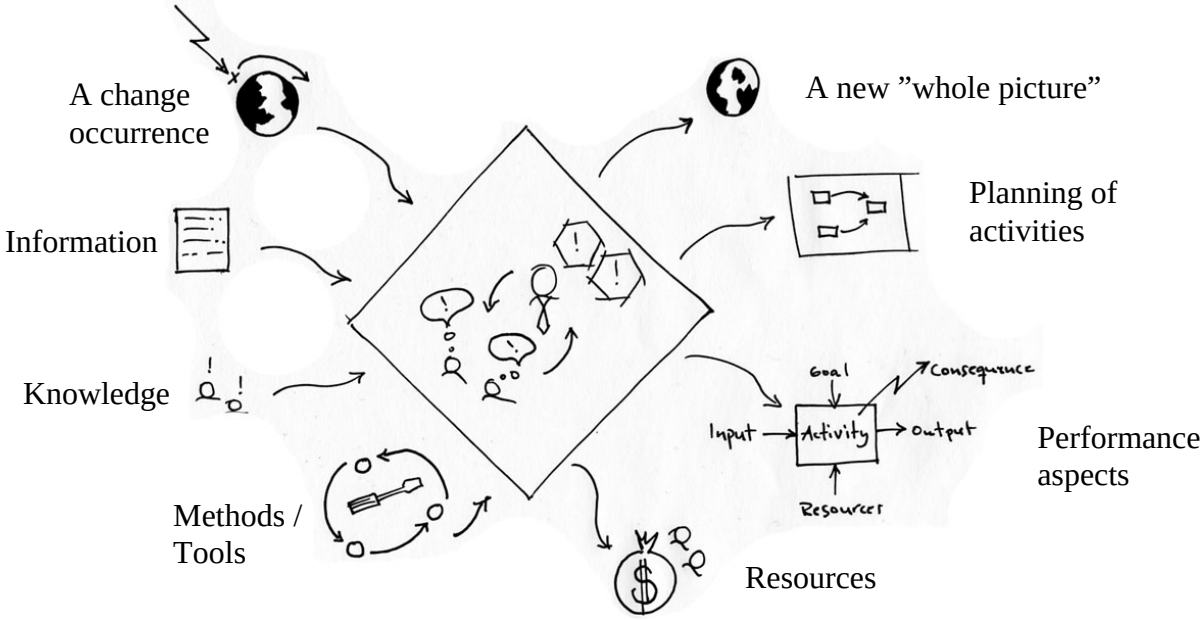

Figure 1. The planning situation’s input and output.

What are the essential objects of consideration during project management decision-making?
The essential objects of consideration have been found to be related to both project and product performance which could be considered as the whole delivery for the project manager. The essential objects of consideration related to project performance are: the project life cycle including its interactions with stakeholders, project progression and tractability, tasks in relation to project performance, budget (included in business), team, and the delivery. The essential objects of consideration related to product performance are: specifications, the product life cycle, and product cost (included in business). Figure 2 illustrates the essential objects of consideration during planning and reviewing in order to make project decisions with the whole of the project in mind.

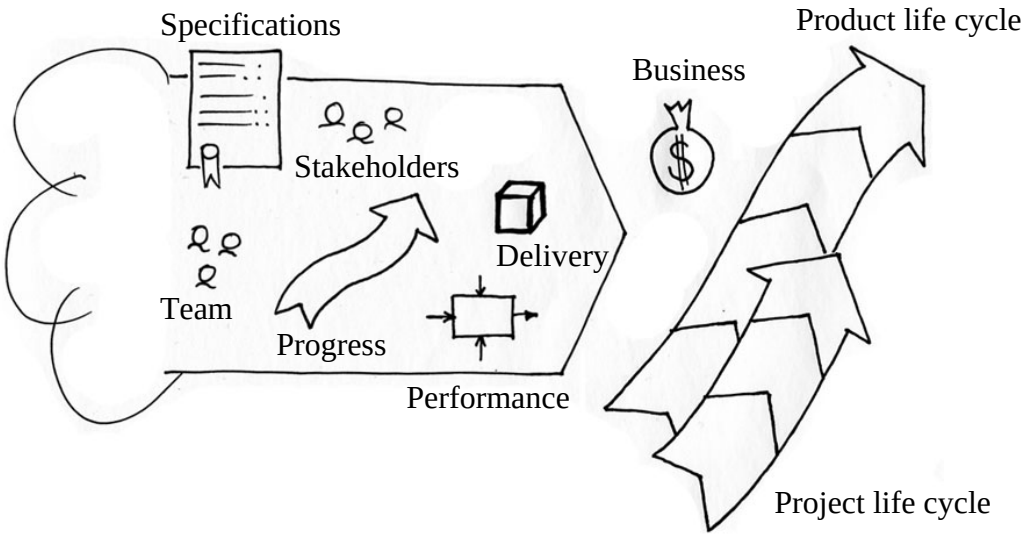

Figure 2. The project manager’s decision map.

6 Discussion and conclusions

In practice methods supporting clarifications of decision situations are rarely used and the authors see a challenge in investigating the essence of project management in product development projects and to propose a suitable mindset based on both empirical studies and prescriptive literature about the nature of decision-making.

Our first contribution was the planning activity which shows the essential input and output of planning and reviewing situations in a product development project. This model links empirical findings with the recommendations within prescriptive project management and design methodology literature. The second model, called the decision map, is an illustration of the essential objects for consideration when planning and reviewing after a change has occurred. The two models are idealized compared to industrial practice and are thought to be used as a point of discussion when a change has occurred.

When comparing Hansen and Andreasen's design decision mindset [12] with the proposed mindset for a project manager in this paper, the fundamental common aspect is clarification of decision situations, but the processes differ. Designing is about synthesis controlled by tentative decisions and validation, while project management is about planning and reviewing suggestions of actions in order to manage changes in a project.

When comparing the mindset for a project manager with empirical findings and the prescriptive literature, the mindset include the essential objects to consider and should support the articulation of uncertainties when planning. The models have been superficially validated by discussions with three professionals within project management and a prized author within project management with 40 years of experience within management of product development projects. The discussions showed a positive response to the content of the two models but the notion was that there need to be ways to actively work with the models in an industrial setting and should be further researched. The research is continued and is now being investigated at two additional companies in Sweden in order to validate the results further.

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