INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, STANFORD, CA, USA

HOW ARE KNOWLEDGE AND INFORMATION EVALUATED? – DECISION-MAKING IN STAGE-GATE PROCESSES

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ABSTRACT
In stage-gate processes decisions are made based on the knowledge and information developed during the preceding phase. The purpose of this study is to explore the state-of-practice in industry regarding the assessment of knowledge and information at gates. The result indicates that gate reviews relate mainly to assessments of technical performance and function. Relatively little attention is given to assess the quality of the knowledge base, making it difficult to identify outdated, irrelevant and non-applicable information and knowledge. Further, tacit knowledge plays an important role in the decision-making process, as reviewers ask for the design rationale and further evidence of what has been done and why. However, evaluating such knowledge is currently a poorly understood aspect of gate reviews. It is concluded that even though the specific focus of such meetings is not on the evaluation of knowledge and information, the opportunity to work towards a better support of such activities is promising, especially since the respondents perceive the benefits that come from an increased attention to assessments of both the explicit and tacit knowledge base used in gate reviews.

Keywords: Knowledge management, stage-gate process, decision support, maturity

1 INTRODUCTION
Striving for innovation and generating new ideas and product offerings is one way for firms to stay competitive in a business environment driven by globalization and fierce competition. In this environment firms need to team up in strategic alliances, such as virtual enterprises [1], to make effective use of each other's competitive advantage, i.e. their knowledge, when developing new product and service offerings. Being able to trust each other's information and knowledge will then be an important part of the day-to-day work; therefore, ensuring confidence in the material used in product development processes, such as the common stage-gate process [2], is paramount. Ensuring that the knowledge used in decision-making is valid, mature and of high quality will become increasingly important, since this is the main constituent that actions are based upon. Identifying situations when the knowledge base is of low quality is crucial to avoid loosely-based decision-making. A better understanding of the knowledge base status promises better results from future actions in the product development process, since it becomes clearer whether or not additional work is needed at decision points. Hence, a decision support that can help ensure the high quality and maturity of the knowledge and information is needed, or at least to help decision makers in conducting an honest appraisal of the knowledge base and determine a clear course of action depending on the current level of maturity. Until now the main work in this area has been to evaluate stage-gate from a learning perspective, i.e. [3, 4], to evaluate the rigidity of stage-gate versus facilitation of learning.
Gated maturity assessment [5] was an action-based development effort, where the respondents assisted in the development of the assessment method and its tool, while they elaborated on issues seen in companies today. However, to guarantee that the right problem is solved, some groundwork in this area is required. Therefore, this paper will attempt to fill this void, by stepping back slightly and examining the problem situation in industry today, when it comes to the relation between decision-making practices and the status of the knowledge assets used to support gate reviews.

The purpose of this study is to examine decision-making in new product development (NPD) from two Swedish manufacturing companies. From this, two sub-goals can be derived. Firstly, the focus is to identify the knowledge and information required in the decision-making process in new product development, and to gain an understanding for how it is used. Secondly, the aim is to identify the critical aspects that influence decision-making in new product development.
Essentially, this research work stems from the hypothesis that assessing maturity and thus the quality of knowledge in a decision-making situation will positively influence the quality of the decisions taken. This should lead to better quality in projects, though many other factors influence project success, i.e. it might be able to measure this in terms of performance measurements.
The research approach used in this paper describes the design of the study, the data collection and the analysis and relates them to the literature. Further, the case companies and respondents are shortly presented. After this the theoretical background is presented, focusing on areas related to stage-gate, knowledge management and maturity. Thereafter a report on the interview results follows. Finally, the paper is rounded off with a discussion of the results, the conclusions that can be drawn from the paper, and some elaboration on future work.

2 RESEARCH APPROACH

This paper is based on a multiple case study [6] performed at two Swedish manufacturing companies. Case study was chosen because the purpose is (partly) derived from a "how"-based research question (i.e. How are knowledge and information used in the Stage-gate decision process?), the focus is on contemporary events, and finally, it is not possible to conduct an experiment because the area of focus is embedded in the processes. According to Yin (2003) this points towards case studies being a viable approach.
This study was conducted as a multiple case study [6], since the two companies operate in two rather distinct environments, adding variety to the sample. The stage-gate process is common, but its application is often quite different. In addition, having multiple cases provides varying views of the studied phenomena and the possibility to compare results [7].
The main unit of analysis [6] in this study is the respondents' perception of the information and knowledge that they prepare for and bring to the gate meetings. What is the form of information and knowledge? What are the contents? What is the quality of the information and knowledge? How is it used to aid decision-making?
As sampling criterion, the respondents should have long experience from different development projects within areas related to the innovation process.
The modes of data collection were semi-structured interviews and workshops with respondents at both case companies. These modes were chosen because they allow the respondents the freedom to speak from their experience of working at the companies. The respondents' stories and experiences were important to capture in this phase of the study. Telephone interviews were performed and recorded to be replayed later and transcribed.
The atmosphere of the conversations was understood to be quite honest; the interviewees stated clearly when they could not answer a question. Therefore, the risk that the respondents were guessing or making up answers to any questions is assumed quite small. During the analysis, any answers with a risk that the respondents might have misunderstood the question were removed from further analysis.
In the analysis, the recordings made during the interviews were first transcribed. These transcripts were sent to the interviewees for iteration, so that they could read, agree or correct, and comment on the answers. At this point they also responded to questions that the researchers developed during the initial screening and analysis of the material. Thereafter, themes originating from the purpose of the study were used to classify the information provided by the respondents. The data were reduced, where information and quotes were ordered in a mind map to provide an overview of the contents, which then formed the basis for the report, i.e. this article. Based on the material, a story of the current situation in the case companies unfolded, with several quotes from the interviews used to further illustrate some important points.
Of note, a need to complement the data from this study with other types of data and make use of triangulation is still needed [6]. This is further elaborated upon in the future work section.

3 THE CASE COMPANIES AND THE RESPONDENTS

In this study, two Swedish manufacturing companies participated. These companies and their respondents have been anonymized in this paper and will be referred to as Company A and B, and Respondent A1, A2, B1 and B2.

Company A is a developer and manufacturer of components for both civil and military airplane engines as well as rocket engines used for space applications and gas turbine engines. Further, they have a business in the maintenance, repair and overhaul (MRO) of airplane engines. They usually work as a tier 1 supplier or risk-and-revenue-sharing partner to the main engine integrators of airplane engines. The company has a business philosophy of working very closely with their partners.

Respondent A1 is employed as an industrial Ph.D. Student at Company A, but is not affiliated to the same university as the authors, or directly involved in this study. He is educated as an engineer and has 13 years experience at the company. He has worked as a line manager at the company and has participated in several projects related to technology development.

Respondent A2 works as a project leader for a technology development project at Company A and holds a Master of Science and Business Administration. He has 16 years experience at the company, including working in different areas and locations (i.e. Sweden, USA).

Company B is a manufacturer of tools for the metalworking industry, with products in areas such as turning, milling and drilling. They mainly develop their products in-house, but are heavily reliant on the cooperation with their customers to identify and understand the needs and problems to address.

Respondent B1 is a manager at the milling department of Company B and responsible for design and product development. He has worked there since 1985, during which time he has held different positions, such as product leader, designer and developer.

Respondent B2 is product development manager for drilling tools at Company B. His educational background is in mechanical engineering. He has 10 years experience at the company. During this period he worked as development engineer and later in various product management positions.

4 THEORETICAL BACKGROUND

4.1 Decision-making in New Product Development (NPD)

One of the primary focuses of the stage-gate process is decision-making [8]. The idea is to decide to either continue or disband a project as early as possible, to reduce wasting resources on projects that show little promise. Stage-gate is based [8] on principles of rational decision-making [9]. Rational theories of decision-making are mainly based on four aspects [9]: knowledge of alternatives, knowledge of consequences of alternative actions, consistent preference ordering, and a decision rule by which to select a single alternative of action. This is reflected in the Stage-Gate model.

4.1.1 Stage-Gate

Stage-gate, developed by Cooper [2, 10], is a process that moves projects from idea to launch of product. It is based on a process referred to as phased review [2, 10] or phased project planning [3], which NASA implemented [3] during the 1960s to manage development projects by breaking the process into stages with reporting in-between. At that time, projects were very complex because they were essentially at the forefront of technical development. Therefore, the phased process was implemented to gain control of the projects and to either cancel or re-prioritize projects at an earlier stage [3]. Stage-gate can be seen as a set of information-gathering activities [10]. The overall process map is showed in Figure 1 below.

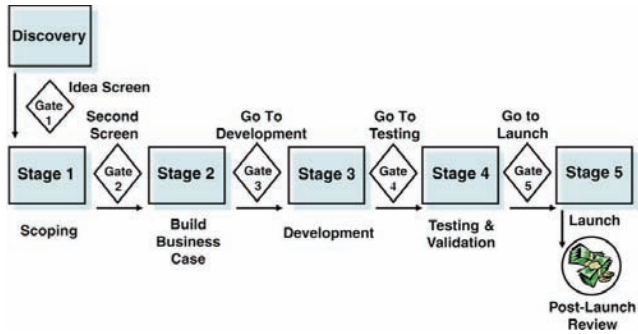

Figure 1. Stage-gate process overview (from [10]).

The main structure of stage-gate is the presence of one stage, where activities take place and one gate where information is assessed and decisions are made, see Figure 2. These two are described more in detail below.

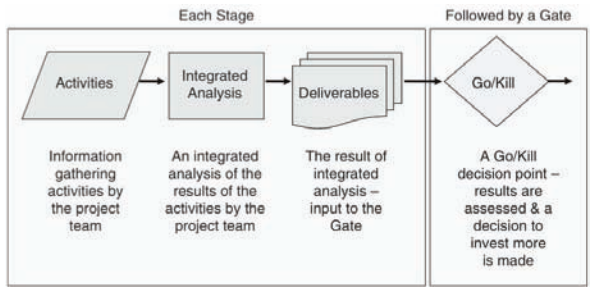

Figure 2. Stage-gate structure with a stage followed by a gate (from [10]).

Each stage can be seen as a information and knowledge gathering activity that produces deliverables as input to the gate [10], see Figure 2. Within each stage, activities are normally undertaken in parallel and sequentially. The role of the gate is to evaluate what has been done in the previous stage and to decide the way forward, what should be done in the next stage, how that path forward should be undertaken and how much resources should be allocated for the next stage [10]. Reviewers evaluate the information, or the deliverables, developed during the stage. This information is matched against a number of criteria to make a decision. According to Cooper [2], the reviewers have four options to choose from. The first option is "GO", when the project is fine and can keep going onto the next stage. Resources are allocated for continued work. The opposite of this is "KILL", when the work has not progressed as expected and moving further presents a major risk, and the project is thus terminated. In the middle is either the option to "HOLD" or to "RECYCLE", meaning that providing certain changes are made, the project can still go on.

Once at the gate, Cooper [10] advocates the use of scorecards to score the project against a set of predefined key criteria. These criteria include, for instance (from Cooper [10], p. 227):

- Alignment with business strategy and impact on business
- Competitive advantage of product
- Market potential and attractiveness
- Leverage of core competencies
- Technical feasibility
- Financial reward versus risk

4.2 Information and knowledge

Information and knowledge are usually defined in relation [11] to one another, to define the relation of the terms data, information, knowledge, and wisdom [12]. This can be done using the Data—Information—Knowledge—Wisdom (DIKW) hierarchy [13], also known as the knowledge hierarchy or the knowledge pyramid, see Figure 3.

Figure 3: Knowledge Pyramid also known as knowledge hierarchy or DIKW hierarchy (adapted from [13]).

Data is about the raw facts and symbols; it has no meaning by itself and no relation to other data or information. *Information* is data that has been given meaning and understanding by relating it to other datasets and other information. *Knowledge* appears when even more understanding and context are added and when, by combining different sets of information and data [11], a pattern appears. Data and information are about the past, but knowledge is more about the present, when you can start taking action and make decisions based on it. Knowledge is also about knowing "how", which relates to actions. *Wisdom* is about the future, where accurate forecasts on the impacts of decisions and actions can be produced. Wisdom is about knowing "why". In this paper information and knowledge depict the material produced and the learning that people do in the development process.
Another way to relate to knowledge is to distinguish between tacit and explicit knowledge [14]. *Tacit knowledge* is dependant on the people who possess it and their contexts. It is difficult to write down and codify so that it can be shared in a document format. *Explicit knowledge* is the opposite, the kind found in documents, written down and codified.

4.3 Maturity

Maturity is a way to assess the state of completeness and predictability of either an artifact or in a process. Bohn [15] defines maturity of knowledge as *"understanding the effects of the input variables on the output"*(Bohn [15], p.63). He further states that:

"The manager's or process engineer's goal is to manipulate the raw materials, controls and environment to get output that is as good as possible. It is customary to treat the environmental variables as exogenous and uncontrollable. However, with enough knowledge, the environmental variables can be turned into control variables and, therefore, are not exogenous" (Bohn [15], p.63)

There are two widely adopted frameworks on maturity in different industrial sectors, Technology Readiness Level (TRL) and Capability Maturity Model (CMM), where the latter has evolved into Capability Maturity Model Integrated (CMMI) in later years.
TRL is a concept that was developed by NASA [16] to work as a framework and guide the development of technologies and systems to be used in space missions. Because the cost of any failure can be extremely high, there is a need to ensure that any component or system being fitted onto a product going into space is properly and sufficiently tested and validated in environments relevant to the final mission. The TRL features a 9-level criterion scale that represents technologies in development from a research/laboratory state to a "flight proven" implementation in a product.
CMM/CMMI was developed to support software engineering [17]. It was previously common that development projects ran over time, over budget and did not deliver the functionality as promised. Successes were often dependant on the heroic efforts of individuals, and when they did not work on a project, the project failed. Therefore, CMM/CMMI models were developed to assess the capability of development processes in the software companies. This is in contrast to TRL, where the artifact is assessed. A company with high process maturity will meet targets on time and budget, because the development process is well developed. Further, there is also a level of repeatability in a mature process, where companies continuously manage to deliver.
Based on the maturity frameworks of TRL and CMM/CMMI, Johansson et al [5] have explored the use of maturity thinking in the context of knowledge, rather than technologies or processes. The idea behind this knowledge maturity concept is to narratively prescribe the necessary activities and the necessary level of detail needed to sufficiently fulfill a level and pass a decision point with confidence. As it works prescriptively, it is also a way to evaluate the level of knowledge. In this work, knowledge is based on three dimensions, viz. the input to the project, the method used to refine and create

knowledge, and the experience and expertise of the people doing the work. Figure 4 depicts a generic scale that is intended to be adapted to the specific working context.

5	EXCELLENT	*The content and rationale is tested and proven. It reflects a known confidence regarding, for instance, risks. *The procedure to produce the content and rationale reflects an approach where tried out methods are used and where workers continually reflect and improve. *Lessons learned is an important element.
4	GOOD (between 3&5)	
3	ACCEPTABLE	*The content and rationale is more standardised and defined. *There is a greater extent of detailing and definition. *The procedure to produce the content and rationale is more stable with an element of standardisation and repeatability.
2	DUBIOUS (between 1&3)	
1	INFERIOR	*Content and rationale is characterised by instability. *The procedure to produce the content and rationale is dependant on individuals and formalised methods are non-existent.

Figure 4. Knowledge Maturity criterion, adapted from [5].

5 RESULTS

Findings from the interviews are presented here, beginning with an overview of the development process in the respective companies and an overview of the gate meetings. The focus is then on the knowledge and information in the gate meetings.

Innovation & Innovation process

Innovation activities at the case companies are managed through a series of processes with activities that take the products from ideas to finished product. The drivers of innovation are different in the two companies. In Company A, common aerospace industry goals drive the direction of aerospace development and what type of development efforts the company should focus on. In Company B, the voice of the customer is an important driver together with the technology insight that drives the development of new technologies. Company B works very closely with "driving customers" (i.e. lead users [18]) from markets that the company prioritizes, because they believe these markets will grow better than average and still have representative needs for their other customer base.

In both companies, new product development activities are divided into sub-processes, called technology development and product development in Company A, and knowledge development and product development in Company B. Product development contains little uncertainty, i.e. the products are very well-defined. When this part of the development project is initiated, they have little doubt that they cannot deliver. In Company A contracts are signed before this phase is initiated, in Company B there is a fixed launch date. In the phase prior to product development (technology or knowledge development), both companies have development activities to ensure that they master their technologies and know enough about the technology to introduce it to product development. In Company A, technology development projects follow the TRL scale from level one to level six (out of nine), before being handed over to product development. In Company B, similar activities are referred to as knowledge development projects.

Stage-Gate process

In both companies, processes are managed with a stage-gate influenced process to control the process and make decisions. In Company A, the process has been redesigned compared to Cooper's definition [2, 10], where several gates have been added. Further, the decisions are divided into either two or three meetings, depending on if the customer is involved in the decision process at the particular gate or not. The first point is the technical review meeting, where technical details and technical feasibility are reviewed. This works as input to the main gate meeting, where the focus is on risk, scheduling and

cost issues. The final part is the customer gate meeting, where technical progress and scheduling are again the main interest for the customer. Company A values input from the customer and collaboration with the customer very highly.
The stage-gate process in Company B is very similar to the definitions by Cooper [2, 10] and is managed with a computer support using predefined templates that must be filled out and stipulate what should be taken care of during the gate meeting.

Gates
All company functions affected by the project are represented from the management at the decision meeting and from the project the project leader is present. In Company B, where the decision has little uncertainty and the material is of good quality, the project leader may not even be required to take part. In Company A, due to the nature of technical review meetings, technical experts are present. The main focus in an internal gate meeting is on the business case and representatives from these functions are therefore present, whereas at the customer gate meeting the engine integrator hosts the meeting and key personnel from Company A are present.
Some gates are more important than others, where shortcuts and bending the gate criteria are not accepted. At Company A, the most important gate meetings are those involving the customer, because they are so dependant on what their customers, the engine integrators, think. Gate meetings with management are also important, because this where resources for the next phase are decided. In Company B, the most important gates are those where big investments are due or where stock buildup needs to be decided.
It is very rare in both companies that projects in the product development phase are stopped at the gates. Projects in Company A are managed a bit softer due to, for instance, contractual terms.

"…we already signed the contracts with our partners, so it would be a breach of contract actually…"

In Company B, introduction dates are an important driver. Therefore, they sometimes have to take a shortcut if time is short. This is especially true for high profile projects.

"…most of the times it's successful, but the risk that something is forgotten or that something goes wrong are of course very high."

Both companies usually try to catch up as much as possible during the course of the project, and still meet the final deadline. For instance, the project leader in Company A has to devise a detailed plan with actions for catching up with the things that fall behind at a particular gate.
However, technology development and knowledge development phases have a stronger incentive to make sure that projects going through are mature. Developments can be either reworked or killed, because the technology is either too complex, too costly, or not sophisticated enough, to name a few reasons.
Presently, neither company focuses explicitly on knowledge or information and the quality in the gate reviews. They are mainly concerned with aspects such as product performance, if the function meets the specification, if the time schedule is met, what the cost is, and so on. It is usually assumed that the people in the project are knowledgeable, that they learn, and that the knowledge base builds during the course of the project. One respondent at Company A said:

"…it's kind of assumed that the people who are involved in the development, they learn as they go through product development, and they build up their personal knowledge and this is reused in the next project when they enter into the next project, and they take that knowledge with them. But it's very much their own knowledge"

However, Company A has a design justification file where they document the progress made and why things look the way they do. Company B is moving towards focusing more explicitly on knowledge to ensure that they document their activities better with rationale for each gate. One respondent said:

"…when you start the project with more knowledge, the project time will be shorter."

As with knowledge in general, tacit knowledge is not an explicit topic at the gate reviews. However, there is an indirect understanding for it. One respondent at Company A said that the management group is interested in who has done the work or who the project leader is:

"…you are always interested in who has done this analysis, or who is leading this project, or who are the designers involved in this design group…"

Further, when project teams are assembled, there is an understanding for the concept of tacit knowledge, as reflected in this quote regarding when experienced project leaders want to recruit team members:

"When I worked as a line manager…they gave me a list of names of the people who they wanted for their project team. And it was always the list with the dream team."

It is understood that an experienced team has an influence on the end result, the quality of the work, and on the time and money spent on the project. An experienced team knows what to do, where are the challenges and where they should focus. Similarly, in Company B experience is an important element for passing the gates.
Regarding gut feeling, in particular, there is no doubt that this is an important component in the gate meetings. In Company A gut feeling is important, but this needs to be supported with figures and data, and technical information to prove the validity in decisions is therefore important:

"If you say my feeling is that this will work and you have twenty years of experience, then the review team will say 'fine that sounds really good, that makes us more comfortable, but we need you to come up with the figures that support your gut feeling'."

One respondent at Company B said that they come from a tradition of very much trusting their gut feeling. They trust their employees highly. In some cases, gut feeling may help bend the rules slightly at the gate, where the project leader says that he/she has a feeling that things will be ok for the next gate. Still, Company B is moving towards a more fact-based style of assessing the gates, where as at Company A, you need to come up with the figures. In both companies however, gut feeling needs to complement the facts. As one respondent at Company B said:

"If the project members are not convinced themselves, or believe in the product, we have a huge problem. Because if you don't believe in it, it won't happen, it's just that simple."

Further, he said that there is a risk when you have contradictory analysis results, when teams want it so badly that they do not see the bad result and try to understand why things are the way they are. This is where decision makers have to be careful and try to be aware of the state of the team's gut feeling. A gut feeling can also tip over changes to design solutions, if the gut feeling is that the original option will not work.
Table 1 below summarizes some of the main points from the interviews to provide the reader an overview of the results from the two companies.

Table 1. Summary of interview results

	Company A	**Company B**
Innovation Driver	Common industry goals	Voice of the customer; driving customers
R&D process (pre-PD)	Yes; "Technology Development"	Yes; "Knowledge Development Process"
Stage-gate	Yes; revised according to company needs	Yes; computer support with pre-defined templates
Decision meetings (gate meetings)	Technical review (tech. experts); Internal Gate meeting (business case & management); Customer Gate Meeting (engine integrator; technical focus)	Review of templates
Gate "let-through" (i.e. without fulfilling criterion)	Yes; catch up during the project (contracts have penalties for delays; final gate important due to aerospace regulations)	Yes; catch up or modify acceptance criteria (introduction dates are drivers)
Knowledge and information focus	Not explicit; implicit assumption and understanding; design justification file contains rationale	Not explicit; more focus will come in future with new developments to process
Tacit knowledge focus	Not explicit; indirect understanding; "who" is important; dream team formation by experienced project managers; tacit knowledge needs the figures and facts as well	Not explicit; experience is an important element; trust gut feeling; moving towards more fact-based decision
Maturity thinking	Yes; TRL drives development (Technology development versus Product Development)	Not explicitly

6 DISCUSSION

Knowledge is focused upon in this study because based on knowledge, actions are taken [11]. This is especially interesting in this context, since the purpose of the gate meeting in the Stage-Gate process is to make decisions and take action. Therefore, it is not inconceivable to assume that the better knowledge and quality of knowledge (i.e. better quality of result from development activities) in the stage-gate process, the better are the decisions and actions. Presently, neither company explicitly focuses on knowledge and information. In Company A, it is assumed that project teams learn in the project, but this is not verified. It is interesting to relate to Engwall [3], who says that product development is a knowledge journey and that you have to allow for learning in the stage-gate process. Therefore, it seems reasonable that to check that you have actually learned something when making decisions. There is an importance to not only focus on the performance related aspects more explicitly in the gate meetings, but also on the knowledge that these aspects reflect and the maturity of this knowledge.

Clarifying that the performance aspects should still be the central focus of the gate meetings is necessary, but there is a need to bring in the knowledge maturity aspect as a complement to the review process. Making progress in a project is not just about meeting the technical objective in terms of performance; it is also about learning about the product. This is essentially the core of the knowledge maturity idea. Having high knowledge maturity is a reflection of you having learned about the product you are developing and that unpleasant surprises are rare or non-existent.

The lack of focus regarding knowledge and information is consistent with findings from a previous study [19], where comments from industry experts point towards the issue of assumptions versus facts when presenting solutions and concepts for decisions. In that case, the feedback was that it was difficult to differentiate assumptions from the proven facts because people wanted things so badly. Just because you reach a desired level of performance or functionality in a conceptual design activity does not mean that this will be the end product. From the interviews it is evident today that the main

focuses of the gate meetings are the performance and function aspects of the material, and not the learning aspects or quality of information and knowledge created in the process. This lack of knowledge and information focus is something that they feel is either a disadvantage or they are making strides towards improving.

Further, it is interesting to see in the interviews that the gates seem to lack the teeth or influence that Cooper (2008) [10] prescribes. In these companies keeping the projects running and not falling behind with deliveries is more important; thus, only in extreme cases are projects stopped. In Company A, product development is based on contracts with customers and partners. These contracts have clauses that make it a breach of contract to stop a project at a gate. Therefore, they try to catch up during the course of the project. Cooper [10] brings up this phenomena as *"'We never kill projects, we just wound them.'" (p.218, [10])*. On a similar note, we have comments from one of the case companies, when discussing these issues, stating that *"[the stage-gate] is the law [of the company], but where is the sheriff?"*; pointing towards the different views on this topic. Theoretically [10], the main objective with the stage-gate process is to facilitate the movement of a product from idea to launch in as an effective and efficient manner as possible. Feeding into this, the main purpose of the gate is to take GO/KILL decisions to facilitate the overall objective with the stage-gate process. What is evident from our studies is that reality is not as clear-cut as Cooper states. In practice HALT or KILL are very rare, it is more that you try to appreciate the risk of going forward with a GO decision that might not have full confidence and devise a suitable action plan for how to catch up. A maturity approach could help companies in their current situations and further assure better confidence for decision makers. Having a good understanding of the limitations and benefits with their current knowledge base is better than not knowing anything about it at all.

In technology development in Company A and knowledge development in Company B, there is, however, an incentive to at least not push the project through. In these activities there are no contracts with external partners or launch dates that pressure the project. In fact, here you do not want the technology to move into product development at an immature stage. Only once it proves to provide a benefit for the company, it will be taken into the product development stage. There is a need to value information and knowledge more easily and to reduce the dependency of individuals in the team. It should be possible for outsiders to contribute to the development effort and to solve problems if the picture of what knowledge already exists, what knowledge needs to evolve and what knowledge is missing altogether are clear.

7 CONCLUSIONS

This has been an explorative study whose purpose was to examine decision-making in new product development (NPD) in two Swedish manufacturing companies. From this, two sub-goals were derived. First, to identify the knowledge and information required in the decision-making process in new product development, and to get an understanding for how it is used, and second, to identify the critical aspects that influence decision-making in new product development.

General conclusions

It is quite evident that the main focus of the gate meetings in both companies is the performance and function related aspects, together with others such as business case feasibility and risk. Decisions are taken when the performance or business case matches what is good enough, i.e. the performance indicators indicate that the product should have a desired level of performance or the business case indicates that the company will make a certain profit. However, decisions are also occasionally taken when they have to and not when the performance or the business case is healthy.

Regarding knowledge and information, content is needed but quality is not a specific topic in its own right. Of course, it is a feature in the sense that a certain level of evidence is needed, such as a certain method for analysis (i.e. simulation, physical tests, etc.). Knowing this in advance, they plan for it and try to perform what is good enough. However, no true acceptance criteria exist in terms of what quality level in the knowledge base is sufficient to make a confident decision.

Industrial implications

Since this study has had a descriptive focus, the main contribution of this article towards an industrial perspective is mainly the awareness of the opportunities available from attaining a more explicit focus concerning knowledge and information, as discussed in this paper.

For instance, a more pragmatic handling of gate decisions is an example where focusing on knowledge maturity could support in making a more confident decision about how to handle the gate, which actions are necessary and how much resources should be devoted to catching up with the particular item. 'How much do we know?' and 'What are the difficulties we can expect?' are some of the questions that can be asked and answered when more attention is given to the knowledge aspects.
This study points to the value of both tacit knowledge and gut feeling in the process and its implicit understanding. However, focusing more explicitly and systematically on this factor is valuable to have a greater conscious of it when managing projects and taking decisions.

Academic contribution
This study has pinpointed the pragmatic perspective of stage-gate found in the companies as a point where practice differs from the theoretical view presented by Cooper [2, 10]. This echoes some of the critique that other authors have voiced regarding the rigidity of Cooper's stage-gate. This provides an opportunity to further investigate this aspect and find ways of supporting these decisions that become even more delicate. 'Should the project be allowed to continue even though the criteria are not fulfilled?'. This is a question that should be supported to provide better confidence for the decision makers.
In the theory [2, 10], the stage in the stage-gate process is regarded as an information gathering activity that creates a foundation for the decisions needed to be taken in the gate. However, from this study and the theory it is evident that there is no real focus on the quality of the information and resulting knowledge created in the gate, when the decisions are to be taken. Hence, the main focus is what the content says, i.e. what is the function, performance, etc. that can be drawn from the product. This finding provides opportunities for an increased focus on maturity of knowledge as well as product in the gate decision.

8 FUTURE WORK

To further improve the work, more sources of evidence should be investigated [6], what Yin [6] refers to as triangulation. Therefore, it would be of interest to observe a typical gate meeting in either of the companies, as well as study archival data, such as process descriptions, guidelines for gate meetings, and protocols from previous gate meetings. Also, it would be interesting to interview more people in other functions at the two companies to gain an even better picture of the situation.
More interviews are needed, especially from complimentary areas of expertise, as both companies try to form the development work and the decision-making around cross-functional teams.
On a more specific note, it would be interesting to dig deeper into the more pragmatic handling of the gates decisions, where many things are allowed to pass the gate with action plans, instead of being stopped as theory [2, 10] prescribes. Understanding the reasons behind this, finding the nuances where different decisions are taken and then naturally being able to support these kinds of decisions made so often in the development processes is of great interest for future efforts.

ACKNOWLEDGEMENTS

We would like to extend our gratitude to the case companies and the respondents of the interviews that this paper is based on.
The Product Innovation Engineering program (www.piep.se), a Swedish research and development program for increased innovation capability in organizations, has contributed to this work.
Further, the authors acknowledge the support from the Faste Laboratory, a VINNOVA Excellence Center within Functional Product Innovation.

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