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Risk Management Practices in Product Development Companies

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Abstract

Product development (PD) is inherently linked to taking and managing risks. For risk management (RM) to be truly effective, it cannot be treated in product development in isolation. Instead, a holistic perspective is required that recognizes and leverages the communication and connections between RM sub-disciplines across the organizational hierarchy, including e.g. enterprise-, portfolio-, project-, and product RM. Therefore, the purpose of this study is (i) to investigate current RM practices on the strategic, tactical, and operational levels, and (ii) to increase the understanding of how RM sub-disciplines are connected and interact. To answer these questions, semi-structured interviews were conducted at two large multinational PD and manufacturing companies in Sweden. Also, based on previous research, a novel self-assessment tool was developed and tested to map areas of strength and identify improvement potential. The results show that RM processes are mostly formalized and systematic, but there is variation in the quality of performed RM activities. Qualitative support tools are dominating. The tools themselves are considered to be helpful, however, the challenge is to make people use them in value-adding ways. Other challenges and success factors include competence and awareness, culture, top-down demand for high quality RM activities and deliverables, a dedicated role with clear responsibility, and working early and continuously with RM. The importance of experience is stressed, however, no systematic way to work with lessons learned and knowledge sharing is in place at the companies. Risks are found to be primarily escalated bottom-up. The corresponding top-down flow constitutes of objectives, which ideally are cascaded all the way from company vision and strategy into product requirements. Through these findings, the contribution of this study is (i) providing detailed insight into current RM practices, not limited to the PD function, but considering a broader organizational context; and (ii) clarifying the role of goals and objectives for connecting RM on different levels.

Keywords: Risk Management, Product Development, State of Practice, Case Study, Requirements Management

1 Introduction

Each company got a purpose and a vision it wants to accomplish. However, when planning for the future, nothing is certain and an infinite number of potential events can affect whether the company succeeds to realize its vision or not. Risk management is in essence about managing the future; a future, which is characterized by uncertainty. Risk is however not the same as uncertainty, but rather a subset of it, and can be defined as "the effect of uncertainty on objectives" (ISO, 2009). This definition from the ISO 31000 standard implies that risks can both have a positive effect on the achievement of objectives, i.e. opportunities, as well as a negative effect, i.e. threats.

Product development is inherently linked to taking and managing risks. In fact, it can be viewed as a structured way to reduce uncertainty (Oehmen, Olechowski, Kenley, & Ben-Daya, 2014). Numerous empirical studies have highlighted the positive effect of risk management activities on overall project performance (e.g. Mu et al., 2009; Raz et al., 2002; Zwikael and Ahn, 2011), e.g. through improved resource allocation, stakeholder confidence, loss prevention, and organizational resilience. Several examples exist of how companies have standardized their risk management practices (e.g. Prevel Katsanis & Pitta, 2006). Other studies have analyzed how different product development approaches, such as stage-gate, spiral development, lean, and design for six sigma incorporate a risk perspective (Bassler, Oehmen, Seering, & Ben-Daya, 2011) and how companies can tailor their product development processes to suit their individual risk profiles (Unger & Eppinger, 2009). Škec et al. (2012) investigated how specific types of risk emerge in certain phases of the product development process. Methods and support tools for risk management in product development were reviewed by Oehmen et al. (2006).

One goal of the ISO 31000 standard (ISO, 2009) is to establish communication and interaction between risk management processes along the value chain and along different organizational levels of decision-making in the hierarchy. A literature review of risk management in product development found, however, that such in depth integration is lacking (Oehmen, Ben-Daya, Seering, & Al-Salamah, 2010). The same study also highlighted that no agreement seems to exist regarding the establishment of objectives, which are at the core of risk management in line with the ISO definition, to be used as a basis for risk management activities.

Therefore, the purpose of this study is to investigate current practices of risk management at different levels across the hirarchy at product development and manufacturing companies. In specific, the following research questions (RQs) are addressed:

- RQ1: What are some insights regarding current risk management practices at product development and manufacturing companies, based on investigations at two case companies?
- RQ2: How are risk management sub-disciplines on different levels across the organizational hierarchy connected?

By answering these questions, the main contribution is to provide an in-depth insight, based on empirical data, into how product development companies currently work with risk management. The unique characteristic of this study is that risk management is not studied in product development in isolation, but that all organizational levels, as well as connections between them, are investigated.

2 Method

To derive at answers to the research questions, an exploratory and a descriptive approach were combined, Figure 1. First, exploratory interviews were performed at two product development and manufacturing companies to get an overview of the organization and processes in relation to risk management. Based on the results from this exploratory step, the focus for the descriptive study was defined: the interview protocol was further developed and refined and relevant company functions and roles were identified to be targeted for additional interviews. As a complement, a novel self-assessment tool for risk management was developed and tested, utilizing previous research, to see how the companies perform in relation to characteristics of successful risk management. Together, these methods provided an overview of current risk management practices at multiple organizational levels at product development companies, as well as insights on how risk management relates to other company functions. The applied methods are described in more detail in the following sub-sections.

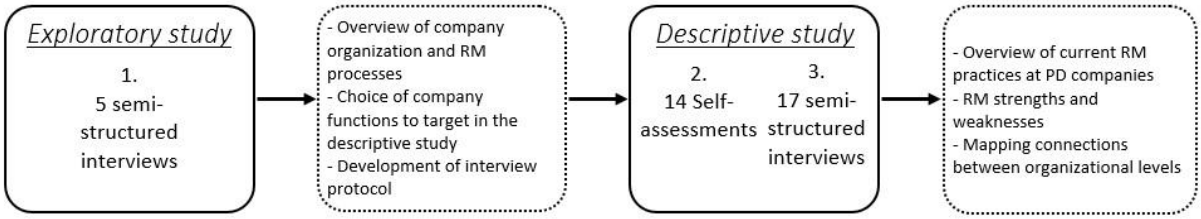

Figure 1. Visualization of the research method and main outcomes from each step.

2.1 Semi-structured interviews

A total of 22 interviews were conducted at two large multinational product development and manufacturing companies located in Sweden. Company A has about 2000 employees and develops and manufactures aircraft engine components. Company B has about 4000 employees and is in the construction machine industry. The interview study started with 5 one hour exploratory semi-structured interviews (Fontana & Frey, 1994) with key people at the companies, i.e. those responsible for risk management processes on different organizational levels, such as enterprise risk management (ERM) and product development.

The results of these interviews, i.e. an overview of the organization and existing risk management processes, were used to refine the questions. In addition, the results provided the necessary information for purposive and strategic sampling, identifying both persons with deep knowledge about risk management, but also persons with less but still some connection to the topic. Thereby, variation in the data gathering activity, as well as including multiple perspectives, were ensured (Karlsson et al., 2009). Additional 17 semi-structured interviews were conducted. In line with the research questions, the aim was to include roles from both the strategic, tactical, and operational company levels. The interviewees were selected and contacted with the help of a principal informant at the companies. Mostly experienced employees with more than 10 years of experience were selected. Table 1 provides an overview of all roles that were included in the study.

The interview questions addressed the following areas: (i) theoretical background, including the meaning of risk and how to relates to the interviewee's work, the purpose of risk management, and connections between risk management on different organizational levels; (ii) pure inquiry, focusing on how risk management processes look like and what support tools that are used; (iii) exploratory diagnostic inquiry, mainly asking about areas of strength and improvement possibilities. Prior to the descriptive interview phase, pilot testing was done,

which led to the improvement of the interview protocol. All interviews were recorded and transcribed and the transcriptions were sent back to the respondents for validation. This step was followed by the coding process, which was guided by the three-step scheme presented by Strauss and Corbin (1990): open coding, axial coding, and selective coding. Some of the codes were pre-defined, based on e.g. the risk management steps as described in ISO 31000 and the division into strategic, tactical, and operational levels. This approach was combined with post-defined codes to be able to derive codes directly from the data (Miles, Huberman, & Saldana, 2014). Dual coding was applied to be able to structure the data in multiple ways (Blessing & Chakrabarti, 2009). Both within-case and cross-case analysis were performed (Eisenhardt, 1989). Clustering, comparisons, noting patterns and relations, were some of the tactics for the data analysis as suggested by Miles et al. (2014).

Table 1. Overview of the roles that were included in the interview study at the case companies.

Company A	Number	Company B	Number
Commercial director	1	Senior manager	2
ERM process expert	1	ERM process expert	1
Product or technology planner	1	Product or technology planner	3
Product risk manager	2	Product risk manager	2
Procurer	2	Procurer	1
After market manager	1	After market manager	1
Environmental manager	1	Environmental manager	1
Process risk manager	1	Project manager	2
Product cost engineer	1		

2.2 Development and testing of a self-assessment tool

Generally, one of the main challenges with risk management is the difficulty of assessing the effectiveness of current risk management practices. This is due to the fact that the true existence, as well as probabilities and consequences of risks usually remain unknown. For example, a product development team might completely miss to identify a critical threat with a high likelihood and severe consequences. However, the event does not occur. As a result, the team remains unaware that their risk management activities have missed an important threat and that their work might be ineffective. This is true not only for the identification of risks, but also for their assessment and mitigation: if the team had identified this critical threat, they might have spent resources on mitigation actions. The event does not occur. Still, in this case, the team does not know whether the risk really existed, whether they assessed likelihood and consequences correctly, and whether mitigation actions were effective. Companies however, strive for continuous improvement of their risk management practices, which requires clear objectives and success criteria. These needs represent the motivation for identifying characteristics of successful risk management that companies can use as guidance and as a destination to work towards. One way of addressing this challenge is through risk maturity models (RMM). In general, RMM are designed as matrixes in which levels of maturity are cross-referenced with a number of attributes. Multiple such models exist, some are addressing risk management in general (e.g. Hillson, 1997), while others target specific sub-disciplines like ERM (e.g. Aon, 2010; Minsky & Fox, 2015; Oliva, 2016), or specific types of companies (e.g. Shah, Siadat, & Vernadat, 2009). Most of these models are however not applicable to assess the current state at both the strategic, tactical, and operational levels of product development and manufacturing companies with a high level of detail.

Oehmen et al. (2014) empirically studied the statistical relationship between risk management practices and overall product development program performance. They also investigated how risk management performance can be characterized other than by overall program performance, presenting three top-level risk management performance metrics: (i) improvement of decision making in the project; (ii) stability with which the project is being executed; and (iii) problem-solving capabilities of the project and organization. Certain risk management practices were identified as being positively associated with these metrics, as well as overall customer satisfaction and schedule adherence. In other words, practices that managers should particularly put effort on in implementing. Based on the characteristics for successful risk management identified by Oehmen et al. (2014) and Olechowski et al. (2012), a self-assessment tool was developed that asks the respondent to assess the current capabilities in relation to each aspect on a 1-10 scale. In total, 46 aspects are included in the assessment, grouped into the following categories: organizational design experience; risk management personnel and resources; tailoring and integration of the risk management process; risk-based decision making; specific mitigation actions; monitoring and review; and remaining ISO risk management principles. In addition, as this results in subjective assessments, the respondent is also asked to state the degree of certainty of the assessment on a 1-10 scale, indicating the level of knowledge for the specific aspect (Aven, 2016). Three versions of this tool were developed, one for ERM, one for product RM, and one for process RM, all including the same aspects, but slightly adjusted to fit the specific risk management discipline. In total, 14 people at the two companies filled in the self-assessment, representing the same roles as for the interviews.

3 Results and discussion

3.1 Thinking risk and risk thinking

All interviewees considered risk management to be an important, integrated, and natural part of their work. Even some respondents who have no formal risk management role stated that *"Risk management is all that I'm doing"* (Senior manager at Company B). The interviewees were however selected because they should have at least some connection and knowledge about risk management and the answers are therefore not representative for all company employees. While several interviewees think that the companies' capabilities for risk management in general have improved over time, they still point out that *"Risk management needs to be de-dramatized and made tangible"* (After market manager at Company B). Based on their experience, risk management is often perceived to be difficult and while people know very well what risks are in their daily lives, they have difficulties to think about risks in their work. Education and training are considered to play a key role to familiarize people with risk thinking in their work.

3.2 Threats and opportunities

Both potential negative events, i.e. threats, and positive events, i.e. opportunities, were considered to be part of risk and described as two inseparable sides of the same coin. This is also due to the fact that mitigating a threat can be an opportunity. Multiple respondents highlight that more actively introducing the opportunity dimension in risk management has been appreciated among the employees as it can open up new perspectives and creativity. In practice however, risk management is mostly focusing on what could go wrong, that is threats. There are exceptions and according to the interviewees it depends a lot on the project leader and his or her knowledge and attitude towards risk management. The experiences from those projects in which opportunities were actively managed, were positive, as expressed by a risk manager: *"It (considering opportunities) went well and we actually made certain decisions to exploit*

some of the opportunities." There is, however, no consistent use of terminology to refer to the two sides of risk: some respondents talk about risks and opportunities, others about positive and negative risks, or about threats and chances.

3.3 Purpose of risk management

In general, risk is considered a natural and necessary ingredient for creativity and innovation. The purpose of risk management is therefore not to create a risk-free company, but *"It's about making the right decisions. We need risk management so we get the information our decision-makers need to make the right decisions"* (Senior manager at Company B).

According to the interviewees, ERM was initially regarded as a compliance issue, but has over time evolved into a process with two main purposes. First, *"There is a current state and a future state. There is a gap between them and the question is how to move from the current state to the future state. [...] ERM is about ensuring that the long-term strategy can be realized"* (ERM expert at Company A). At the same time, each move to fill the gap involves risks, which need to be managed in ERM. This also means that ERM includes a backcasting perspective (Dreborg, 1996), i.e. based on a future vision of success planning is focusing on how to move towards that target. Second, ERM shall *"[...] ensure the current operational capabilities that we have today"* (ERM expert at Company A). That implies that *"At the end of the day, all risks are in some way measured in terms of a) profitability or b) sustainability. And when I say sustainability, I'm not talking about the world, but about the company."* (Manager at Company B). The interviewees' description of the purpose of ERM is well in line with the COSO (2004) definition of ERM. On the tactical level, *"Product planning is about balancing the portfolio regarding risk"* (Product planner at Company B). This includes both considering financial aspects, but also the strategic fit of products and technologies. On the operational level, the purpose of project risk management in described as *"[...] making sure that project goals, mainly in terms of time, cost, and quality, are met"* (Project Manager at Company B). From product developers' point of view, risk management checks that *"[...] requirements, e.g. in terms of compliance with regulation and standards, or customer needs, are met and that remaining risks are manageable or acceptable"* (Product developer at Company B). Finally, process risk management focuses on whether the company can *"[...] manufacture products in line with the requirements of the technical drawing"* (Process risk manager at Company A).

In summary, the purpose is considered to be managing the effects of uncertainty on objectives, or as one project manager put it: *"That's what risk actually is – something that could affect my plan."* The objectives look differently depending on the organizational level, e.g. strategic company objectives, project goals, or product requirements. These findings show that the perceived purpose of risk management at the companies is perfectly in line with the ISO 31000 definition of risk.

3.4 Connections between organizational levels across the hierarchy

The respondents had a vague understanding of how risk management sub-disciplines are connected and interact across the different organizational levels of the hierarchy. Some connections were however mentioned, mostly regarding the areas that were close to the respondents' own role. For example, product developers clearly saw a connection between product- and project risks. Still, the full picture of how risks interact across the hierarchy was missing. The interviewees provided consistent answers, saying that risks are escalated in the organization, if they are above a critical level regarding likelihood and consequences. In this way, it is ensured that severe risks are dealt with at the right level and by the persons with the

corresponding responsibility. This bottom-up escalating of important risks is mostly formalized and included in company processes and tools, but there is no top-down flow between risk management sub-disciplines. There are no formalized ways for how e.g. portfolio risks provide input for project risk management, and the interviewees did not express a need for that either.

As risk is about the effect of uncertainty on objectives, the respondents were asked to explain where the objectives come from that are used as an anchoring point for risk management on the level they work on. A variety of answers was given, but two main pathways for how objectives are derived emerged. First, objectives are derived based on what creates value for stakeholders. The main purpose of a company is to create stakeholder value within the societal system it is operating in (Freeman, 1984). This includes external stakeholders like regulators, the local community, and customers, and internal stakeholders, such as employees and owners. All of these stakeholders have needs or requirements that can be direct, e.g. legislative compliance, or related to value drivers, such as is the case with customers. Customer value drivers can include a variety of different aspects, e.g. ease of maintenance, purchasing cost, reliability, image, environmental friendliness, etc. Examples of internal stakeholder value are employee motivation, production cost, or ease of assembly. Companies strive towards creating stakeholder value as long as it contributes to short-term profitability or long-term competitiveness. The second pathway has its source in the company vision or purpose. Based on that, internal objectives are defined, which are rooted in e.g. company heritage, founder or CEO belief, core values, etc. It is clear from the interviewee answers that they are part of the company identity and do not necessarily need to contribute to a business case.

Figure 2. Interaction between risks and objectives on different organizational levels across the hierarchy.

"Good risk management starts with targets" (Risk manager at Company A). The ability to translate stakeholder value creation and company vision into tangible objectives is therefore a decisive prerequisite for effective risk management. The interesting thing, as pointed out by the respondents, is that objectives in most cases come from the top, i.e. vision and strategy, and an interpretation of stakeholder needs. They are then broken down and cascaded throughout the organization, resulting in objectives for portfolios, projects, and detailed product requirements. Objectives and risks can be considered as two supplementary flows, Figure 2: objectives are cascaded top-down to guide company activities in line with the strategy towards the vision, while risks are escalated bottom-up to make sure that the objectives are achieved. It should be noted that this does not mean that all risks have their origins on the operational level. Instead,

what it indicates is the direction in which risks and objectives are connected and flow across the different levels of the organizational hierarchy.

3.5 Processes and the use of support tools

At the strategic level at both companies, ERM is further divided into hierarchical levels. For example, there is ERM on business unit level, site level, company level, or company group level. Again, risks are escalated upwards between these levels. Company A has a formalized and well-developed ERM process. It is based on backcasting from a desired future state, which is based on the long-term (10 year) strategy. ERM is used to assess the risks in relation to both actions that are planned to fill the gap between current and future state, and the current operational capability. Company B has a documented process but according to the ERM expert, the company is struggling with giving ERM the right place and effectively integrating it with other exiting processes. For example, it is unclear which time perspective that ERM should focus on. Ongoing work is taking place to move towards a more systematic and formalized process on the ERM level. At both companies, it is a quarterly process, which starts with the head of functions or groups at the functions creating a risk matrix for their specific area, e.g. through a brainstorming exercise. These results are then further discussed at a meeting with representatives from each function. At that occasion, everyone shall look at the complete picture, not only the risks for the specific function. The risks are then consolidated, assessed, and grouped into predefined categories, such as financial, compliance, etc. At Company A, the biggest risks are integrated into policy deployment matrixes to work and follow up on them on different levels. On the tactical level, including e.g. product and technology planning, it seems that there are no distinct risk management processes. Instead, a risk perspective is integrated into some other processes and tools, for example competitive intelligence, business cases, and customer buying criteria. On the operational level, especially at Company B, processes were perceived as very systematic and well-developed. Product risk management is described in detail in operational management systems and coupled to the stage-gate product development process. FMEA is the dominating tool at both companies, but also some other traditional risk management tools are used in some cases, e.g. 5 Why, fault tree analysis and Ishikawa diagrams. Within procurement, risk management is primarily done as part of supplier assessment and selection, using questionnaires, site visits, etc.

In general, the interviewees perceive processes and tools to be mostly functional and followed in practice. They rather see the challenge in making people use the tools in meaningful ways, which they say is largely dependent on top-down demand from managers. It is also noticeable that almost entirely qualitative tools are used on all levels, even though some respondents state that they consider introducing more quantitative and probabilistic tools in the future. Several interviewees point out that there is a value in having systematic and formalized processes for risk management to ensure that the right activities are done in the right time and in the right way. However, at the same time the importance of experience and gut feeling is emphasized, especially on the strategic and tactical levels. Processes therefore need to strike a balance between the degree of formalization and leaving room for personal experience.

3.6 Challenges and improvement areas

According to the interviewees, building a risk-aware culture is at the root of effective risk management. To accomplish this, two key factors are emphasized: *"[...] 1. Awareness and 2. Competence. If you can fix or protect those two, the rest becomes really easy"* (Senior manager at Company B). Setting targets is important for creating awareness and training is needed to build competence. Many of the other existing challenges are rooted in a lack of either awareness

or competence. This is also true for the degree to which managers request risk management activities. Several respondents have described how the seriousness and quality of risk management has changed drastically, when there was a change of the manager. For the better or for the worse. Also, the interviewees state that some employees at least occasionally perceive risk management activities to be more of a ticking-a-box activity, rather than value-adding. This is also related to the challenge that the companies are perceived to be better at risk identification and assessment, than at actually mitigating risks. A more clearly defined risk appetite with sharp instructions on the threshold beyond which risks must be mitigated is one proposed solution to this problem.

Specifically for ERM, the companies are struggling with the complexity and volatility of today's business environment. For many important and emerging risks, such as reputational risks, sustainability risks, etc., likelihood and consequences are very difficult to assess as they are characterized by deep uncertainty (Aven, 2016). But also the identification of risks is considered to be challenging, especially when it comes to black swan risks, which are unfamiliar but can have far-reaching effects (Taleb, 2007). Within procurement, the companies are struggling with how to incorporate new kinds of risks, such as CSR and sustainability. Their importance is increasingly acknowledged, but the companies need to find ways for how to work with it, even with small suppliers. In product development, starting early and keeping up the work continuously are considered to be of main importance. While experience was pointed out as central for good risk management, there are currently no formalized ways for knowledge sharing and lessons learned. An interviewee suggested to use FMEA as a vessel to gather experience at the company over time. Regarding FMEA, it is also noted that too much time is spent on obvious and known risks and a leaner way is asked for, e.g. by re-using FMEAs in a smart way.

3.7 Areas of strengths and weaknesses

With the help of the self-assessment, areas of strengths and weaknesses in relation to characteristics of successful risk management were identified. The results are generally well in line with the results of the interviews. Unsurprisingly, the aspect "Identified risks are quantified on scales for probability and impact, e.g. 1-5" received high scores on all levels. The same is true for the aspect on risk management contributing to continuous improvement in the organization. Teams are also mostly rated as being cross-functional. Aspects that have received low scores include that the upside of risk, i.e. opportunities, is not systematically and effectively included. Also, risk management does not currently seem to contribute to setting better goals and more realistic objectives. The most relevant findings of the self-assessment, i.e. aspects that have either received exceptionally low or high rankings, are presented in Table 2.

Interestingly, the persons who filled in the assessment for ERM rated the aspect high: "We coordinate and integrate RM activities of different functions and across the hierarchy". In contrast, people who filled in the assessment for product development rated this aspect very low. These results are in line with Figure 2: ERM actively takes risks from other functions and levels of the hierarchy into account, if they are important and escalated to the ERM level. Hence, the aspect is rated highly by the respondents. On the other hand, there is very little information flow from ERM to e.g. project- or product risk management, as risks are rarely cascaded top-down. As a result, this aspect is rated low by the people working with project- and product risk management. This contrast in the rating of this aspect is, therefore, not necessarily a negative sign.

Table 2. Excerpt of the results of the self-assessment of current risk management practices. For each aspect, the respondents rated both the current level and the degree of certainty regarding their assessment on a 1-10 scale.

Aspect	ERM averages				Product RM averages				Process RM averages	
	Company A n=2		Company B n=2		Company A n=4		Company B n=4		Company A n=2	
	Level	Certainty	Level	Certainty	Level	Certainty	Level	Certainty	Level	Certainty
The group of people carrying out RM activities is familiar with key technologies	8	8	7	7	8,3	7,5	7,3	6,3	8	8,5
RM is tailored/adjusted to the specific needs and preconditions of the company and its parts (ISO)	5,5	3	6,5	6	8,0	7,3	7,3	5,8	7,5	7
We coordinate and integrate RM activities of different functions and across the hierarchy	6,5	10	8	7,5	5,3	5,0	5,5	6,8	8,5	8,5
RM is integrated with risk management processes on other levels	7	10	5	7,5	5,0	6,7	5,3	6,0	6,5	7,5
RM teams are cross-functional and cross organizational	8,5	7	7,5	8,5	6,3	8,7	7,3	7,3	7,5	8
Risks and RM activities are communicated to stakeholders	9	10	6,5	7	7,3	8,3	7,8	7,0	7	8
The upside of risk (opportunities) is systematically and effectively included in risk management	3,5	8	4,5	7,5	4,7	6,0	5,8	6,8	8	8
Risk-benefit trade-offs are used systematically	3	3	6,5	7,5	5,0	6,0	5,8	5,8	6	6,5
Identified risks are quantified on scales for probability and impact, e.g. 1-5	9	10	9	8	9,0	9,3	7,3	6,8	10	10
The impacts of risks are quantified using technical performance or quality as a dimension	5	6,5	4,5	5	8,8	8,3	7,3	7,5	6,5	7
Risk assessments are used to set more realistic or achievable objectives	3,5	5	4,5	7,5	6,0	6,7	6,3	6,8	6	6
RM is a formal part of goal/requirement setting	6	6	4	4,5	-	-	-	-	-	-
Standard work/processes are defined to increase process reliability	9	10	8	8	7,0	5,8	7,5	7,5	8,5	8,5
RM creates and protects value (ISO)	8	9	8	6,5	5,0	4,8	8,3	8,3	9	9,5
RM facilitates continuous improvement in the organization (ISO)	8,5	10	7,5	6,5	3,7	4,7	7,0	6,8	10	9

4 Conclusions

Based on interviews and the development and testing of a new self-assessment tool, this study has investigated current risk management practices at two product development and manufacturing companies in Sweden. The results were analyzed to get an insight into practitioners understanding of the concept of risk, how existing processes look like, which support tools that are used, and how risk management is connected between different levels of the organizational hierarchy.

4.1 Learnings regarding current risk management practices at product development and manufacturing companies?

The study found that all interviewees were well familiar with the concept of risk and considered risk management to be an important part of their daily work. It is, however, pointed out that this is not the case for all employees. Instead, risk management is said to be perceived as difficult and sometimes bureaucratic by some employees, while the interviewees think that the basics of risk thinking and management are rather easy and a lot about common sense. On all levels, the perceived purpose of risk management is very well in line with existing definitions, mainly

being about identifying and assessing the effects of uncertainty on long-term and short-term objectives to improve decision-making. The opportunity side of risk is recognized as inseparable from the threat side of risk. While specifically including opportunities in risk management activities does happen in some cases and is appreciated by employees, most of the work and tools have a strong focus on threats. For ERM, documented processes exist, but Company B is struggling with giving ERM the right place and integrating it with other high-level processes. On the operational level, systematic and formalized processes for risk management are in place at both companies. They are well integrated with other processes, such as the stage-gate product development process. Tools are mostly qualitative, but the introduction of quantitative, probabilistic methods is considered at both companies. While tools and processes are perceived to be functional and mostly followed in practice, there is a challenge in making people use the processes and tools in meaningful and value-adding ways. Competence and awareness are pointed out as key success factors in this regard. A lack of those two is also at the root of many other challenges, such as insufficient request from managers. Other challenges include too little attention to risk mitigation and too much focus on obvious risks. Also, the importance of experience for high-quality risk management is stressed. At the same time, effective ways for knowledge sharing and lessons learned are largely lacking for risk management. These findings can be used by practitioners and researchers that aim to improve risk management practices. They also provide an in-depth inside into companies' current state and preconditions, which is a valuable starting point when striving to integrate new tools or aspects into risk management.

4.2 How are risk management sub-disciplines on different levels across the organizational hierarchy connected?

The interviews revealed that risks almost entirely are escalated bottom-up in the organizational hierarchy. If a risk exceeds a certain threshold, e.g. a specific risk priority number, there are formal ways for how such a risk is brought up to the next level in the organization. In that way, it is ensured that important risks are dealt with at the right level. At the same time, little top-down cascading of risks was observed. Instead, the complementing top-down flow consists of the objectives, which are the foundation for risk management. Two main sources for how objectives are derived were identified: first, objectives can be based on the vision and purpose of the company. Second, objectives can be derived from internal and external stakeholder value creation. Thereby, these findings clarify the interaction between risk management processes along the different organizational levels of decision-making in the hierarchy. The implications of these insights are that it is not only of key importance to integrate risk management processes to ensure an escalation of important risks, but it is just as important to integrate risk management processes with the corresponding processes that define the objectives, e.g. strategy, technology plans, project goals, and product requirements. Together, the flow of objectives and risks ensure that the company stays competitive and moves in the right direction. Researchers and practitioners that aim to include new types of risks into processes and support tools, therefore need to start by looking at whether precise objectives and requirements are defined in relation to these risks, or how these new types of risks could affect existing objectives. This may lead all the way back to investigating how the risk and the objective that is coupled to it, are connected to internal and external stakeholder value creation. These findings also have implications for the integration of risk management on different levels, e.g. portfolio- and project risk management (Weng, Oehmen, Ben-Daya, & Finke, 2013). Such integration can only be fully accomplished by studying and linking not only the risks but also the objectives and how they are derived on the specific level of the organization. In essence, the results of this study provide insights for a holistic understanding of risk management in product development

companies, which is necessary for effectively supporting the achievement of goals and objectives across the organizational hierarchy.

4.3 Limitations and future research

The exploratory and descriptive studies were conducted at two product development companies in Sweden. Hence, the generalizability of the findings is limited. The purpose of this study was, however, not to acquire a broad overview, but rather in-depth insights. Future research should connect the findings with existing theory and tools in the areas of strategy, value, and requirement management.

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