Integrating Risk Management with Software Development: State of Practice

Jaana Nyfjord and Mira Kajko-Mattsson

***Abstract*—In this paper, we investigate the state of practice of integrating risk management with software development in 37 software organizations. We do this by using a set of evaluation criteria covering various process integration aspects. Our results recognize that process integration in this domain is still in its infancy. There is a great need for process integration and process integration models within the industry studied.**

***Index Terms*—Process model, process integration, agile**

I. Introduction

The spiral model, based on a risk-driven and cyclic approach, is one of many suggestions for making software development more effective. Despite the fact that it was already pioneered in 1988 [3], it has been only partially realized. Its cyclic character has been adapted by many current development approaches, such as iterative and agile development. Its risk-driven approach, on the other hand, has not been as influential. Still, development and risk management processes live somewhat isolated lives. Recently however, their integration has become recognized as an important business and development driver [5].

In this paper, we investigate the state of practice of integrating risk management with software development in 37 software organizations. Our goal is threefold: (1) to find out how the industry has integrated risk management with their development processes (2) to identify issues that might aid in improving the integrated process, and (3) to find out the differences between agile and other development approaches.

The remainder of this paper is structured as follows. Section 2 describes the research method taken during our study. Section 3 describes our evaluation model. Section 4 presents the status within the organizations studied. Finally, Sections 5 and 6 make concluding remarks and suggestions for future research.

II. Research Method

This section describes the research method taken during our study. Section II.A lists and describes the research steps. Section II.B discusses the sampling and validity.

Section A – Introduction

1. What is you name?
2. What is your email?
3. What is your telephone number?
4. What is the name of your company?
5. What is the number of employees?
6. What is your role in the company?
7. What type of products/services does your company develop/provide?
8. What is generally the size of your projects?
9. What software development process model(s) do you use?
10. Does your organization identify risks?
11. Could you please briefly describe your risk management process?

Section B – Software and Risk Management Process Integration

12. Concerning the organizational levels (business and engineering), does your organization have the same levels?
13. Do you conduct risk management on the business planning level?
    a. Who conducts product vision planning?
    b. Does this/these role/roles manage risks?
    c. How does this role manage risks?
    d. What is the outcome of this phase?
    e. What are the main risk management activities in this phase?
14. Do you conduct risk management on the engineering planning level?
15. For each of the phases (*product roadmap, release and iteration planning*):
    a. Do you conduct the planning in this phase?
    b. Who conducts the planning in this phase?
    c. Does this/these role/roles manage risks?
    d. How does this role manage risks?
    e. What is the outcome of this phase?
    f. What are the main risk management activities in this phase?
16. Do you conduct risk management in the implementation/development phase? Please, describe briefly.
17. Do you consider risks within testing? If yes, what types of risks do you encounter?
18. Is your risk management process integrated with the software development process model or is risk management a separate process?
19. What criteria do you use for integrating the risk management process with the software process?
20. When integrating the risk management with the development process model, what criteria should one use to achieve maximal result?
21. Are there any problems or shortcomings with how risk management is integrated in your software projects currently?
22. Could you please provide an example of a software project where risk management was a failure and a success, respectively? Please motivate briefly.
23. Do you think that integrating risk management with the software process is important?

Section C – Agile vs Traditional Software Risk Management

24. Can the risk management standards/templates presented in this interview be useful in agile environments?
25. Could we please quickly browse through the figures of the process and the risk information template and identify the parts that are pivotal in agile environment?
26. Is there any difference in how risk management is conducted in agile and traditional projects? Please, motivate briefly.

Figure 1. Our questionnaire

A. Research Steps

As a first step, we determined the evaluation criteria covering various integration aspects. These aspects are described in Section 3. We then created a questionnaire whose questions were based on (1) these criteria, (2) a synthesized risk management process model [10] and (3) a template of risk management information [8]. The questionnaire is described below and presented in Figure 1.

In the second step, we interviewed the companies. For this purpose, we used students attending an advanced software engineering course, being part of an international master program. In total, 37 organizations were interviewed. The profiles of the organizations and the roles of the interviewees are presented in Table 1.

As can be seen in Figure 1, our questionnaire was open-ended and semi-structured. The purpose was to give

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Table 1. Organizations studied

Org	No of employees	Products/services	Country	Software process model(s)	Roles interviewed
Org 1	480 000	Automation & control, communication, medical, power services, transportation	Germany	Iterative and waterfall (V-model/internal)	R&D department head
Org 2	273 027	Telecommunication networks	China	-	Project manager
Org 3	75 000	OS, database, games, business and development applications	Sweden	MSF and iterative/agile (internal)	Department manager
Org 4	60 000	Retail, online grocery shopping and delivery service	Sweden	Plan-driven (Integrated Product Development Model)	Vice president
Org 5	> 20 000	Mobile phones	Finland	Plan-driven (internal)	R&D engineer
Org 6	> 17 000	IT consulting	Sweden	Plan-driven and agile (internal)	Senior programmer
Org 7	> 16 000	IT consulting	Sweden	Spiral (internal)	Software engineer
Org 8	5700	Insurance and banking systems	Germany	Plan-driven and iterative/agile (internal)	Executive IT manager
Org 9	> 5000	IT consulting	Mexico	-	Project coordinator
Org 10	5000	Online media, telecommunication services, entertainment services, e-commerce	China	Agile (internal)	Project manager
Org 11	> 4000	Software and IT service provider	China	Plan-driven and prototype, MSF (internal)	Team leader
Org 12	2300	Develops software for embedded systems	Germany	Waterfall (internal)	IT consultant
Org 13	1200	Provides in-house service with "on demand" software (AutoCAD plug-ins)	Morocco	Iterative and agile (OpenUP)	Project manager
Org 14	1100	Business intelligence, data warehouse technology, mobile solutions, business app.	Finland	Agile (Scrum)	Software engineer
Org 15	> 800	Software outsourcing services, application development and maintenance	China	Iterative (RUP)	Software engineer
Org 16	> 800	Telecommunication services	Iran	Component-based model (internal)	Project coordinator
Org 17	> 600	Support systems for textile industry	Pakistan	Waterfall, incremental/evolution (internal)	Senior software engineer
Org 18	> 500	E-business and system integration solutions provider	Pakistan	Waterfall and evolutionary (internal)	Technical project manager
Org 19	> 500	IT solution provider	USA	Iterative (RUP)	President
Org 20	> 500	Technology and business consultancy, ERP, CRM, outsourcing, e-business	Pakistan	Iterative (CMMI)	Technical/project lead
Org 21	500	Business technology solutions provider	Thailand	Waterfall, increment/evolution (CMMI)	Project manager
Org 22	> 400	Evolution and maintenance of in-house MIS	China	RAD	IT department manager
Org 23	> 350	Consulting services, specialized products for the aerospace and defense sectors	Spain	CMMI, ISO, UNE-EN, AQAP/PECAL	Project manager
Org 24	> 350	IT consulting, outsourcing, support and custom development	Colombia	Iterative (UP)	Director strategic solutions
Org 25	350	Evolution and maintenance of in-house business applications	Sweden	Iterative (RUP)	Software engineer
Org 26	> 300	Data warehouse technology development	Pakistan	Incremental (internal)	Line manager
Org 27	300	Business technology solutions provider	Pakistan	Waterfall and iterative (internal)	Senior process engineer
Org 28	300	Internal software development of tools for testing team	China	Agile (TDD)	Project manager
Org 29	150	Business applications provider	China	Agile (XP)	IT department manager
Org 30	> 100	3G mobile applications	Sweden	Agile (Lean)	System engineer
Org 31	> 100	eTravel Management, eProcurement, eLogistics and eService applications	Sweden	Plan-driven and agile (internal)	System architect
Org 32	> 100	Develops software systems for the health care sector	Pakistan	RAD	Senior software engineer
Org 33	100	Spatial information processing software	China	Prototype/iterative (internal)	Department manager
Org 34	> 50	VoIP and video telephony systems	Finland	Plan-driven (internal)	Senior software engineer
Org 35	50	Oracle application solution provider	Thailand	Waterfall (internal)	Project manager
Org 36	40	IT consulting	Sweden	Iterative (RUP) and agile (Scrum)	Agile mentor
Org 37	30	Mobile content distribution	Pakistan	Plan-driven and prototype (internal)	QA engineer

freedom to respondents to answer in their own terms. Such type of interviewing has a positive effect in a sense that while interviewing, one may elicit more knowledge about the studied domain [13]. Its drawback however is the fact that the interviewer must possess a good understanding of the domain studied, in order to adequately react to irrelevant answers.

To optimize the interviews, we assured that each question transitioned smoothly from previous questions [1]. We ordered questions with respect to their ease of understanding the industrial practice. We first asked questions regarding the background of the company and its processes. Then we asked concrete questions regarding risk management in different development process phases. We then continued with questions regarding the process integration practice. This order allowed the interviewers to first understand the industrial practice before going over to the integration aspects.

Because we used students in our investigation, we run the risk that some answers might be misunderstood. To avoid misunderstanding, three preventive actions were taken. First, we presented our risk management model in detail to the students[10]. Second, we described the goal of the interview, the questions and the questionnaire design for the students. Detailed directives regarding the expected answers, and possible follow-up questions were also inserted into the questionnaire. Third, each interviewee was asked to provide their name and contact details to allow follow-up questions.

Finally, in the third step, we analyzed the results. The data collected by the students was gathered to enable the collective analysis of the status of all the organizations studied.

A final list containing the combined status results was then created. The results were discussed and reviewed in order to verify the quality and the findings of this work.

B. Sampling and Validity

The data sampling method was convenience sampling [12]. This means that we did not control the choice of the organizations involved in our study. It was students who did it. Due to the fact that it is difficult to make organizations show willing for an interview, the students were allowed to choose just any organization (large/medium/small and/or private/ government) in any country. The only requirement was that the organizations studied should have a risk management process in place.

Many of our students, coming from an international master program in Sweden, chose organizations in their own countries. Table 1 presents the details of the organizations studied.

Due to the sensitivity of the material presented herein, we do not name these organizations. Some of them however are major multinational organizations.

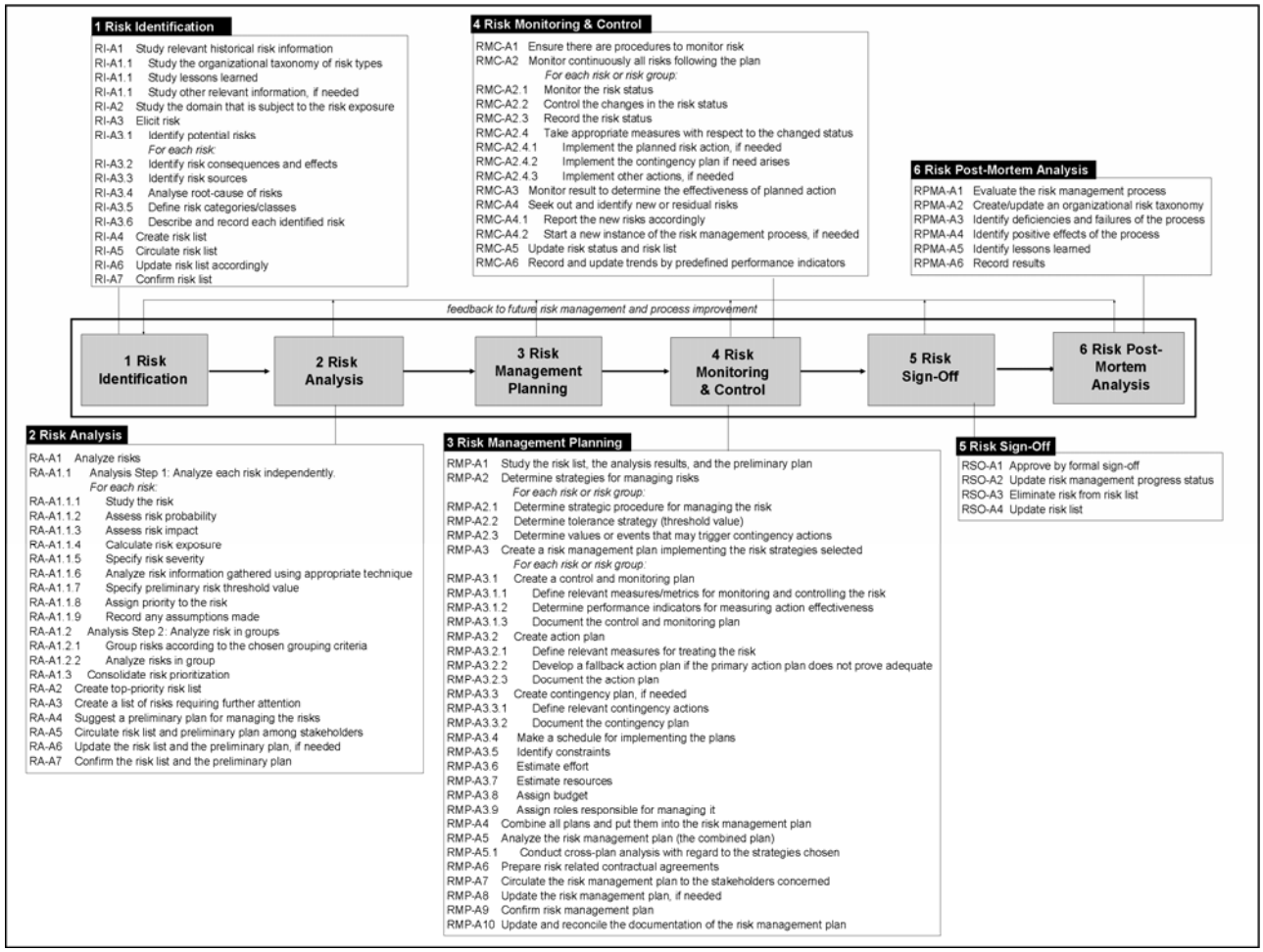

Figure 2. Synthesized risk management process model [10]

III. Model For Evaluating State of Process Integration Practice

To structure our investigation, we created an evaluation model. This model consists of the following five criteria covering various process aspects:

- *Organizational levels*: Most software organizations conduct their business on various organizational levels [14]. As illustrated in Figure 3, they usually distinguish between *Business* and *Engineering* levels [9]. The *Business* level involves planning of more strategic nature to establish the product vision, while the *Engineering* level involves realizing that vision by planning and developing the product [9]. Risk management is relevant for both *Business* and *Engineering* levels. For this reason, using *Questions 12-17*, we inquired about the state of conducting risk management for each of these levels and their inherent process phases.
- *Integration aspects*: When integrating processes, one needs to identify appropriate criteria for doing it. Due to the fact that there are very few process integration models regarding this domain, we inquired about the criteria to be used when integrating risk management with software development. So, using *Questions 18-20*, we wished to find out (a) whether the organizations studied integrated their risk management processes with their development processes, and (b) the criteria they used in this integration.
- *Integration problems*: Problems, successes and failures provide a good platform for evaluating the integration attempts by indicating their deficiencies and strong sides. For this reason, in *Questions 21* and *22*, we elicited problems, successes and failures of process integration as experienced by the organizations studied.
- *Importance of process integration*: The software industry has an opinion about the importance of integrating risk management with development processes. This opinion should be listened and paid heed to. It may provide indications of the procedures to be enforced or avoided during integration. To find them out, we asked *Question 23*.
- *Applicability of risk management in agile context*: Due to the fact that agile methods claim to be risk driven [1][4], we wished to hear the industrial point of view about this issue. For this reason, we first presented the synthesized process model (see Figure 2) and a template for managing risk information (see Figure 4) in order to find out about their applicability in an agile context. We did it using *Questions 24-26*. We then inquired about the differences between the agile and other development approaches with respect to the risk management practice.

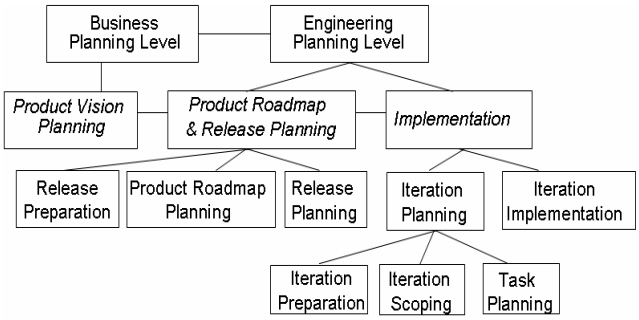

Figure 3. Organizational levels and agile process phases [9]

IV. Interview Results

This section presents the interview results following the order of the criteria as listed in our evaluation model.

A. Organizational Levels

Thirty-two out of the 37 studied companies have the *Business* and *Engineering* levels. In the remaining five companies, the interviewees were not familiar with the work conducted on the *Business* level.

Twenty-eight out of the 32 companies have a phase corresponding to the *Product Vision Planning* phase during which they manage risks (see Figure 3). The risks managed at this stage are primarily business and market risks.

When managing risks in the *Product Vision Planning* phase (see *Question 13* in Figure 1), the organizations conduct their own risk management processes, mainly by having face-to-face meetings. The stakeholders involved in them are primarily represented by various senior management roles (e.g. *CEO, CIO,* and *CTO)* and the roles coming from the business department, such as sales and product managers.

Concerning risk management on the *Engineering level*, thirty-two companies claim that they conduct risk management using their own organizational risk management process models. They claim that the choice of activities, the types of outcomes and the roles involved vary depending on the engineering phase.

In the *Product Roadmap Planning* phase (see *Question 15* in Figure 1), the roles involved are mainly represented by various managers (business, product, project), customer, business analysts and requirement engineers. Since it is still a planning activity, the risk management activities conducted herein are *Risk Identification* and *Risk Analysis*. They are mainly conducted via meetings or brainstorming sessions.

Regarding risk management in the *Release Planning* phase (see *Question 15*), it follows the same organizational risk management process as in previous phases. However, some differences were identified with respect to the roles and the risk management process phases. The roles identified in this phase include release managers, technical leaders, team leaders, senior software engineers and QA. The phases identified are *Risk Identification*, *Risk Analysis* and *Risk Management Planning*. There is also a shift of the focus on the types of risks managed in this phase. For instance, as stated by the interviewee of Org 21: *"Risks in this phase concern issues such as the stakeholders' satisfaction with the release plan, and not only the business risks"*.

Regarding risk management in the *Iteration Planning* phase (see *Question 15*), fourteen companies state that they do not conduct *Iteration Planning* because they use non-iterative development approaches.

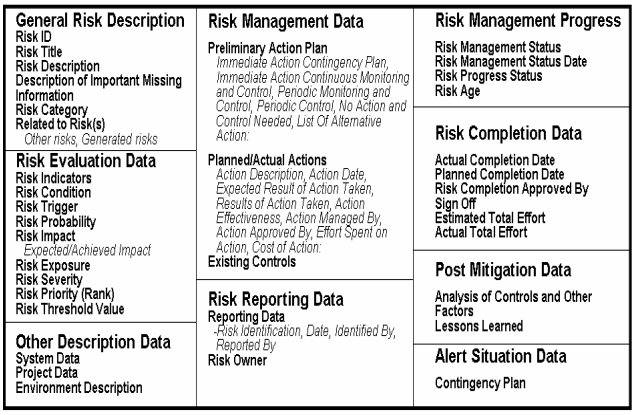

Figure 4. Template for managing risk information [8]

In the remaining organizations, risk management in the *Iteration Planning* phase is conducted according to the organizational standards. The differences identified concern the roles involved, the risk management activities, and the types of risks focused on.

The roles involved on this level are mainly engineers, represented by system architects, software engineers, testers, system integrators, and other roles. In a majority of the companies having iteration planning, risk management is led by the project manager.

Generally, the activities in the *Iteration Planning* phase cover almost all the risk management phases, including *Risk Identification, Risk Analysis, Risk Management Planning, Risk Monitoring and Control* and *Post-Mortem Analysis.*

B. Integration Aspects

The integration of the software and risk management processes varies within the organizations studied. As illustrated in Figure 5, nineteen companies have integrated their development processes with risk management, six companies have partially integrated them, and another twelve have them as separate processes.

In the first group of organizations, risk management directly or indirectly affects the development activities, work products of the planning and execution process phases, and various parameters. It is an ongoing process that is carried out by the team throughout the whole project life cycle.

In the next group of companies (six companies), the processes are claimed to be partly integrated. Reasons are varying. For instance:

- In *Org 20,* one runs two separate processes, one for development and one for risk management. These processes have separate process owners. Although, these owners share the responsibility for managing and controlling risks, they still follow different processes for carrying out their work.

In *Org 4*, the degree of process integration depends on the project characteristics. In most of the projects, risk management and development processes are integrated. In large projects having complex risk profiles, one runs a separate risk management process. The reason is the fact that the risk management process requires more resources.

When integrating the processes (see *Questions 18* and *19*

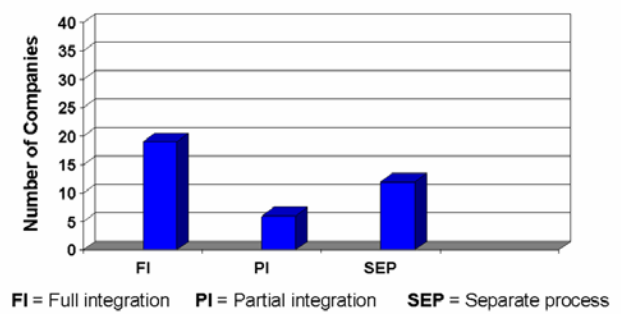

Figure 5. State of process integration in 37 software organizations.

in Figure 1), the companies (the nineteen organizations in the first group as identified in Figure 5) mainly use criteria such as activities, resources and roles. These companies suggest that one

- assigns resources to the integration effort,
- adapts the integration process to the risk type by combining appropriate risk assessment and elimination techniques,
- identifies appropriate activities and resources for each risk type,
- adapts the risk management process to the project type, and finally,
- thoroughly documents information about risks and identifies development phases that may be affected by the risk.

Several factors were pointed out to be important to achieve maximal results from process integration (see *Question 20*). These are:

- Establish good communication between the development team and the risk manager (*Org 9* and *Org 22*)
- Involve the right people (*Org 26* and *31*)
- Ensure that the people on the team have good collaboration skills (*Org 26* and *31*)
- Determine which roles should do the risk management activities, and decide how they have to cooperate with the other roles (*Org 4* and *16*).
- Assign the right risk management activities to the right development process phase (*Org 16*).
- Make the risk management process flexible to fit the development process model and the project needs (*Org 3*)
- Create risk integration architecture, i.e. a process integration model (*Org 33*)
- Continuously assess the risk management and adapt the risk management process to the status at hand (*Org 5, Org 18, 23, 27, 34* and *37*)
- Balance the processes with each other in order to avoid too much or too little focus on one or the other process *(Org 8*)
- Make the process homogenous. To achieve it, you have to make sure that the risk management and development activities belong to the same process and are treated in the same way (*Org 13*)
- Integrate risk management into the overall development plan (*Org 11* and *15*).

C. Integration Problems

Twelve out of the 37 organizations studied claim to have problems with the process integration (see *Question 21*). The problems identified are the following:

- Resource problems
  - Training cost is too high (*Org 22*)
  - Lack of resources to conduct risk management (*Org 21* and *Org 33*)
  - Lack of time to conduct risk management (*Org 11*)
- Organizational problems (*Org 16*)
  - Different roles have different attitudes towards risk and risk management (*Org 29*)
  - Lack of competence (*Org 10, Org 21* and *Org 33*)
  - Work overload for project manager (*Org 8*)
- Scope problems
  - Lack of control of external risks (*Org 35*)
- Process problems
  - Lack of process coordination (*Org 15*)
  - Lack of process integration (*Org 11, 15* and *31*)
  - Lack of plan (*Org 11*)
  - Lack of process (*Org 31*)

One organization points out that although integration is important, the success still depends on the project management (*Org 8*). If the project manager can control the integrated process, it is an advantage. However, if the project manager has not enough time to have an overview of the whole process, a separate risk management process led by some other role can be more useful.

The other twenty-five organizations claim that they have no problems at all. However, twelve out of them have not integrated their processes.

D. Importance of Process Integration

All the organizations claim that the integration of the software development and risk management processes is very important (see *Question 23*). They motivate this by stating that (a) applying a single process is easier than two different processes, (b) integration makes the risk management process much more effective, (c) risk management can help prevent problems and risks in development, and (d) the organization will produce better software products with lower cost.

E. Applicability of Risk Management in Agile Context

The answers to the question regarding the usefulness and applicability of our synthesized risk management model (depicted in Figure 2) in agile environment vary between the organizations studied (see *Question 24*). They are the following:

- Sixteen companies state that the model is useful and applicable in agile environments. They claim that risk management is needed in any development model, whether traditional, agile or other.
- Eleven companies state that the model is partly applicable in agile environments. It threatens the balance of agility. Hence, it should be adapted to the agile context. *Org 13* motivates this with the following: "*It goes into too deep details that can violate one of the basic concerns of agile environments, which is to keep software development process low-ceremony. Thus, some of the data need to be refined to fit within the "simplicity" requirement of agile models*".
- Four companies claim that the risk management is not useful in agile projects. They motivated it with the following: (1) the risk management model is too complex, (2) the agile model with its iterative approach already has risk

management by nature. Hence, the need for separate risk management is limited.

- Six companies did not respond to this question because they were not familiar with the agile process models.

When being asked to go back to our model and to point out the phases that would be considered pivotal for agile projects, (see *Question 25)*, the following phases were pointed out: *Risk Identification* (17 companies), *Risk Analysis* (16 companies), *Risk Management Planning* (15 companies), *Risk Monitoring and Control* (15 companies), *Risk Sign-Off* (15 companies), *Risk Post-Mortem Analysis* (17 companies). Twenty-one out of 37 companies responded to this question explicitly. The remaining companies did not respond to this question because they felt that they were not sufficiently familiar with the agile models.

The results of *Question 25* indicate that the organizations studied are of the opinion that all the risk management process phases are relevant in an agile context. The organizations, however, had conflicting opinions about them. For instance, whereas 15 organizations identified the *Risk Sign-Off* phase as important, some voices were raised against it. The motivation was that the *Risk Sign-Off* phase would hurt the team spirit within an agile team. Formal sign-offs would discourage the team members from collaborating with one another.

Concerning the question about the differences between projects using agile and other types of process models (see *Question 26)*, sixteen out of 37 companies claim there are differences in how risk management is carried out in agile versus other projects. Five companies claim there are no differences and sixteen companies did not respond to this question. The differences identified are:

- *Time aspects:* The risk is not exposed until late in the traditional projects. The iterative nature of agile projects allow them to identify risk areas sooner rather than later (*Org 27, 31, 36*)
- *Development approach and risk management effort:* The iterative development approach minimizes risks and the total risk management effort (*Org12* and *37*).
- *Follow-up and control mechanisms*: The risk management process activities are conducted sequentially in traditional approaches and usually managed via various documents and formal inspections, whereas risks are managed through other types of controls in agile models, e.g. via the backlog and daily meetings. The team jointly manages issues, risks, and solutions. All of them are communicated, followed-up and controlled continually at the daily and other review meetings rather than via documents as in many traditional approaches (*Org 14*).
- *Frequency of risk management*: In the agile model, risk management is conducted more frequently than in traditional software process models. The agile cycle is shorter than in other models (*Org 10*).
- *Level of process formality*: In agile environments, one usually does not have time for managing risks at the same level of detail that is described in traditional risk management models (*Org 18*).

V. Concluding Remarks

In this paper, we have studied the industrial practice of the integration of the software and risk management processes within 37 software organizations. We considered both the traditional and agile development contexts.

Our study shows that the majority of the companies conduct risk management on both the *Business* and *Engineering* levels. The risk management process however, varies with respect to these levels and their inherent phases. Essentially, different types of risks are managed in different development phases, different types of activities are conducted in these different phases, and there is a shift of roles throughout the phases. Hence, we draw the conclusion that one needs to carefully consider the organizational levels, and their inherent development phases, activities and roles when considering process integration.

The majority of the organizations studied have fully or partially integrated their risk management with the software process. They mainly use criteria such as activities, resources and roles to realize the integration. However, the process integration is conducted on an ad hoc basis. The organizations studied have not defined any process integration model. They do not have any model to follow, i.e. a model providing guidelines for how to integrate processes. Hence, we conclude that there is a need to create a process integration model.

Our study has also revealed some problems within the industrial process integration. These problems primarily concern organizational issues, people, skills, processes, tools, resources, and knowledge management. These problems constitute an important platform for analyzing and improving the current process integration practice.

All the companies studied agree that the integration of risk management with software development is important. They claim that a properly integrated process is a great aid in managing risks effectively. To achieve successful process integration is however a task that is experienced to be very difficult by the organizations studied.

We have found that risk management is needed in any development model, whether traditional, agile or other. Although, there are claims that the agile models include risk management by nature, the agile models provide very general guidance for managing risks [6]. Risk management models, on the other hand, provide detailed guidance. In accordance with the majority of the studied organizations, we believe that agile models should be more active in integrating more risk management aspects. It is only in this way, one may make sure that risk management is implemented and run in an effective way.

VI. Epilogue

In this paper we have found out how the industry has integrated risk management with the software development process. Our results show that integration of these two types of processes is still in its infancy and that a lot of work still needs to be conducted. Hence, we suggest that more similar studies be made.

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