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EXPLORING UNCERTAINTY FROM PRIORITIZATION PERSPECTIVE IN INFORMATION SYSTEMS DEVELOPMENT

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Epävarmuutta on havaittavissa kaikkialla, ja järjestelmäkehitykseen liittyvät epävarmuudet ovat jatkuvasti kasvavan kiinnostuksen kohteena. Perinteisesti negatiivisiksi koetut epävarmuudet vaikuttavat ihmisten käyttäytymiseen, projektien onnistumiseen ja organisaatioiden toimintaan. Tämä tutkimus selvittää järjestelmäkehityksessä koettuja epävarmuuksia ja vertailee näiden ilmenemistä. Tutkimus sisältää sekä laadullisen että määrällisen osuuden, joista laadullinen selvittää haastatteluihin pohjaavalla sisältöanalyysillä järjestelmäkehityksessä koetut epävarmuuskategoriat. Koetuista epävarmuuksista selvitetään kaikkia kategorioita yhdistävä ydinkategoria. Tutkimuksen määrällinen osa sisältää kyselyanalyysin, jonka pohjalta aikaisemmin havaittujen kategorioiden keskinäinen tärkeysjärjestys saadaan esille. Tutkimuksen tuloksia ovat 9 epävarmuuden aiheuttajien kategoriaa, jotka ovat Kommunikaatio, Teknologiat, Työvoima, Asiakkaan tarpeet, Hallinnointi, Asiakkaan taidot ja osaaminen, Tilannekuvan selkeys, Kehityksen sisäiset epävarmuudet ja Kehityksen ulkoiset epävarmuudet. Yli 20 havaittua alakategoriaa muodostavat kategorisoinnin rungon. Järjestelmäkehityksen ydinkategoriaksi havaittiin tieto, johon vaikuttavat myös taitoon liittyvät henkilökeskeiset ominaisuudet. Kategorioiden välinen koettu tärkeysjärjestys muodostui kyselyn pohjalta, nostaen esiin Hallinnoinnin, Asiakkaan tarpeet, Kommunikaation ja Asiakkaan taidot ja osaamisen eniten epävarmuutta aiheuttaviksi kategorioiksi. Tutkimus edistää epävarmuustutkimuksen kasvavaa tutkimusalaa järjestelmäkehityksen näkökulmasta.

Asiasanat: Epävarmuus, ISD, järjestelmäkehitys, selvittävä, kategorisointi, ydinkategoria, tärkeys

ABSTRACT

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Uncertainties are everywhere, and uncertainties in system development has been under increasing interest. Traditionally negatively perceived uncertainties affect the behaviour of people, project's success and organizational functions. This research investigates the uncertainties perceived in the system development and looks into them from prioritization perspective. Research includes qualitative and quantitative parts. Qualitative part includes content analysis for interviews, creating a categorization for uncertainties in system development. Analysis includes identification of the unifying core category in system development. Quantitative part consists of a survey, which quantifies the perceived importance of found categories. Research results include 9 uncertainty categories, consisting of Communication, Technologies, Workforce, Needs of customer, Management, Customer's skills and knowledge, Situational clarity, Development: External uncertainties and Development: Internal uncertainties. Over 20 sub-categories were identified during the categorization. Information was noted as the core category in system development, affected by the characteristics of participants. Four categories were perceived as causing most uncertainty, including Management, Needs of customer, Communication and Customer's skills and knowledge. Research contributes to the increasing body of uncertainty research, investigating it from system development perspective.

Keywords: Uncertainty, ISD, system development, explorative, categorization, core category, importance

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1 INTRODUCTION

With the continuous increase in global IT spending (Garfinkel, 2018) development activities are a focus of great interest. Traditional targets of increasing efficiency, lowering costs and facilitating work have forwarded the research of factors affecting the success and efficiency of system development. One identified factor, generally called "uncertainty", has been under investigation for some time. Initially considered through economic and managerial mediums, importance of understanding and managing uncertainty has been steadily increasing. Existing research notes the high influence of uncertainties and risks to success of final product (Islam, Msouratidis, & Weippl, 2014), prevalence of uncertainties throughout the project (Ibrahim, Far, Eberlein, & Daradkeh, 2009) and possible threat uncertainties pose to operations (Jun, Qiuzhen, & Qingguo, 2011). At the same time, positive opportunities and new perspectives towards risks have emerged as areas of interest in the uncertainty research (Dönmez & Grote, 2018; Ward & Chapman, 2003). Growing interest has not equated to clearer understanding – contradictory, large number of researches utilize their own categories, definitions, causal relations and aspects (Dönmez & Grote, 2018). From our point of view, the core aspects of uncertainty – what it is, how it is understood, what are its effects – require further inspection.

Information forms the base for competitive markets where knowledge about customers, organization's internal situation and market changes is critical. Information systems development (ISD) provides means for managing that information, and is defined as "interrelated components working together to collect, process, store, and disseminate information to support decision making, coordination, control, analysis, and visualization in an organization"(Laudon & Traver, 2011). It is an activity aimed at creating new functionality based on computational capabilities. Information systems, outcome of these activities, manage information (creating, using, storing, exchanging it) and consist of people, information and enabling technology (Luukkonen, Toivanen, Mursu, Saranto, & Korpela, 2013).

Uncertainties are prevalent in everyday life. Uncertainty has numerous definitions, most connected via the unclarity of information. Uncertainties can emerge from multiple sources, including incomplete information, inadequate understanding and undifferentiated alternatives (Lipshitz & Strauss, 1997). Nature of uncertainties as "unknowns" has historically been seen as something to negate, allowing higher control over uncertain subject. This viewpoint has been recently challenged with the introduction of opportunity and threat -approach (Dönmez & Grote, 2018; Ward & Chapman, 2003). Uncertainties can take many forms, including ambiguity and equivocality of information, unfamiliarity of situations and confusion caused by lack of information.

Our main objective is to explore the uncertainties encountered by the people working in information systems development field. This result is achieved through applying both qualitative and quantitative research methods, with the focus on inductive generation of novel results. Interview analysis creates the uncertainty categorization. Following survey results analysis is used in support of prior qualitative categorization and allows better overlook towards the prioritization of different uncertainties. Importance of identified uncertainty areas is based on the perceived importance of found categories, allowing us to assume the most critical uncertainty areas to focus on both in research and practice. Results are utilized in forwarding the growing field of uncertainty research, improving the understanding about this phenomenon from system development perspective.

Research problem and question were formed as initial steps in the start of the research, with the purpose of clarifying our intentions and focus. Research problem reads

- How is the uncertainty viewed in information systems development by the IT professionals?

Usage of this research problem allows us to frame the context of our study: uncertainty, information systems development and views of IT professionals. For our research purposes this problem contains the starting point but is still insufficient. Research question is used to further direct our intentions:

- What areas of uncertainty are viewed as most important?

This research question provides us with the target (areas of uncertainty, consisting of emerging categorization) and quantification (most important, based on the comparisons made during analysis) of the results. These remarks become important in the interview analysis and following survey analysis.

Our research includes two main parts, content analysis of the interviews and survey analysis improving the results of interview analysis. First part consists of literature review and analysis of interviews conducted to 12 IT professionals. End result of this part includes the categorization of uncertainty, establishing overview on what interviewees thought as uncertainty in system development. Following research sections utilize the categories created in interview analysis in creation of a survey, allowing us to quantify the importance of categories through questions. Second part includes survey result analysis, utilizing limited descriptive and comparative statistics.

Chapter 2 introduces us to information system development and discusses historical evolution, emergence of Agile development, project management and current state of the industry. Chapter 3 discusses uncertainty in earlier research, introduces uncertainty and risk -viewpoints, goes through uncertainty management and includes existing categorizations of uncertainty. In chapter 4, data collection and research methods used in both interview and survey analyses are outlined. Chapter 5 includes results from the interview analysis, including uncertainty categorization and identified core category, and results from survey analysis. Chapter 6 discusses results of the research further. Chapter 7 concludes the research.

Interview analysis results include 9 uncertainty categories consisting of 22 sub-categories, providing us with categorization of causes of uncertainty in system development. Categories include Communication, Technologies, Workforce, Needs of customer, Management, Customer's skills and knowledge, Situational clarity, Development: External uncertainties and Development: Internal uncertainties. Core category of information, affected by the characteristics of participants, was identified through grounded theory approach. Perceived uncertainty of created categories and sub-categories was investigated through the survey, with survey results indicating contents of Customer's skills and knowledge, Communication, Needs of customer and Management -categories as the major causes of uncertainty in system development.

2 INFORMATION SYSTEMS DEVELOPMENT

Information systems have increasingly important role in the economy, with companies becoming more and more dependent on the information they manage and possess (Jun et al., 2011). As the industry grows, efficiency of related activities becomes more relevant. Information systems require different development methods, organizational activities and supportive tasks to be effective, forming a starting point for information systems development.

Information systems (IS) manage information (creating, using, storing, exchanging it) and consist of people, information and enabling technology (Luukkonen et al., 2013). This definition positions IS as a "socio-technical entity", integrating both human and technological aspects. Examples of IS include different transaction systems used in stores, enterprise resource planning software used for accounting, project management and production planning and executive information systems enabling efficient decision making. For the purposes of this research, organization-centred definition of "interrelated components working together to collect, process, store, and disseminate information to support decision making, coordination, control, analysis, and visualization in an organization" by Laudon and Traver (2011) is sufficient.

Information systems development (ISD) aims at creating new functionality based on computational capabilities. Bourgeois and Bourgeois (2016) describe ISD as a process, including development life cycle and numerous development methodologies. Systems development works through team effort, with development team(s) combining their knowledge with participating stakeholders (Stair & Reynolds, 2010). Luukkonen et al. (2013) mention sub-activities of analysis, design, development, implementation and evaluation of ISD. They continue noting that depending on the viewpoint, ISD could be considered as software engineering, application acquisition or a development process with differing methodologies, targets and processes. From our point of view this obscurity is not negative. Locking the conversation about ISD into single aspect or viewpoint would allow more targeted results but might lead to dismissing of potentially vital information. For ISD, broad definition of "set of activities needed to construct an information systems solution to a problem or opportunity" by Kautz, Dawson, Nielsen & Russo (2013) was deemed adequate. In this research "ISD" and "system development" are used as interchangeable, based on their likeness and common usage in the IT industry.

Following chapters go through the history of ISD, consider the methodological changes in recent years leading up to Agile approaches and present the state of current ISD standing. These chapters establish an overview on the context of our research and lead up to discussion about uncertainties and their existence in considered ISD areas.

2.1 Historical evolution

Brief timeline of ISD was gathered by Avison and Fitzgerald (Chapter 11 from book of Currie, Galliers & Galliers, 1999). They consider it as a consecutive evolution from pre-methodological to methodological and finally post-methodological era. Pre-methodological era included development and implementation without formalized methods, high focus on technical skills and low interest on requirements (wanted properties of a product or service). Workflow was highly static, including write-test-implement rotation and finished programs being run by computer operators. Created solutions were often functional copies of already existing manual systems, e.g. allowing logging of working hours in digital format instead of archived papers. Most of the time was spend on keeping the existing products operational, with little time allocated to new system development. Estimations include 70-80% of working time used on upkeep duties. Changes in the environment lead to increased need for people in development with analytic and design focuses, instead of traditional skills of a programmer (mainly mathematics). As the demand for more complex business support systems arose and problems of current development habits (high costs, late delivery) became evident, more disciplined approaches were explored.

Methodological era started in early 1970s with the introduction of systems development life cycle (SDLC), more commonly known as the waterfall model. Methodologies (described as "recommended series of steps and procedures to be followed in the course of developing an information system") started to gain ground. Identification of phases and stages was focused, with each phase including series of defined tasks conducted by workers with specialized skills. Each phase had their own outputs and the workflow was predictable. Focus was on planning and preventing undesired outcomes, e.g. budget overran. SDLC had many positive aspects: standardized documentation allowed information to be shared between stakeholders, division of the project makes it more manageable, expected outcomes could be understood beforehand and it shortly became very used and tested. After years of usage, the limitations of "pure" SDLC became more apparent. These included inflexibility in altering design processes, unambitious system design stemming from highly incremental advancements based on earlier models, heavy computer-oriented and ambiguous documentation and lack of support for managerial needs. Problems lead to numerous movements of IS development, some trying to improve existing waterfall model, some trying to distance themselves from it. Created methodologies had two sources, practice and theory. Most of the earlier types were products of experience, "it works this way". Some methodologies were formed based on theoretical considerations, stemming from universities or research institutions. Examples include IBM business systems planning in strategic level, prototyping in support of requirement management and "incremental approach" of dividing system into components that could be developed simultaneously. Methodologies allowed improving the quality of end product, reducing costs and time needs and forming a standardized process easing the work distribution and control. Methodological era had a large supply of different approaches, but it is mentioned that even in its peak, methodologies were not used in many organizations. Usage included scattered, modified and in-house products on top of the advertised, global ones. Next step in development landscape came in the form of Post-methodological approaches, facilitated by rapidly improving global infrastructure.

Post-methodological era, emerging in late 1990s, has its roots in criticism towards methodological approaches. Criticism includes methods working in theory but not in practice, inefficacy of created systems and unnecessary simplification of complex systems. Other problems include i.e. too high complexity (methodologies themselves requiring lot of skill to use), inflexibility to alterations during development, one-dimensional approach of being too restricting, overly simplified yet invalid assumptions (e.g. assuming existence of well-documented strategy already in place) and developers focusing on the process instead of the goal. ISD methodologies did not provide hoped efficiency, stability and profit themselves, but required certain situations to be effective. Avison and Fitzgerald (2006) extended upon their earlier work and gathered four reactions to perceived problems. First one, external development, included shift from creating in-house solutions to buying packages. This reaction can be seen as an indicator for change towards organizations targeting their core competences (resources, skills and abilities enabling one to distinguish themselves in the marketplace (Prahalad & Hamel, 1990)) instead of general abilities. Second, continuing refinement and improvement, includes changes stemming from external effects (new technologies, web development). Methodologies are forced to specialize, with adaptability or "agility" becoming more important. Third, Ad-hoc development and Contingency, returns to the roots of IS development and considers the methods of development. In contingency approach, structure for conducting work is still present but how to achieve results (tools, techniques) is let for developers to decide. Fourth and last one was Agile development, integrating parts of earlier reactions with the focus on streamlining work and delivering a good product.

2.2 Towards Agile

Agile has become increasingly popular development approach since the release of Agile Manifesto (by Beck et al., 2001). In its core, agile development does not directly assess how to develop, but instead provides values to follow: **Individuals and interactions** over processes and tools, **working software** over comprehensive documentation, **customer collaboration** over contract negotiation, **responding to change** over following a plan. Handling changes throughout the project (instead of only in its planning stage), better management of inevitable variations stemming from numerous sources and achieving good outcome instead of a good process are mentioned as drivers for this "agile response" (Highsmith & Cockburn, 2001). Numerous development techniques have formed throughout last few years, some extending the approaches of post-methodological era, some following new paradigms. Examples include Scrum, Agile modelling, Lean development, eXtreme Programming (XP), Pragmatic programming and Test-driven development. Comprehensive overview of early agile methodology can be found from the works of Abrahamsson, Salo, Ronkainen and Warsta (2002).

Agile development was originally focused on software development (Fowler & Highsmith, 2001), but has spread to other areas of ISD. Agile itself can be considered more of a movement than a simple set of development techniques. Bourne (2010) explained this notion through considering the fit of different methodologies (Lean, Scrum, XP) to different organizational levels (Executive, Management, Development). Lean thinking, originating from Toyota production, focused on removing waste, optimizing organization and forwarding valuable aspects of work. Providing organizational-level support, Lean was considered the best fit for Executive level. Scrum, framework facilitating team organization and upkeeping high product quality, was seen benefiting the team organization, management and product delivery. Management level was considered as the best fit for this approach. XP, a programmer-centric methodology, focused on aspects of communication, simplicity, feedback and courage in providing best results from engineering perspective. This fits the development level of organization. Concerning the same area of implementing Agile, Hoda and Noble (2017) build upon the notion of staged Agile adoption and promoted Agile transitions as "ongoing, continuous, long-term" transformations. They theorized five dimensions of transitions: software development practices from traditional to Agile, team practices from manager-driven to team-driven, management approach from driving (commanding) to empowerment, reflective approach from limited learning to embedded integration and culture from hierarchical to open. Researchers note the transition in software development practices influencing (cascading) other transitions, team and management transitions being highly connected and reflective practice change being achieved only through also achieving "lower" transitions. Cultural change is slow, and it itself influences how other transitions happen. This research provides us with examples of *where* Agile transformation can happen, instead of only presenting *what* it includes.

2.3 Project management

Projects are unique, temporal processes with defined scope and resources used to achieve singular goal. Project management makes reaching this goal possible, working as the "application of knowledge, skills, tools and techniques" used to meet the project requirements (Project Management Institute PMI, 2018). This definition includes several processes: initiating, planning, executing, monitoring and controlling and closing of the project. Projects allow the utilization of multiple people's skills and expertise at the same time, with project management being interested on i.e. human resources, communication, risks and stakeholder management.

Projects are highly popular in the software development and continuously adapt to surrounding changes (McBride, 2008). Examples of these changes include changing life cycle methods, introduction of Agile, internet-enabled distributed development and outsourcing of development activities. Related to these changes, McBride (2008) focused on the development level of ISD and identified project management mechanisms employed by the project managers in software development projects. First management area, *project monitoring*, was found including formal and informal mechanisms. Most used one was weekly review meeting with the team, combined with more informal conversations with personnel and customer. Two identified sub-categories for monitoring were early warning systems (formal measures e.g. scheduled milestones triggering the manager to investigate the problem, usually gathering the overview of the "health" of the project) and multiple sources of information (project managers utilizing mixed indicators, e.g. project progress and informal conversations to reduce uncertainty about the current state, "health" of the project). Second area, *project control*, included varied but constant use of project plan (from "to-do"-lists to formal schedules and work structures), interest on project objectives, development process, informal upkeeping with personnel and mentions of "control by requirement", referring to attributes of recruited employees. Project controls were mentioned numerous, but only few were "employed to any great extent". Third and last management area, *project coordination*, included use of schedule and partition of tasks. Formal team meetings were popular, with documented reviews being less used. Other project coordination mechanisms included conversations (informal comments, mentions) and co-location with the customer (placing development team close to customer, if possible). Research supports the notion of project managers' simultaneous usage of multiple different management mechanisms at the same time, with the intention of increasing richness and consistency of available information.

Project risks are one of the key management areas observed from the literature. Risks are defined as "undesired events that may cause delays, excessive spending, unsatisfactory project results, safety or environmental hazards, and even total failure" by Raz, Shenhar and Dvir (2002). These risks are managed through project risk management practices, including risk assessment (identification, analysis, prioritization) and risk control (management planning, resolution, monitoring, tracking and taking corrective actions) (Boehm, 1991). Different tools of risk management were explored by Raz and Michael (2001), who discovered multiple positive project management practices and risk management processes (e.g. risk impact assessment, risk classification, ranking, periodic reviews). These tools were considered benefiting the organizations and giving them competitive advantage, with the notion that many organizations were just beginning to adopt risk management practices. More recent research by Hijazi, Khdour and Alarabeyyat (2012) presents risk management as integral practice of all development methods, with some faring better in certain situations than others. One example included waterfall model struggling with continuous requirement changes and long production stages, causing risks of becoming obsolete before release and difficulties in estimation of required time, cost and other resources. Another example, Agile development, was noted having different difficulties. Considerable risks rose from high reliance on human factor, distributed development environments and expanding scale (through communicational difficulties). Researchers note that risks are inevitable in most development methodologies and should be controlled whenever possible.

Changes in conceptualizing project management were the interest in a study conducted by Svejvig and Andersen (2015). They noted the emergence of RPM (rethinking project management) as a consistent approach in 2006, with some considerations being made in mid-90s and early 80s. RPM seeks to forward the classical project management approach, where the execution and task-orientation directs the projects into controllable and linear format, "project as a tool". RPM considers projects as "temporal organizations", with project management working as a holistic discipline enabling "project/program/organizational efficiency, effectiveness and innovation" instead of working as a set of tools and techniques. Conducted literature review of 74 articles from 1983-2012 identified 6 RPM focuses which seek to expand project management as a whole, with RPM enhancing (instead of replacing) existing project management thinking. First focus, *Contextualization*, is described expanding the conception of the project, taking into account elements such as environment and organizational strategy. *Social and political aspects* focus on how social and political processes shape projects, e.g. through power structures. *Rethinking practice* considers the possibilities in offering or suggesting alternatives, methods and perspectives. *Complexity and uncertainty* seek to outline complexity and increasing uncertainties in projects and their environments. *Actuality of projects* promotes increase in empirical studies about projects, as reported happenings might drastically differ from reality. Last focus, *Broader conceptualization*, seeks to offer alternative perspectives to project-related aspects (management, success), with the driver being broadening field where the project management is being used. "Complexity and uncertainty" and especially "Broader conceptualization" were popular RPM categories. Work of Svejvig and Andersen (2015) notes the new propagation approaches in existing project management field, suggesting RPM focuses becoming more used and established.

2.4 State of the industry

IS development includes division into multiple distinct methodologies. Surveys conducted by Forrester research Inc. in late 2009 (reported by West and Grant, 2010) give some insight into usage of different development methodologies. From the base of 1298 IT professionals, 35% of respondents selected "Agile" as the development process most closely reflecting the one they were using. 30.6% selected using no formal process methodology, followed by 21% following iterative process (incl. Rational unified process RUP and Spiral) and 13% chose waterfall as the best representative. West and Grant (2010) note the high popularity of agile, also reminding that old methods seem to be here to stay: 34% of respondents are mentioned stating to follow waterfall or iterative approaches in the future. Agile has become the most used development approach and can be considered not being a direct supplementation, but instead a lead effector among other methodologies. Research provides support for increasingly diffusing methodology landscape, as mixing of Agile with other agile and non-agile methods is mentioned covering 74% of Agile-utilizing respondents, with rest sticking with non-altered Agile approaches.

Standish group CHAOS report (2015) gathered data from 10 000 to 25 000 software development projects from 2011-2015 and focused on success rates of these projects. Projects were evaluated on Successful-Challenged-Failed scale using six variables: OnTime, OnBudget, OnTarget, OnGoal, Value, and Satisfaction. When discussing all projects, numbers had been relatively stable from 2011-2015 with only 29% of projects considered successful, 52% challenged and 19% failed in 2015. Project size and success was considered and compared between agile and waterfall approaches. Agile and waterfall both managed in small projects (58% successful for agile, 44% for waterfall) with largest differences in large projects (18% successful for agile, 3% for waterfall). Big picture about the success rates was clear: majority of projects face considerable difficulties, with larger projects being more likely to fail or be challenged. Even with taking into account some dissent towards used measurements (Eveleens & Verhoef, 2010) results of CHAOS report can be considered worrying.

Project Management Institute PMI (2017) conducted their yearly survey to over 3000 project management professionals and considered project success from holistic viewpoint. They utilized mix of traditional scope-time-cost measurements and benefits realization, mentioning “better performance identification” as their goal. Results were aggregated into statements, including nearly 70% of projects meeting their original goals/business intent but having difficulties achieving traditional project goals. Examples included around 50% of projects succeeding in their scope and time targets, with around 30% going over budget. Survey results made a large distinction between “Champions” (>80% of organization’s projects achieving all project measures, 7% of total organizations) and “Underperformers” (<60% of projects achieving measures, 12% of total organizations). Champions prioritized developing skills of their workers, targeted benefits realization, utilized PMOs (project management offices) and executive sponsors and focused more on agile practices than their counterparts. PMI reports slowly improving success rates of projects but notes the high differences between organizations with different benefits realization maturities.

Given the findings, state of IS development can be considered as fragmented. Numerous development strategies, questionable success rates and divisive organizational differences presents ISD as an altering field with numerous challenges. At the same time, total global IT spending is predicted by Gartner to rise to 3816 billion dollars in 2019. If the “Devices”-category is excluded from the findings, remaining “Data centre systems”, “Enterprise software”, “IT services” and “Communications services” net to 3110 billion dollars. Lowest expected growth rate goes to “Communications services” with 1.2% growth to 1442 billion dollars in 2019, with highest being “Enterprise software” with yearly growth of over 8% to 439 billion dollars (Garfinkel, 2018). Growing importance of IS positions development activities as a significant factor of global economy.

3 UNCERTAINTY

Uncertainties are ubiquitous in day-to-day life. Simple tasks, like choosing the clothes for the day are affected by multitude of possibilities: Will it rain? Who will I meet? Am I in a hurry? What's in today's schedule? These considerations have a familiar effect: you become uncertain about your decisions, bouncing between alternatives, trying to focus your thoughts. But this outcome isn't predetermined – if you've seen the weather forecast, you can make your selection accordingly, or having a filled calendar in hand suggests you to expect some hurry. Here the available information determines your ability to make decisions, and lack of it leads to uncertainty. Information availability might also have an opposite effect: different sources of information might signal contradictory, even opposite hints. Now the information utilization is central, uncertainty stemming from inconsistencies in available information. Questions arise: Is the uncertainty caused by information availability, its usage or something else? Why is it prominent in some cases, but invisible in others? Do the uncertainties affect contexts they are in similarly? Keeping these considerations in mind, following chapters explore the complex nature of uncertainty, concentrating on it in ISD context. Chapter 3.1 considers the essence of uncertainty, followed by views towards risk assessment in Chapter 3.2 and uncertainty management in Chapter 3.3. Chapter 3.4 investigates uncertainty categorizations conducted in earlier research.

3.1 Uncertainty in research

Term "uncertainty" can be understood from multiple viewpoints. It can be viewed directly as missing information (Kolltveit, Karlsen, & Grønhaug, 2004), seen being caused by unfamiliar situations (Gerrity, DeVellis, & Earp, 1990), divided into separative, functional parts of ethical, option and state space uncertainty (Bradley & Drechsler, 2014) and specified in the organizational context (Galbraith, 1974). Others seek to position uncertainty as innovation enabler (Jalonen, 2011), some consider it through potential outcomes and causal forces of the future (Johansen, Eik-Andresen, Dypvik Landmark, Ekambaram, & Rolstadås, 2016) and few pursue finding its effects (e.g. Ruiz, Philbrick, Zak, Cheung, & Sauer (2009) in their research about the consequences of uncertainties in power management). Based on the literature review, uncertainty definitions can be understood as very dependent on their utilization, explaining high variety even within the same research context. Following paragraphs consider terminology and use of uncertainty further.

Galbraith's (1974) definition of uncertainty, viewing it as a difference between information required and information possessed when carrying out the task, was highly related to information processing within organizations. He states, "the greater the task uncertainty, the greater the amount of information that must be processed in order to insure effective performance". Cooper and Wolfe (2005) understand the reasoning of Galbraith as a continuum, starting from providing "appropriate amounts of information where needed" and leading to reduced task uncertainty, ultimately easing the organizational control.

Uncertainty is often mentioned with supporting or related terms, seemingly enabling the representation to be from broader perspective about the subject. Some research include the use of "ambiguity", viewed as a precursor for uncertainty (Taipalus, Seppänen & Pirhonen, 2018), also noted by Ward and Chapman (2003). Johansen et al. (2016) took a different stand via contrasting the ambiguity with uncertainty, putting it as "different interpretations of the same piece of information". Project-related uncertainty is mentioned having its root cause in the lack of available information, with ambiguity being connected to stakeholders' interpretation of available information. From this point of view, the provision of additional information would reduce uncertainty, but the amount of ambiguity would remain same. Given the considerations, ambiguity could be positioned either as an effector of uncertainty or as a base construct for it. Compromise would be to understand ambiguity as a highly related concept, including possibility for more context-specific defining.

Equivocality, gathered by Daft and Lengel (1986) as "ambiguity due to the existence of multiple and conflicting interpretations", connects to uncertainty through media richness theory. Theory mentions the need of matching the richness (broader information delivery) and volume (amount of information) of information processing in both uncertainty and equivocality to gain benefits (Daft & Lengel, 1986). Cooper and Wolfe (2005) extended this notion through implementation of IT adaption information processing model, noting the reduction in adaption uncertainty and equivocality and matching of uncertainty/equivocality requirements to information processing volume/richness being beneficial for IT adaptions. These theories can be said to position equivocality as an equal to uncertainty and treat them as separate entities, distinction also used by Sakka, Barki and Côté (2016). Equivocality could be seen as a refinement of ambiguity-construct, concerning same context area as uncertainty but a with differing focus. Common usage in parallel with the uncertainty makes the disassociation challenging.

Contradicting and overlapping terminology might be a side effect of subjective and objective sides of uncertainty. Lipshitz and Strauss (1997) used the division of uncertainty types (initially created by Weick, 1979) into issues (what you are uncertain about) and sources (what are the causes for uncertainty). Issues included affected person ("decision makers" in the research) having doubts about alternatives, outcomes of these alternatives and the nature of the situation. Sources were the causes behind these doubts, including incomplete information, inadequate understanding and undifferentiated alternatives. First one, *incomplete information*, was considered objective and mentioned the most popular source of uncertainty in earlier research. Following two, *inadequate understanding* and *undifferentiated alternatives*, were subjective and considered from the information processing perspective: is the available information usable (abundance of alternatives, conflicting meanings, difficulties in utilization) and what route to follow (alternatives as good or as bad as their counterparts, the difficulty of choice). This positioning of three sources as explanatory factors of uncertainty was also used by Grote (2009), who considered the extensive division of uncertainty into subcategories (e.g. ambiguity) being caused by the focus on "lack of information" -source, with subjective sources being neglected. Taking this notion into consideration, usage of "sources of uncertainty" provides us with route of distinguishing between different uncertainties through their core causes.

Multitude of definitions could be considered as an indicator for fragmented research area, but the definitions used in ISD-related research were congruent in their inclusion of "availability of information" and "effects on project" -constructs. We found the definition of "incomplete information that bears the potential for positive or negative consequences of high impact on project objectives" by Dönmez and Grote (2018) fitting our research context well, as it captured the core concepts of our research: Inconsistencies in information forming a starting point for uncertainty, positive and negative consequences referring to differing forms of uncertainty and project objectives concerning one of the main ISD areas (projects, linked to development through objectives).

3.2 Uncertainty and risk

Risks, recently described as "uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality" by Project Management Institute (2013) have been the focus of numerous risk management literature (i.a. Chapman, 1997; Froot, Scharfstein, & Stein, 1993; Kwak & Stoddard, 2004). Risks were considered from project standpoint in chapter 2.3. Discussion about the relationship of uncertainty with the term risk, commonly discussed within ISD requirements management, can be traced back to Knight (1921): risk is a measurable uncertainty. Knight's strict division of two into quantitative and non-quantitative types might seem natural, but later research has been unclear with the distinction of the two. Some integrate both ("[Risk is] an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objective" used by Project Management Institute (reported by Rose, 2013)), some note their widespread usage as synonymous (Johansen et al., 2016) and some strive for integration of risk into part of uncertainty in their threat/opportunity divide (Dönmez & Grote, 2018; Ward & Chapman, 2003). This transformation towards threat and opportunity has been a topic of interest in recent uncertainty research.

Risks are considered one of the key uncertainty objects present in projects, but the term itself is becoming increasingly irrelevant (Raydugin & Raydugin, 2013). Researchers considered uncertainty being divided into types of "Known uncertain event", "Unknown uncertain event", "Discrete uncertainty event", "Given" and "General". Term "uncertainty" is seen having a better fit to the "hard" (scope, quality, performance, schedule, budget) and "soft" (safety, environment, reputation) risk management objectives than currently used "risk". Raydugin and Raydugin (2013) criticize the inconsistent usage of risk: it is generally considered unfavourable, but is used in risk management to include positive (upsides) and negative (downsides) aspects. Risk is also mentioned implying some probability of occurrence, which is against their view on General uncertainties having their own certainties of occurrence (might or might not happen at all). Research instead opt for using four uncertainty categories, including "Downside uncertain events", "Upside uncertain events", "Downside general uncertainties" and "Upside general uncertainties". As such, following "risks" terminology seem to not capture the full extent of uncertainties and the usage of "uncertainty management" terminology (discussed in chapter 3.3) is preferred.

Perminova, Gustafsson and Wikström (2008) note the usage of word "uncertainty" in risk-related literature, with some definitions basically merging the two. They see these views as lacking, with the two being "better described as cause and consequences" and distinction being necessary (in their research of exploring effects of uncertainty to project performance). Researchers describe the risks being *implications* of uncertainty, instead of traditional approach of seeing risks *as* uncertainty. Dönmez and Grote (2018) continued this way of thought, discussing the position of risk relative to uncertainty. To avoid confusion, they opted for using threat and opportunity instead of positive and negative risk when describing effects associated with uncertainty. This change could be seen as largely thematic, but their reasoning included negative-loaded "risk" being problematic when discussing uncertainties and usage of threat/opportunity allowing users to explore positive effects, instead of focusing on diminishing the negative ones. Their view integrates risks as an effectual part of uncertainty, describing its effects as positive (opportunity) or negative (threat).

Example of opportunity utilization was highlighted by Dönmez and Grote (2018). They were interested in finding out how agile development teams approach uncertainty as threats and opportunities. Research included interviews with agile software development teams from industry areas spanning from software development to finance, insurance and telecommunications. Researchers found intriguing examples of positive uncertainties, named "opportunities", through interviews. One example was a decision to split the product into two (design alteration, increased uncertainty on resources and requirements of project). Following this decision, it was noticed that two parts needed a way to communicate with each other. An API (application programming interface) was created for this task. The API itself was understood as a new product and was packaged to be sold separately after its usefulness was noted. In the end, the increased uncertainty brought forward an opportunity, which was realized as added product value to existing and new customers. This example highlights the opportunities integral to uncertainty and the multitude aspects that can be considered in uncertain situations.

3.3 Uncertainty management

Uncertainties have been established as an integral part of ISD, leading to interest in managing them. Projects have traditionally focused on "maintaining predictability and keeping all critical factors under control" (Johansen et al., 2015), forming a starting point for uncertainty management. Management activities have transformed from early negative-loaded "diminishing of uncertainty" to increasing focus on exploiting opportunities (Dönmez & Grote, 2018). This change is connected to alterations in uncertainty/risk-divide (discussed in previous chapter). Following paragraphs provide insight into uncertainty management approaches.

Pich, Loch and Meyer (2002) describe the project management timeline starting from task scheduling techniques (PERT, CPM) in 1950s. This was followed by project risk analysis and graphical evaluation and review techniques (GERT), allowing probabilistic outcomes and looping tasks, ultimately leading to replacement of identification of "one critical path" with measuring of task criticality. From 1970s onward tasks were viewed as decision outcomes (compared to seeing them as "given"), leading to use of sequential decision-making. Risk management, defined as "the identification of possible (but uncertain) events and their impact on the project" (Pich et al., 2002), started to gain ground. de Bakker, Boonstra and Wortmann (2010) note the division of risk management into "evaluation" and "management" approaches, with former being an analysis process and latter focusing on dealing with unexpected and undesired events. Together these views position risk management as a preventive task, striving to negate unexpected events. Risk management's negative-loaded view towards uncertainty have been increasingly challenged in last few decades (Dönmez & Grote, 2018; Ward & Chapman, 2003), leading to emergence of uncertainty management.

Question "How uncertainties can be managed" can be understood and answered from different levels of fidelity, including direct techniques, overarching strategies and global statements. Lipshitz and Strauss (1997) were interested on how decision makers cope with uncertainty and managed to gather three basic strategies for it from existing research: reducing, acknowledging and suppressing uncertainty. *Reducing* uncertainty was mentioned most used and obvious strategy, accomplished through e.g. information collection, deferring decisions until more information is available, assumption-based reasoning and shortening the decision time-horizon (from long-term commitments). *Acknowledging* uncertainty is mentioned following if uncertainty cannot be reduced, by taking the uncertainty into account when making decisions or preparing to confront or avoid resulting risks. Mentioned tactics include option, probability and outcome evaluations, avoidance via preferring known options, forming buffers for negative occasions (time, work, needs) and anticipatory rearrangement of priorities. *Suppressing* uncertainty strategies include denial (ignoring unwanted information) and rationalization (understanding possible uncertainties but doing nothing to them), working as the baseline "do nothing"-approach. Another mentioned strategy included *acknowledging*-related *contingent coping*, with the focus on achieving reasonably (but not fully) managed situation. Lipshitz and Strauss (1997) expanded upon this division in their research, finding five prevalent and broad uncertainty strategy categories: reduction, forestalling, assumption-based reasoning, weighing pros and cons and suppression of uncertainty. Reduction (collecting additional information, asking for advice, utilizing formal rules) was most used. It was followed by *acknowledging*-based trio of forestalling (incl. improving readiness and pre-emptive generation of specific responses to negative outcomes), assumption-based reasoning (forming grounded mental model of how to act, retracted if countering evidence emerges) and weighing pros and cons (choosing best available alternative). Suppression (acting upon intuition, ignoring uncertainty, "taking a gamble") was seen as least popular strategy. Identified categorization of strategies is seen useful when considering how emerging uncertainties can be managed.

Management literature often considers uncertainties from pragmatic standpoint, meaning formation of direct "cause-correction" relationships. Effects of uncertainties to processes not only differ, but also vary in effects based on the processes themselves. Jun et al. (2011) considered the situations where uncertainties, project processes (planning, control), integrational tasks and user participation moderate the process and product performances. User participation was seen benefiting the end-product quality but affecting process performance negatively, indicating the need for striking a balance between no and extensive user participation. In uncertainty-related part, high and low amounts of uncertainty were found needing different approaches based on the used criterion. Choosing of management approaches that fit degree of risk or uncertainty included in the project was mentioned by Barki, Rivard and Talbot (2001), and Jun et al. (2011) extended this way of thought through statements: if process performance is the key criteria, project with high uncertainty "call for lower levels of formal planning and control". If instead the product performance is the key criteria, project with high uncertainty "call for higher levels of user participation". These results indicate the need for identification of uncertainties embedded into projects and utilizing context-specific approaches to negate seemingly negative effects of uncertainty, ending up with improved process or end-results.

Ward and Chapman (2003) mention the transformation towards usage of "uncertainty management" from established terms of "risk management" and "opportunity management". Managing uncertainty is explained as broader than simply noting threats, opportunities and their implications – "identifying and managing all the many sources of uncertainty which give rise to and shape our perceptions of threats and opportunities" is mentioned a way in understanding origins of uncertainty. Focus on understanding "where and why uncertainty is important in given project context and where it is not" is mentioned as a shift from earlier project risk management research. This understanding was not yet realized in usable frameworks or techniques. Dönmez and Grote (2018) note in their more recent research the still present lack of general framework in managing uncertainty. They identified two prevalent approaches to the subject from existing literature: minimizing uncertainty (described as increase in control, with focus on eliminating uncertainty) and coping with uncertainty (described as a flexible approach, acknowledging the existence of uncertainties but leaving some unattended). They mention the possibility of some uncertainties being integral, not possible to be removed, and the negative side of eliminating certain uncertainties (deprecation of opportunities for innovation).

Johansen et al. (2016) note the difference between theory-based views (i.a. Hillson, 2002) towards uncertainty management process and reality of the subject. Based on theory considerations, downside uncertainties (risks, threats) should be even in number with upside uncertainties (opportunities) and considered having a similar importance. Contradicting these, Johansen et al. (2016) found 8-10 times the number of threats compared to opportunities during brainstorming sessions, signalling great difficulties in finding positive advancement possibilities. They note general focus on identifying both positive and negative uncertainties at the same time as lacking and promote using separative process for both. Opportunity management requires resources and time, making it vital to understand the beneficiaries and effects to other management activities before implementation.

Uncertainty management is not only interested on what is done, but also on how the management activities succeed inside organizations. Karlsen (2011) conducted interviews with the purpose of studying the "effectiveness of current uncertainty management practice in projects with a special focus on the organization's cultural dimension". Organizational culture, described as "patterns of fundamental assumptions (e.g. human nature, social interactions, perceptions about the environment) within the organization", was considered affecting the efficiency of management activities. He utilized Hillson's (1997) uncertainty management maturity model, which states four levels of maturity: *Naïve* (organization unaware of uncertainty management), *Novice* (some knowledge but no generic, structured approach), *Normalized* (uncertainty management included in normal processes and implementation, organizational culture includes accepted policy for uncertainty management) and *Natural* (uncertainty-aware culture with proactive approach to uncertainty management, emphasis on managing opportunities). This model presents four variables effecting the "Effective uncertainty management (maturity)", including Processes, Application, Experience and Culture. Karlsen (2011) concluded the characteristics of supportive uncertainty management culture including 12 aspects, i.e. Commitment of time and resources, Understanding of uncertainty management, Proactive uncertainty management, Clear responsibilities, Accepted and operationalized policy and terminology and Senior managers asking and using uncertainty information. Research emphasizes the need of understanding uncertainty management (what it is, what it does) and the commitment of senior managers to the process. This would improve the organization's maturity, which would result in more successful uncertainty management process. Recruiting personnel with positive attitude towards uncertainty management is mentioned as a long-term goal, enabling the communication and lessening the risk of "culture of blame", where risk identification might be seen as a weakness.

Work of Dönmez and Grote (2018) gives some insight into practical execution of project management strategies. Their research concentrated on finding uncertainty management practices used by agile software development teams and combined them into four main principles. First, *Uncertainty anticipation*, included planning with uncertainty (focusing on requirements that are least likely to change, allowing high flexibility with the rest) and developing vigilance (remaining in alert for possible opportunities, e.g. new service realization). This principle includes acknowledging the high chance of changes happening, limiting their negative effects and bolstering positive ones. Second, *Information accrual*, included incremental feedback (frequent communication between stakeholders, advancing step-by-step through short iterations), team-based task analysis (eased control through constant estimations, utilizing whole team's expertise and experiences) and knowledge sharing (pooling of knowledge into accessible databases, knowledge exchange through seminars and pair programming). Second principle deals with availability of information and its efficient distribution. Third, *Solution inspection*, included prototyping (creation of testable placeholders, helping with requirement management) and creating alternatives (keeping optional development routes open, allowing best alternative to be chosen for better results). These two practices included possible negative consequences, e.g. customer getting stuck with single (presented) solution in prototyping, or high resource cost in upkeeping alternatives. Third principle eased the selection of best course of action. Fourth and final principle, *Role-based coordination*, included creating functional roles (helping with task focusing and distribution of responsibilities), stakeholder integration (integration of customer into requirement decision making) and task switching (ensuring the availability of work assignments, preventing downtime and unnecessary wait time). These practices were noted having some negatives: functional roles might lead to "lock-in" of tasks to certain people and possibility of difficulties in synchronizing schedules with customer. Fourth principle focused on efficiency of working and people management.

3.4 Categorization of uncertainty

Uncertainty categorization is often conducted in support of specific research goal, working as a medium for researchers to conduct their work from specific viewpoint. For example, Daft and Lengel's (1986) inclusion of Technology ("knowledge, tools, and techniques used to transform inputs into organizational outputs"), Interdepartmental relations (challenges in integration across departments) and Environment (external effects, i.e. market and customer alterations) uncertainty categories allowed exploring of organizational information processing from wanted perspective. Another example was Tatikonda and Rosenthal's (2000) use of technological novelty ("newness… of the technologies employed") and project complexity (task and subtask nature, quantity and magnitude in a project) categories to study relationships between "product development project characteristics and project outcomes". Importance of categorization is mentioned by Dönmez and Grote (2018), who state being able to unequivocal attribute findings to one uncertainty type important for their research. Following paragraphs demonstrate the numerous existing categorization approaches.

Dönmez and Grote (2018) considered the categorization of uncertainty achievable in multiple different ways. Some use singular focus (e.g. requirement uncertainty), with some developing multiple constructs (e.g. Jalonen's (2011) eight different types of uncertainty factors). Dönmez and Grote (2018) decided to adopt Moran's (2014) categorization of requirement, resource and task uncertainty, mentioning this categorization being "mutually exclusive while… also exhaustive" and presented types being prevalent in the literature. They provide some critique towards the exclusivity of too fine-tuned categorization approaches and ended up selecting a broader approach. First category, *Requirement uncertainty,* includes external forces affecting project, regulatory effects and social and political changes. *Resource uncertainty* refers to means of production and effects of human and financial aspects. *Task uncertainty* includes knowledge and skills, with operational uncertainties (e.g. effects of a novel problem) becoming visible. Usage of differentiated "exploitation" and "mitigation" uncertainty portfolios, based on e.g. earlier three categories, is mentioned as a useful technique for development teams.

Uncertainties present in software development has been area of interest for some time. Ward and Chapman (2003) linked the uncertainty into different project life cycle (PLC) areas, categorizing uncertainty through the scope of uncertainty in projects. First category was *variability in estimates*, including project parameters (i.e. time, cost and quality) having uncertainty through e.g. lack of clear specification what is required, workers lacking experience and too high complexity. Second, *basis of estimates*, noted that estimates are often made subjectively (by limited number of people), possibly having very different views. Example of this is when pessimistic bias makes managers overestimate the needed work, leading to "what we do now"-situation when all planned tasks are complete. Third, *uncertainty about design and logistics*, suggested that assumptions made in planning phase (who does what, how, at what cost) can lead to uncertainties throughout the project. Fourth, *uncertainty about objectives and priorities*, finds the clarity about objectives and priorities important, also mentioning the effects on earlier areas (relative priorities between time, cost and performance not clear, leading to noticeably increased uncertainty in each). Fifth, *Uncertainty about fundamental relationships between project parties*, deals with people. Involvement of multiple parties (stakeholders, developers, users) can lead to uncertainties through e.g. specification of responsibilities, communicational problems, contractual interdependencies and perceptions about roles and responsibilities. Concerning the research context of software development, uncertainties are described to be present throughout the project lifecycle, and being "particularly evident in the conceive, design, plan and allocate stages".

Marinho, Sampaio, Lima and Moura (2014) conducted a literature analysis with the purpose of classifying the sources of uncertainty. They identified four prevalent categories: Market (sources of uncertainty being customer behaviour, global economy, partners and suppliers), Technological (maturities of different technologies, amount of know-how available or already existing in the company, pressure to renew), Environment (organizational and intra-organizational factors including team capacity, resources, shareholders, size of project life cycle) and Socio-Human (people management, team composition, learning and innovation).

Differing approach to seeking sources of uncertainty was done by Atkinson, Crawford and Ward (2006), who conducted identification of uncertainties from the perspective of project management. They identified 3 key areas: Uncertainty in estimates, Uncertainty associated with project parties and Uncertainty associated with stages in the life cycle. *Uncertainties in estimates* were highly associated with traditional project performance measures (time, cost, quality) and included numerous reasons: lack of clear requirements, high complexity, changing factors during the project, bias of the estimators. Second category, *Uncertainty associated with project parties*, included uncertainty sources of estimations of achieved (working) performance, possibly differing objectives and motivation of each party, quality and reliability considerations, availability of responsible stakeholders and actual skills of anyone involved. Third category, *Uncertainty associated with stages in the project life cycle*, dealt with uncertainties happening throughout the project. Inadequately accomplished early phases of the project might make specifications of production difficult, ultimately affecting the quality of the outcome. Allocation stage included more vague effects, mainly associated with risks and possibility of different opinions affecting work. Execution stage uncertainties were related to design changes, with introduction of new needs, modification of already formed aspects and removal of attributes being possibility. Uncertainties were considered negative to project performance.

Project uncertainties were also the interest of Sakka, Barki and Côté (2016), who ended up with a division of uncertainty into two types: Uncertainty related to project scope and uncertainty related to project novelty. First type was defined to include "people involved in the project, its cost, its duration; the number of users affected by the system and the number of systems linked to the new IS" based on works of Davila (2000), Sicotte and Langley (2000) and Barki et al. (2001). *Scope* uncertainty is mentioned affecting organizational structure, with larger scope needing more coordination between project members (including monitoring of project cost and schedule). Second type included new functionalities, systems and activities of project novel to team members (Keller, 1994; Withey, Daft, & Cooper, 1983). Increasing amounts of *novelty* is mentioned leading to more unpredicted events and issues, requiring extra work in information processing and requirements management. Sakka et al. (2016) included two types equivocality with previous uncertainty types to complete their view on project characteristics. These two equivocality types were related to ambiguity of user needs ("existence of different interpretations among the participants to the project about the system to be developed") and technological complexity (difficulties in implementing project when used technology is innovative and complex). Categorization made by Sakka et al. (2016) might seem limited in size and questionable in their integration of related constructs (uncertainty, equivocality), but this decision supported their focus on understanding improvements on ISD project performance through usage of project control system (mediated by amounts of uncertainty and equivocality). The integration decision can be though as an example of utilizing unconventional categorization aimed at improving research results.

Uncertainty categorization can be formed through mixing of collective and exploratory research, as done by Petit (2012). He utilized project uncertainty categories created by Leifer (2000) and connected them to uncertainty classification approach by Meyer, Loch and Pich (2002) in his research exploring how uncertainties affect project portfolios managed in dynamic environments. First step included division of uncertainties gathered from interviews into four categories: *Technical* (included technology, effects of 3rd party product), *Market* (customer needs, competitor's offering, new markets and customers), *Organizational* (availability of resources) and *Financial* (funding structure). Fifth category not present in Leifer's (2000) original work was *Norms and regulations* (agreements, regulations), which was added to the structure based on the prevalence of connected uncertainties. Following steps included division of categories into foreseen and unforeseen uncertainties, used by Meyer, Loch and Pich (2002). Foreseen uncertainties had identifiable uncertainties and connected projects had stable goals, with unforeseen being the opposite. Foreseen uncertainties included sources of Technical, Market and Norms and Regulations, impacted project portfolio and scope/structure and had existing structures and mechanisms able to sense them. Unforeseen uncertainties included sources of Organizational and Financial, directly impacted project and ability to deliver and had no formal mechanisms in place for management.

Jalonen (2011) explored uncertainty inherent in innovation. His literature review categorized different kinds of uncertainty related to innovation (new, improved idea, practice or object), focusing on it from innovation process standpoint. 8 uncertainty factors were identified: "Technological", "Market", "Regulatory/institutional", "Social/political", "Acceptance/legitimacy", "Managerial", "Timing" and "Consequence" uncertainties. These factors manifested themselves differently in uncertainty, e.g. Managerial uncertainties including "fear of failure" and Market uncertainties "lack of knowledge about the behaviour of competitors". Jalonen (2011) noted the interdependencies between different factors, mentioning possibility for using aggregating "umbrella categories". This included combining of technological, market and regulatory/institutional uncertainties into "environmental uncertainty" and positioning socio-political uncertainty under "managerial uncertainty". Mentioned examples indicate the possibility to diverge from clear-cut categorization, leading to more manageable outcomes. Three main categories created by Moran (2014) and two uncertainty categories (enriched with two equivocality ones) by Sakka, Barki and Côté (2016) can be considered examples of this aggregation paradigm.

4 RESEARCH METHODS AND DATA COLLECTION

Research consisted of qualitative content analysis based on interviews and survey conducted in support of content analysis results. Workflow is visualized in the figure 1. Following chapters explain conducted data collection, research methods used with interviews and methods used with survey.

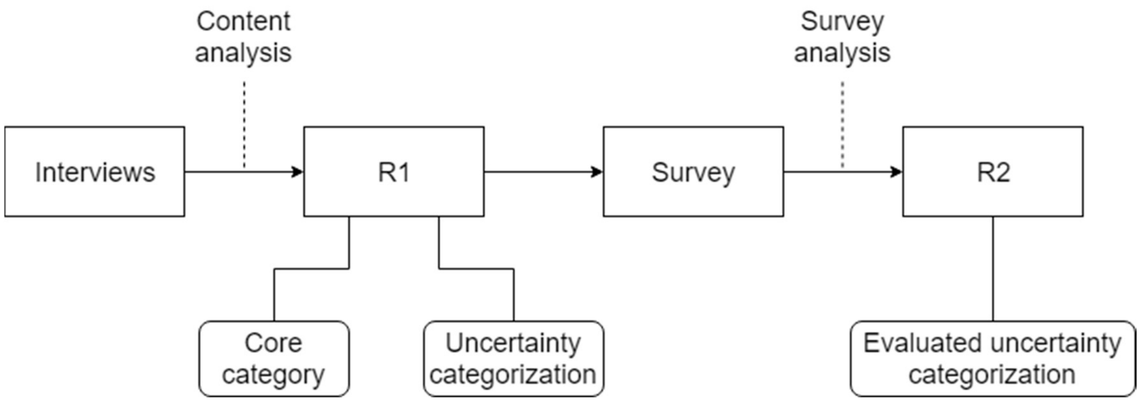

Figure 1: Workflow, methods and results

4.1 Data collection

Interview analysis utilized existing interviews conducted by Taipalus, Seppänen and Pirhonen for their research "Uncertainty in Information System Development: Causes, Effects, and Coping Mechanisms" (Taipalus et al., 2019, unpublished). Research area was highly related to our research, which made utilization of interview data possible.

Interviews were conducted in Finnish. Number of interviews used in the analysis was 12, with 10 being available from the beginning of research and 2 being added during the research. Interviews can be categorized as open-ended expert interviews, aimed at generation of ideas through unstructured conversations. All interviews were conducted in person and recorded for later transcription. Interviewees had variable work histories, including positions as project managers, development managers, consults and developers. All interviewees worked in ISD at the time of their interviews. Most of the interviewees can be positioned into upper- or middle management, with experience from operational activities.

All interviews included 3 main conversation areas: "What causes uncertainty for you", "How does the uncertainty manifest itself in your work" and "How do you cope with uncertainty". Conversations were interviewee-driven, where the interviewer started the dialogue and reacted to statements given by the interviewee. Transcribed texts resulting from the interviews ranged from approximately 2000 to 9900 words, with most following word-by-word transcription including both interviewee's questions and full answers of the interviewed.

Survey was created to support earlier interview analysis and allows us to better understand the importance of identified uncertainty categories. Target audience of the survey was people with working experience in the IT industry connected to system development, being very close to initial interview respondents. Relatively broad target audience allowed inclusion of wider range of positions (e.g. consultants, designers, product owners and executive managers) compared to strictly operational (constructive) activities of system development (e.g. software developer, project manager). Target audience characteristics were close to the people participated in the interviews. Having working experience in the IT industry was preferred.

Survey was distributed in the digital format through the combination of social media platforms (namely Facebook and LinkedIn), email and personal contacts. Survey was distributed in a form that allowed everyone with the link to fill out the survey. Responses were accepted for 3 weeks in May 2019. Number of submitted survey responses utilized in the analysis was 26 (N = 26).

4.2 Research methods for interviews

4.2.1 Analysis

Analysis of interviews followed the qualitative content analysis method, described as a "research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" by Hsieh and Shannon (2005). Qualitative content analysis has sometimes been positioned between quantitative and qualitative approaches, being understood as a tool leaning towards qualitative interpretation and creation of codes (Morgan, 1993). Used method allows us to swiftly utilize analysis results in following survey creation.

Conventional content analysis consists of several steps, compiled by Hsieh and Shannon (2005): First, data is read through repeatably to achieve immersion and understanding of the research area. Second, data is read word by word to identify codes, highlighting the passages or words that seem to capture key thoughts. Third, researcher notes the first "impressions, thoughts and initial analysis" from text, leading to discovery of inclusive labels for codes and creation of initial coding scheme. Fourth, codes are sorted into categories based on links and relations between codes. Fifth, emergent categories are sorted into clusters. Hsieh and Shannon (2005) mention steps of reorganization of categories, developing definitions for each created construct and choosing of exemplars from constructs for reporting purposes as possible continuation.

Grounded theory approach was used to further the understanding of the uncertainty categories resulting from the analysis. Grounded theory ultimately builds a theoretical explanation to the specified phenomena, discussing conditions for their emergence, how they are "expressed through of action/interaction", followed with considerations about the consequences and variations of these (Corbin & Strauss, 1990). Grounded theory follows qualitative coding paradigm, highly related to the method mentioned by Hsieh and Shannon (2005) but going further in its coding practices. First, *open coding* is used breaking down the data, giving the emerging codes labels and interpreting the grouping of codes. Similar codes are grouped together, with a possibility to break these groupings into subgroups based on various connecting factors. Second, *axial coding* is used to relate categories to their subcategories and further the categorization in hand (possibly noticing new or reorganizing old categories). Relations between categories can be observed through noticing differences, variations between concepts, and enriching earlier assumptions through newly emerging information. Third, *selective coding* identifies the central "core" category which represents the main, uniting phenomenon of all categories. Corbin and Strauss (1990) mention questions aiding the core category identification, e.g. "What is the main analytic idea presented by this research?" and "If I had to conceptualize my findings in few sentences, what would I say?". Core category can be formed in different levels of generalizability, with more abstract one covering wider array of possibilities. Our research integrated the grounded theory open, axial and selective coding into category analysis, but the research did not ultimately produce theoretical explanation for observed phenomena. As such, grounded theory approach was utilized in limited scale.

Analysis was conducted under two presumptions. First, results from this analysis would be utilized in creation of a survey answering the research question (What areas of uncertainty are viewed as most important). This presumption directed our analysis in a few ways: codes and categories had to be defined in a way that they would be usable in creation of the survey questions. We decided to use "causes of uncertainty" as a main way of thought during coding, with the intent to find reasons behind uncertainty emergence. Causes were linked to sources by Weick (1979), who described sources as "i.e., what causes this uncertainty". Grote (2009) proposed a distinction between source and cause constructs in uncertainty, with *sources* consisting of incomplete information, inadequate understanding of available information and undifferentiated "equally attractive or unattractive" alternatives and *causes* including reasoning behind these effects. Example of this could be uncertainty being caused by missing an email containing vital information, with the source of uncertainty in "Incomplete / Lack of information". We found no real divide between "cause" and "source" constructs, and the two seem interchangeable. "Cause"-construct was more commonly used in our research as it allowed us to clearly describe the reason behind uncertainty and code the passages (used in code creation) in unified fashion.

Second, the existing categorizations of uncertainty wouldn't be used as a base for our uncertainty categorization. Instead, an inductive research approach was used. Inductive approach of generating content categories, key words and themes is mentioned as a way to keep the results grounded (Kondracki, Wellman,

& Amundson, 2002) and allow formation of novel data (Hsieh & Shannon, 2005). The focus was on finding what interviewed people thought about uncertainty, and approach of conventional content analysis by Hsieh and Shannon (2005) seemed the best fit. Other available qualitative analysis techniques, including summative content analysis (counting and comparison, keyword-driven interpretation of the underlaying context) and directed content analysis (theory and existing research -driven creation of initial codes) were considered when making the technique selection.

4.2.2 Methods applied in coding

Our research applied conventional content analysis approach with some alterations. Second and third step of the five steps compiled by Hsieh and Shannon (2005) were conducted in parallel, highlighting the passages that were thought to include mentions of the cause of uncertainty and including comments if deemed necessary. Comments were used to clarify and summarize the passages. Creation of codes was done during these steps. Fourth step included allocation of codes to categories that emerged during the coding. Fifth step overlapped with axial coding paradigm (Corbin & Strauss, 1990) and provided us with uncertainty categorization.

The nature of uncertainty as somewhat ambiguous term, common in day-to-day use but lacking specific boundaries caused difficulties during coding. In some cases, interviewees seemed to associate uncertainties with problems. As an example, this led to confusion if the interviewees were talking about problems in their work in general or trying to tell the uncertainty-related viewpoint. Another problematic situation was when uncertainty couldn't be inferred from interviewee's answer, comments being too broad or too general. These answers were omitted from coding and were not utilized in categorization.

Coding-related problems included interpretation of interviewees' answers. In some cases, interviewees were not able to provide concrete answer to question "What causes uncertainty to you" but returned to the subject afterwards from a different perspective. Example of this was a question about the interpersonal trust in project team, answered through explanation about the criticality of being able to ask questions, getting help if needed and to trust other people's sayings. This answer does not directly assess uncertainty but continues earlier conversation about team-based uncertainties. Given the interviewee's emphasis on importance of trust, following assumption was made: if trust is seen as of critical importance for team-based functions, lack of it causes uncertainty in that context. Code "Interpret: Uncertainty is caused by lack of trust into other personnel (caused by work left undone, not including everyone into communication)" was created. Answers requiring this type of inverted interpretation were commented with "Interpret:"-prefix. Same prefix was used to mark our inferences on unclear answers, easing the review of problematic answers afterwards.

Our analysis utilized "lumping" technique when making initial comments about the excerpts and during code creation. Lumping is used to find the key thought from multi-word excerpt through concentrating it into a single code (Saldaña, 2009). Opposite of this method is called "splitting", line-by-line division of excerpts into multiple codable segments (used by e.g. Graziotin, Fagerholm, Wang & Abrahamsson, 2018). Lumping is mentioned getting to the "essence of categorizing a phenomenon", with splitting allowing more nuanced analysis through multiple created codes. Lumping was chosen based on the targeted analysis goal (finding uncertainty categories) and length of interviews. Possibility of lumping leading to "superficial analysis" (Saldaña, 2009) was considered and managed through integration of affecting antecedent constructs into emergent codes. Example of this was a technology-related comment, which was coded into version that included the main interpretation ("Interpret: Technological changes cause uncertainty") followed by an explanatory ending used by the interviewee ("e.g. not being sure if you are using technology that is obsolete within 2 years"). This approach allowed us to condense the main reasoning, also retaining possibly vital information.

In technical terms, analysis used two software for information management (Atlas.ti 8 and Microsoft Excel) and manual sorting of codes during category creation. Atlas.ti 8 allowed highlighting and commenting of transcribed text. These markings were exported to Excel via build-in tool of Atlas.ti 8. Main coding was done in Excel, which allowed us to see all vital information of each excerpt (ID, Document, Quotation Content, Comments, Codes) in a single line. Trimmed lines (now including ID, Document and Codes -sections) were printed, separated and distributed into categories. All codes and emerging categories were visible at the same time, allowing quick comparisons and reconsiderations to be made.

4.2.3 Methods applied in categorization

Creation of uncertainty categories consisted of multiple phases. Our approach applied the conventional content analysis by Hsieh and Shannon (2005). Categorization started with every code positioned into a single "backlog". Codes were then randomly selected from the backlog and distributed separately, allowing similar concepts to be grouped together over time. Some groupings emerged based on the initial notes of the researcher (e.g. Customers' skills and knowledge), as codes related to this uncertainty area were prominent in most interviews. Some categories started to emerge after only few codes, e.g. Needs of customers (including requirement-related uncertainties) and Communication (confusion about the meaning of things, lack of communication). If the code was considered too unclear for new category or not fitting the current categorization, it was placed back to the backlog. This iterative process was repeated 3-4 times until all codes were distributed into categories or excluded from categorization.

First iteration of categorization included total of 11 categories, consisting of 175 codes gathered from 10 interviews. This version was deemed lacking as it included extreme disparity between category sizes (smallest 4 codes, largest 45 codes), was partly based on descriptive grouping (sorting based on external characteristics, e.g. occurrence of certain words) and lumped apparently differing statements under the same definition. To overcome these problems, categories were divided into sub-categories and reorganized based on their relationships between other categories. Alterations included e.g. positioning of uncertainty category of "Management" as high-level category and transferring "Roles and responsibilities" under it, based on the general notion of these codes being consequences of failing management practices. Another example included creation of a new high-level category "Workforce", linking together existing and newly emerged categories. This label combined existing "Worker skills" and "Worker availability", allowed emergence of new sub-category "Doubts about personal competences" and was noted to embody "Lack of trust", earlier positioned under "Communication"-category, more accurately. These revisions were considered through axial coding of grounded theory, managing to enrich the existing conclusions.

Second iteration of categorization was realized after inclusion of two new interviews, conducted in late 2018. This brought the total number of processed interviews to 12. 28 codes were derived and distributed into existing categories. Only 3 codes were deemed as unsuitable for existing categories, suggesting some validity within current proposal. Following this, unclear codes and current categories were revisited with codes dismissed or re-designated if considered necessary. Second iteration included total of 9 categories and 22 sub-categories, consisting of 172 codes. Categorization is present in table 1 in the chapter 5.1.

4.3 Research methods for survey

One of the goals of the research was to quantify the found uncertainty categories and their sub-categories, allowing us to assess the perceived importance of categories. Achieving this outcome was deemed inaccurate based on purely qualitative analysis, driving us to use different approach for more accurate results. A survey, consisting of a digitally distributed questionnaire aimed at IT professionals, was created based on this notion. Following chapters describe the survey design and used analysis.

4.3.1 Survey design

Survey included total of 6 preliminary (demographic) and 28 survey questions positioned into starting page and 9 question pages. Survey questions consisted of statements e.g. "Lack of communication with the customer causes me uncertainty", combined with five response alternatives and one avoidance alternative ("Did not understand / question not relevant for me"). Response alternatives were Not at all - A little - Some amount - A lot - Very much, following the 5-step Likert scale. Each question page included an optional text box for comments, allowing answerers to include their personal input about the subject. English and Finnish versions of questionnaire were created in parallel, allowing us to focus on the meaning of given statements instead of translating them directly. Questions used in the questionnaire are available in appendix 1.

Likert scale, described as a "technique for the measurement of attitudes" (Likert, 1932) was used as the questions were designed to measure the interviewees' level of agreement with given statements. Based on the division made by Clason and Dormody (1994), our survey used limited version of Likert scale as the questions derived from sub-categories were used to combine single composite score (perceived importance of the whole category). Individual questions were also utilized independently in the analysis, following Likert type -classification. Survey was used in support of existing analysis, and we saw Likert scale having the best fit for researching the perceived importance of uncertainties.

Questions were based on categories and sub-categories explained in chapter 5.1. Most of the questions were derived directly from their sub-category. Some sub-categories had clear uniting theme but included internal dissonance, prompting us to divide the sub-category question into two for more accurate results. Four categories were processed, including Communication-category's sub-category "Lack of communication", Technologies-category's "Understanding the current usage", Situational clarity-category's "State of the project" and Customer's skills and knowledge-category's division into "experience"- and "skill and knowledge"-based questions. These divisions can be understood as an extension to the earlier content analysis. Example of the process was sub-category "Understanding the current usage". It was noted to include both uncertainties connected to currently used technologies and more specific mentions about difficulty of choice, heavily connected to choosing of best technologies for the project. Even if the higher-level construct (uncertainty in utilization of current technologies) stayed the same, these two viewpoints couldn't be stated through single question. Statement was divided into two: "Current technologies cause me uncertainty" and "Choosing the most fitting technologies for the project cause me uncertainty". Divided statements were named "Understanding the current usage 1" and "2" for reporting purposes, visible in the survey results-chapter (chapter 5.3). Similar process was repeated for other questions.

Questions were designed to correspond to the theme of their base sub-category or category without making the questions too specific. This was to allow respondents with different job descriptions, e.g. software developer, project manager and consultant to answer the questions from their personal viewpoint. Usage of avoidance alternative allowed us to prevent the forced choice -bias resulting from a faulty scale (Choi & Pak, 2005). Divisions of sub-categories into two (when considered necessary) allowed us to further control the ambiguous question- and complex question -biases that could lead respondents answering to totally different subject than initially thought.

4.3.2 Analysis

Survey analysis methods included descriptive statistics and limited comparisons based on the preliminary information of the respondents. Category and sub-category results were reported in averages. Relationships between two categorial variables were observed through cross-tabulation based on the averages. Example of this was division of respondents into two groups ("in an organization with 100 or more people" and "in an organization with under 100 people") and comparing the groups' response average to single question "Changes in the project requirements cause me uncertainty" (results of 3.62 and 2.9, respectively). All question averages could be combined into single average, giving us a numerical data on how much the respondent group agreed with given statements. We refrained from using more complex comparisons and data analytics based on the limited number of survey responses and the survey's main purpose of supporting earlier content analysis.

5 RESULTS

5.1 Content analysis results

Uncertainty categories were identified as an outcome from content analysis conducted to interviews. Table 1 includes the category name, sub-category name, number of interviews used in the sub-category creation, codes in sub-category and total number of codes. Contents of each sub-category are explained in the following sub-chapters.

Table 1: Uncertainty categories, interviews and codes

Category name	Sub-category name	No. of interviews	Codes	Total
Communication	Lack of communication	7/12	12	20
	Confusion about the meanings	2/12	4	
	Lacking means of communication	4/12	4	
Technologies	Concerns about the future	7/12	9	14
	Understanding the current usage	4/12	5	
Workforce	Retaining skilled workers	4/12	8	35
	Lack of "best workers"	4/12	5	
	Worker skills	6/12	8	
	Doubts about personal competences	5/12	6	
	Lack of trust	4/12	8	
Needs of customer	"Wants" vs. needs	8/12	16	35
	Changing requirements	3/12	5	
	Confusing requirements	7/12	14	
Management	Roles and responsibilities	3/12	5	13
	Managerial practices	7/12	8	
Customer's skills and knowledge		8/12	13	13
Situational clarity	State of the project	4/12	6	15
	Context of the project	6/12	9	
Development: External uncertainties	Legislation	2/12	4	8
	Markets	3/12	4	
Development: Internal uncertainties	Organizational bureaucracy	4/12	7	20
	Project necessities	5/12	8	
	Unexpected changes	4/12	5	

5.1.1 Communication

Lack of communication combined failing inter-team and customer-developer communication. Uncertainties rose when communication was not frequent enough with the customer (leading to possibility of focusing on wrong things), team was not informed enough (leading to rumours), having no information about the final implementers of the project (their skills, experience) of the project and trying to accomplish unrealistic goals (unclearly communicated by different project parties, leading to development through non-appropriate technology or methods). Uncertainty was caused by necessary information not being shared between participants.

> ″…large factor is project team's communication, and if the (adequate) information is available for team member, preferably in the right time.″

> ″… Yes, it [uncertainty] is in a sense lack of communication and lacking distribution of information. And then the common understanding about the specifications or what the system or software should do… I would rise the reason of "why the system is being made". Who it serves, and what value does it deliver and to who.″

Confusion about the meanings included problematic differences in terminology, not knowing for sure if someone understands same things in a same way as you and cultural differences stemming from international projects. Uncertainty was caused by conflicting ways of relaying the same information, leading to confusion between participants.

> "… 'Name' especially is not clear, e.g. information has to be divided into small parts… it's hard to explain to business people why this (apparently) simple thing must be honed, [because] it is in technical terms complicated."

Lacking means of communication included problems caused by difficulties in finding necessary information, organizational "knowledge hierarchy" leading to assumed "trickle-down" of information which in reality does not happen, communication methods not supporting wanted results and organizational entities not being able to access common resources adequately. Uncertainty was caused by problems in accessing and delivering information.

> "… when we communicate only through phone… it's [just] all talk. Uncertainty is in what was agreed on, what was said and what left unsaid. So I prefer written text and the like…"

5.1.2 Technologies

Concerns about the future compromised of uncertainties based on the change, including introduction of new technologies (differing from current ones) and having to learn and adapt all the time (to be prepared for the unknown future). Uncertainty was caused by rapid change and having to predict the future.

> "With the technology… the thing is that new things come all the time and you don't know if you are investing in technology that is going obsolete after few year (forcing you to do it all again). There has to be research that the right technology is chosen with IT-system you continue working with."

Understanding the current usage included uncertainties stemming from not knowing the technological dependencies which might affect the created solution, not knowing what technology would best fit your work and lacking understanding about project-related technologies. Difficulty of choice seemed to emerge from lack of understanding about current technologies. Uncertainties happened when information about technologies was not available, including confusion about the characteristics of technologies.

> "For example that virtualization and robotics, when they are not understood by all personnel, who are for example in the project and then do not understand how, or what kind of technology it is and where it can really be used and what restrictions it has."

5.1.3 Workforce

Retaining skilled workers had its roots in the labour mobility (worker can easily quit, leaving you in a hurry to find new, suitable personnel), possibility of the "best workers" leaving the company, external changes (e.g. economic growth) leading to increased competition on development resources and possibility of organizational changes leading to uncompetitive intra-organizational wages (causing uncertainty about workers staying in their position). Uncertainties can be considered being caused by numerous reasons, including lack of knowledge about workers' future plans and external changes (competition from same skilled workforce).

> "…that if we invest in some worker, you cannot know for sure if it's still with us here for five years, doing some large-scale things… that kind of uncertainty comes from that."

Lack of "best workers" mentioned limited availability of best workers, lack of experienced personnel (lots of trainees in a team) and changes in business models leading to uncertainty about availability of needed resources (personnel with wanted technological knowledge). Uncertainty causes were not evident, with both lack of information in availability of necessarily skilled workers and general lack of skilled personnel being noticed.

> "Well the workers of course, [we] want best workers, in increasingly growing numbers… even in international stage there's a lack of so called best workers"

> "[When thinking about the resources] it's challenging when… if we manage to get enough the experienced personnel to the projects"

Worker skills included concerns about resources (who are the implementers, their competences), experience of team members (green and seasoned personnel work differently in development projects), having concerns about someone possibly lagging behind in work or not knowing their "stuff" (uncertainty about the quality of their work) and accumulation of knowledge, skills and responsibilities to certain, few personnel. Uncertainties were caused by not being sure about the quality of the works (that your tasks might depend on) and not knowing the competences of related personnel.

> "… you realize that someone might not know their thing and [you're] not sure if that someone can do it at all, or do it in quality that should've been done…"

Doubts about personal competences included doubts about managing new projects, lacking understanding about personal situation (skills and abilities to finish promised tasks), not being sure if your competences are enough for new tasks and if your skills are fit for the task. Uncertainties are caused by lack of information about needed competences.

> "Then there's uncertainty about what I can do… what all can I still promise to join-in and does my promise hold (for everything I've promised to do in the project). Maybe if you promise to take too difficult tasks… there's uncertainty if you can even accomplish them."

Lack of trust included lack of trust between personnel (not asking other workers for help, not being able to trust that tasks will be carried out), lack of trust caused by bad working environment, "atmosphere" (not daring to ask for help, not being able to question other's decision or "speak up"), being micromanagered (signalling lack of trust to worker's competences) and lack of trust into other personnel's doings (caused by work left undone and not including everyone into communication). These notions indicate uncertainties being caused by both skills and knowledge of workers (ability to produce sufficient results) and information deficiencies connected information not being transferred in satisfactory amounts and having to trust others based on information (information that might not be "relayed far enough, down the line"). Unifying cause behind lack of trust -uncertainties remained unclear.

> "It's the atmosphere that we try to build in a project, that we trust and are open, can speak about things with their real names and get help and seek for right direction, because you also cannot be sure about if the task that I just give is so simple that it seems in that moment, when the task is given…"

> "It is important that you know or you can trust that you can do your thing undisturbed, especially when… if the jobs are connected to each other. And so that you don't arrange things behind other's back and you have done [end up with] lots of unnecessary work, and that what is said to you, you can trust that it holds true and haven't changed. If you say to project manager that "these things are going badly, can you bring up those?" and project mgr. promises to do this in e.g. steering group but if he doesn't… [you] don't really bring up problematic things in the same way. In general, it's easier

> to be in contact with people through phones, messenger and email when you know that those people are trustworthy, that you can ask that one for help and get it immediately. And you can trust that information you get is proper, "right".

5.1.4 Needs of customer

'Wants' vs. needs incorporated the differences between initial customer needs and realized "true" needs, dealing with disparity in the expectations and reality. Sub-category included differences in understanding the project's meaning, "true goal" through requirements, prioritization of requirements (based on end product's usage), differences between initial expectations ("simple, swift work") and real situation (problematic work dimensions being ignored), not knowing what you are really trying to accomplish and lack of understanding about the "final, ultimate need" of the customer. Uncertainties were caused by lacking and conflicting information about the goals and needs of the project, amplified by the "noisiness" (inclusion of unnecessary data) during requirement identification.

> "Biggest single factor is maybe that we would understand what is really pursued with that project. So… understanding the needs of the customer"

> "It might sound like an easy task, but it really isn't. That requirements can be conflicting, they can differ a lot based on stakeholders and there can be "latent agendas", all sorts of things behind there, all sorts of things that affect [the project]. Bigger the project, more important it becomes to understand these kind of things."

> "… the "end goal" is not clearly in mind, where we are headed, it isn't precisely defined what we really want as output of this project- if the requirements are defined in title level and they say "to be defined later" and you should implement them at that point, it doesn't… really help from the point of view of software developer."

Changing requirements included rapidly changing requirement in agile projects (inclusion during the project, forcing schedules to change), external directives forcing rapid alterations and requirements given in multiple customer "levels" (e.g. legislation and functionality -related), requiring rapid responses. Uncertainties were caused by information volatility (unpredictable, sudden changes) and conflicting information (new changes introduced in the midst of execution of earlier ones).

> "… if you think about any service provider and their customers, their customers' intents can change and do change all the time. And when you think what defines customer requirements for services, very often it's not the competitors in financial sector but the external happenings that define those… so when we start developing it is one part of it, wanting to respond to those [changes] with systems and technologies but "not without a reason". So it must be efficiency and better service that is pursued in the end."

Confusing requirements included ambiguity (suom. tulkinnanvaraisuus) of requirements, lacking and badly made requirements, unnecessary abstraction of requirements (having to guess what was meant, unclear definitions) and subpar specifications. Uncertainty was caused by lack of and conflicting information about what was wanted (by the customer).

> ″This understanding through requirement management, that what we are doing and why, it is a clear one [cause of uncertainty]″

> ″… usually higher-up it [requirement] comes, more abstract it is… …If though through technological side, then this kind of business requirement, when we start developing some system, it should be very specifically described. Unfortunately, I can say from my own organization that it is not so.″

5.1.5 Management

Roles and responsibilities included uncertainties stemming from "product owner" responsibilities not being clear, confusion about responsibilities leading to overlapping work, not knowing who to contact for information (who is a stakeholder, their roles and responsibilities) and not knowing your own roles and responsibilities connected to those roles. Uncertainties were caused by lack of information about the positions and liabilities of participants in the project.

> ″… if you have unclear responsibilities, it is a thing that easily creates uncertainty or duplicated work, that no-one does that work, those "drop-outs"… it is especially important.″

Managerial practices included uncertainties stemming from functions linked to project management. Uncertainty codes included organizing new projects (new customer and their habits unknown, difficulties in creation of a new project organization), challenging cross-team projects (not knowing how to go through with those), project manager's inability to prioritize tasks and resource them and handling the "overall management" (e.g. differing, changing tasks that are not supported by working structures in place). Identified uncertainties pointed towards difficulties related to managerial tasks but the causes behind these were not clear.

> ″… these are some projects that are made within IT-services, cross-team, even exceeding internal borders. There have been sort of difficulties or uncertainties in the way how the project should be accomplished… or other, project-managerial difficulties like this.″

> ″… project manager does not know how to define what things should be priority one, what things should really be done first and what left last to wait for making, not knowing how to resource the "real" things too″

5.1.6 Customer's skills and knowledge

This category included numerous mentions about the customer's skills and the effect of those to accomplishing the project. Sub-categories were not utilized as most codes seemed to refer to the same higher-level construct. Some indications about differing effects of customer's experience (of working with system development projects) and customer's skill and knowledge (abilities connected to system development) to perceived uncertainty were visible. Category's codes included customer's lack of knowledge about "buying a development project" (working with systems development), stakeholder's inability to define requirements, customer's lack of knowledge about technologies leading to focus on irrelevant requirements and customer's lacking skills and understanding to direct the project team (towards the wanted goal). Uncertainties were caused by lacking skills, experience and knowledge of customer.

> "… great factor causing uncertainty is that the customer hasn't bought a software project earlier"

> "…when the customer does not understand technology, it might concentrate on that kind of things that are (from requirement's point of view) hard, but technically easy to conduct. However customer must set the "level", which requires communication that we get it reasonable… when the customer does not know their own need in that situation."

> "… customer usually knows what they want, but in this case you can do things with that thing in many ways that they don't necessarily understand how they want it done. And again [they] don't necessarily understand to give that [task] for us, in a way of "do it the way you see fit"."

5.1.7 Situational clarity

State of the project included having no clear picture about the ongoing progress of the project, difficulties in understanding the overall situation and lacking knowledge about current situation, forcing you work on top of "unknown" (build upon guesses). Uncertainties were caused by lacking necessary information about the project's current standing.

> "…The creation of the overall picture is very important… the agile development and such, it easily creates uncontrollable chaos especially in the beginning of development, so already in that phase you should be able to build what you start from, where is the desired state you seek and divide the journey intro controllable parts. I'm highly stressed if I can't see what we've done, where we are going."

> "…are we going to finish the end product, are things going according the plan, what's the budget situation, how our quality behaves in each stage of doing… all of these project management's dimensions are important to get quantified. Data is very important from my point of view, in the management of uncertainty."

Context of the project included not knowing what the people connected to the project are doing, not knowing the surrounding context of the project, lack of knowledge about doings of different organizational parts (e.g. leading to overlapping releases, causing confusion and problems) and working with external factors (not knowing how they'll react or act). Some division in this sub-category was noted, namely to the lack of knowledge about doings of people (colleagues, co-workers) and to lack of knowledge about "external" project situation (state of other involved teams, state of possible other systems being developed). Uncertainties were caused by lack of necessary information about context surrounding the project.

> "… you don't know what else is going on with the team members, that the member can be aboard other projects and those other projects- do [the team members] prioritise them more highly and don't focus on this project…"

> "… there are many moving parts at the same time, e.g. if we develop some new IT-system and around it there are five other IT-systems in development, which all have to integrate into it and synchronize all tasks with them… then you don't know what everyone else around it are doing"

5.1.8 Development: External uncertainties

Legislation included changes in EU-level (e.g. GDPR, not knowing what has to be changed, what is considered as "personal data"), unfinished regulations (e.g. things utilizing modern networking technology being ordered but the standard for it not being finished) and overall changes in politics (e.g. new sex "other" being required in new systems). Uncertainties are caused by lack of information about the possible and happening changes in legislation.

> "Then the timetable… you cannot be sure in what timetable the new regulations come, which can affect decisively all the systems inside the company, for example."

Markets included continuously altering IT-field, changes in competitive situation and changing economics, competition and economic situation affecting sales and continuation of sales being dependant on unpredictable changes in the market. Uncertainty is caused by lack of information about market situations and possible events taking place surrounding it.

> "… if you think about software development and role of public sector, development happens there, there's for sure a competitive situation, and sudden economic upturn, which of course leads to uncontrollable risks, which are of course reflected through uncertainty. So you think, for example we had two years ago kind of belief and knowledge that economic rise will continue at significant rate and [-] will be top grower within technology industry in Europe, well, that… not necessarily [true]."

5.1.9 Development: Internal uncertainties

Organizational bureaucracy included disruptive organizational changes (e.g. top-down changes to project organizations), hierarchical flow of information leading to confusion about who made the decision and what it really means and problematic organizational bureaucracy. Uncertainty was caused by organizational bureaucracy amplifying or causing problems during changes in the organizational situation.

> ″Internally, all organizational messing around, and bureaucracy- is an uncertainty factor″

> ″… necessarily the information from the project team, about what is [perceived] important and what isn't, something like what is going badly in the project… does not necessarily reach the top, decision making level [of the organization]″

Project necessities referred mostly to constructs related to traditional project development aspects (cost, scope and schedule influencing the quality of results). Codes included budget concerns, availability of knowledge and skills, schedule concerns, estimations of cost and schedule and lack of required resources. Uncertainty was caused by lack of information about availability of resources in the projects.

> ″… if we talk about uncertainty as uncertainty, then it connects to some kind of things like budget or availability of expertise or schedule…″

> "… well the evaluation of things beforehand, on the other hand it relates… it is connected to requirement management, but those… evaluation of things beforehand, how long does this take, how much does this cost, how different changing situations affect the costs, schedule… these are some clear ones that come to mind″

> ″…longevity in the development, that some project might have its resources retracted to some other project, that other project comes from behind even though that other project might have been a "spearhead", worked for few months…″

Unexpected changes included introduction of sudden extra work, possibility of someone getting sick, changes to the project itself during the project and constant possibility of changes happening. Uncertainty was caused by volatility of information, caused by sudden changes.

> ″…external factors, that you cannot influence, if someone gets sick, gets hurt or is for some other reason inhibited from coming to work″

5.2 Core category

Indications about the overarching "core" category arose during second iteration of categorization. Selective coding present in grounded theory (Corbin and Strauss, 1990) allowed us to approach this analysis in systematic way. We noticed the high occurrence of "Lack of…"-statements by the interviewees, often referring to a missing vital information required for someone to make decisions. It quickly became apparent that most of the codes were heavily influenced by the quality, availability and distribution of information. Still, some of the uncertainties seemed not to be directly caused by information deficiencies but were instead influenced by the characteristics of involved people: their knowledge about the subject area, prior experience, personal skills and expertise in related fields. These person-related uncertainty sources were often coupled with their effects on information, e.g. confusion about wanted features of the project deliverable caused by customer's lack of technical knowledge.

We identified two main reasons behind found uncertainties: **information** (suom. tieto), e.g. lack of information, information being conflicted or "noisy", having too much of it (leading to difficulty of choice) and **knowledge/skill/expertise/experience** (suom. taito), including e.g. participants not knowing what to do, lacking knowledge about the area of concern and lack of experience resulting subpar results. Identification of these two main constructs prompted us to revisit the established sub-categories and write down notes answering the question "what is the core cause behind listed uncertainties?". Answering this question was aided by supplementary questions, e.g. concentrating on found cause of uncertainty and asking what kind of action would help managing it. Core category was considered individually for each subcategory based on their contents (codes).

Results of this analysis were coded as "uncertainty types", representing the most prominent type of uncertainty in observed division of uncertainty into "information" and "knowledge/skill/expertise/experience". Analysis included the perceived "uncertainty source", stating the pragmatic reason behind uncertainty in this category. Type and source were often noticed simultaneously. Example of this process was sub-category "Lack of communication" which was noted to consists mostly of uncertainty codes that would be resolved through inclusion of new information. Sub-category uncertainty source was coded "Lack of information" and type "Information". Another example was category "Customer's skills and knowledge" which was noted to primarily consist of codes related to lacking skills, absence of prior experience and inflated expectations of customer (caused by lack of knowledge about how system development operates). Category's uncertainty source was coded "Lack of required skills + Lack of experience + Lack of knowledge" and type "Knowledge/skill/expertise/experience". Results are visible in table 2.

Table 2: Uncertainty categories, types and sources

Category name	Sub-category name	Uncertainty type	Uncertainty source
Communication	Lack of communication	Information	Lack of information
	Confusion about the meanings	Information	Conflicting information
	Lacking means of communication	Information	Lack of information
Technologies	Concerns about the future	Information	Lack of information
	Understanding the current usage	Information	Lack of information
Workforce	Retaining skilled workers	Information	Lack of information
	Lack of “best workers”	Unclear	Unclear
	Worker skills	Knowledge/ skill/expertise/ experience	Lack of required skills + Lack of experience
	Doubts about personal competences	Information	Lack of information
	Lack of trust	Unclear	Unclear
Needs of customer	“Wants” vs. needs	Information	Lack of information + Noisy information + Conflicting information
	Changing requirements	Information	Information volatility + Conflicting information
	Confusing requirements	Information	Lack of information + Conflicting information
Management	Roles and responsibilities	Information	Lack of information
	Managerial practices	Unclear	Unclear
Customer’s skills and knowledge		Knowledge/ skill/expertise/ experience	Lack of required skills + Lack of experience + Lack of knowledge
Situational clarity	State of the project	Information	Lack of information
	Context of the project	Information	Lack of information
Development: External uncertainties	Legislation	Information	Lack of information
	Markets	Information	Lack of information
Development: Internal uncertainties	Organizational bureaucracy	Unclear	Unclear
	Project necessities	Information	Lack of information
	Unexpected changes	Information	Information volatility

Our findings from the grounded theory selective coding can be summed as follows: Deficient information was the most prominent reason behind found uncertainties in system development, with characteristics of participants influencing the occurrence of uncertainty. Knowledge, skill, expertise and experience of participants were noted to have an effect and sometimes be the main reason for uncertainty formation. **Information is the core category for uncertainty in system development,** affected by the characteristics of participants.

5.3 Survey results

Total of 700 answers with option 1-5 to 28 questions were given by the 26 respondents (maximum of 728). Option 6 (avoidance alternative "Did not understand / question not relevant for me") was selected 28 times. Largest amount of option 6 selections was noticed in question "Lack of communication with the customer causes me uncertainty", 5/26 times. Average of 27/28 questions by each respondent were answered through response alternatives 1-5.

Survey respondents [N = 26] had large variation in their work titles and histories, ranging from software developer and project manager to technology specialist and executive manager. Work histories ranged from 1 to 30 years in the industry, with average of 11 and median of 10 years of work experience. 2/3 of respondents described their work position belonging to their organization's operational level, with 1/3 being in managerial level. Over 80% of respondents worked in private sector. Size of respondents' organizations ranged from 5-19 to over 2000 people, with median in the 100-499 range. 3/4 of the respondents were involved in multiple development-related projects in their work, with 1/4 describing themselves being involved in 0-1 projects. Education histories of the respondents ranged from upper secondary level to Master (or equivalent), with over 60% having finished their Master's.

There were substantial differences in both category and sub-category levels in agreement with given uncertainty statements. In category level, 4 categories were scored around Likert neutral (max 0.25 derivation from score of 3): Communication [3.01], Needs of customer [2.98], Management [2.88] and Customer's skills and knowledge [3.14]. 5 categories were scored less than 2.75, including Technologies [2.39], Workforce [2.71], Situational clarity [2.54], Development: External uncertainties [2.16] and Development: Internal uncertainties [2.58]. Average of all categories was 2.73. Category results are visible in figure 2 (sorted from highest to lowest score).

Sub-category results were diverse and included more variance than category results. Response averages ranged from 3.36 (Customer's skills and experience 1) to 2.0 (Lack of trust). In sub-category level, three sub-categories were scored over 3.25: Lack of communication 1 ("… between people I work with"), Changing requirements and Customer's skills and experience 1 ("…lack of experience in system development projects"). Four categories were scorer under 2.25, including Lack of trust, Markets, State of the project and Legislation. Remaining sub-categories were positioned between these values. Sub-category results are visible in figure 3 (sorted from highest to lowest score).

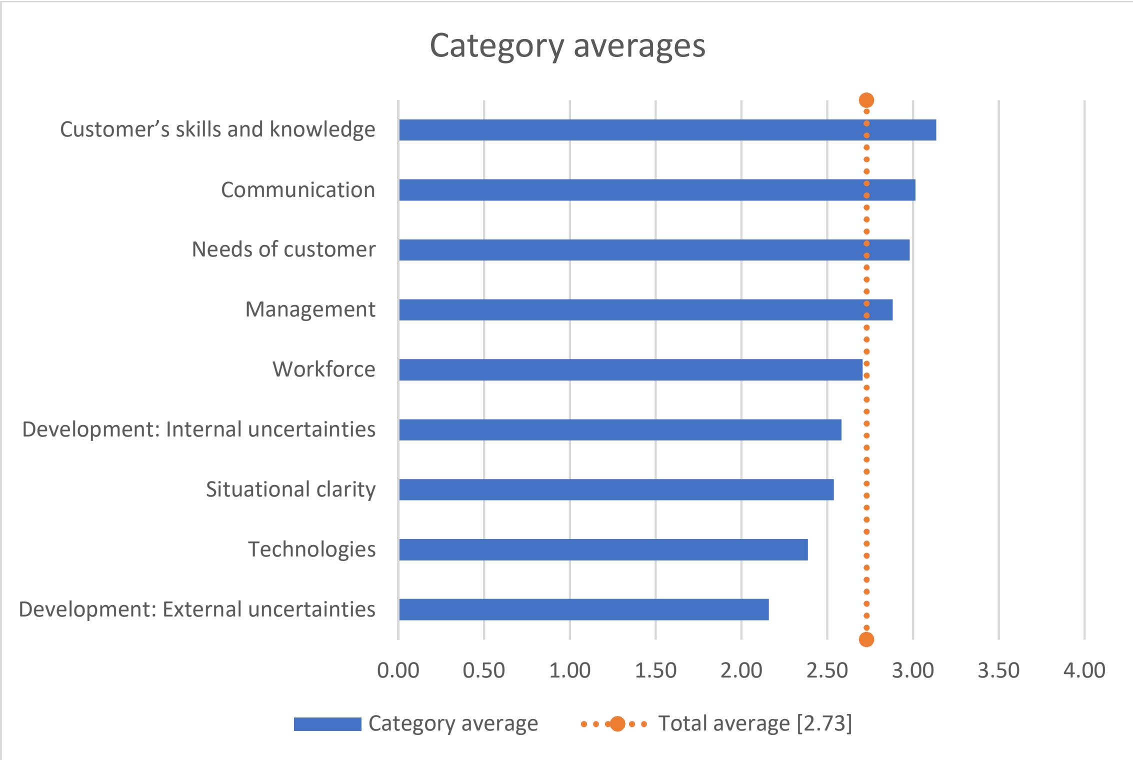

Figure 2: Category averages

Figure 3: Sub-category averages

Numbered sub-categories refer to following divisions: **Customer's skills and knowledge** 1 refers to "lack of experience"-question and 2 to "lack of skills and knowledge"-question. **Lack of communication** 1 refers to internal (inter-team) communication and 2 to customer-developer communication. **Context of the project** 1 refers to lack of knowledge about doings of colleagues and 2 to lack of knowledge about project situation outside immediate team. **Understanding the current usage** 1 refers to current technologies and 2 to choosing of most fitting technologies for the project. Questions created from the sub-categories are found from appendix 1.

Division of respondents into groups gave us some indications about the effect of antecedent conditions to the results. In one case, respondents' answers were divided into groups of "under 100 people in organization" [N = 10] and "100 and more people in organization" [N = 16]. On average, people working in the smaller organizations perceived less uncertainty than people in the larger ones (perceived uncertainty average of 2.45 for <100 group, 2.9 for >=100 group). Numerically largest difference was noted in sub-category "Organizational bureaucracy", where <100 group rated it as 1.7 (between "Not at all" and "A little") and >=100 group as 3.19 (between "Some amount" and "A lot"). Opposite results were found from sub-category "Markets", where <100 group rated in as 2.44 and >=100 group as 1.94.

Another case included division of respondents into two groups, "10 and more years of work experience" [N = 12] and "under 10 years of work experience" [N = 14]. Respondents with 10 or more years of experience perceived less uncertainty from current technologies (1.83 compared to 2.79) than their counterparts. Group averages were close to each other, with 2.75 for 10 more years -group and 2.71 for under 10 years -group. Third case divided respondents into "involved in 5 and more work-related projects" [N = 10] and "involved in under 5 work-related projects" [N = 16]. Group of "5 and over projects" rated Management-related uncertainties relatively highly, especially managerial practices (3.6 for 5 and over -group, 2.47 from under 5 -group). Same type of division was noted in "Organizational bureaucracy" -question. Group averages were 2.88 for 5 and more projects -group and 2.63 for under 5 projects -group. Fourth case divided respondents into "Work position in managerial level" [N = 8] and "Work position in operational level" [N = 17]. Category "Needs of customer" was scored (average of all sub-categories) as 3.44 by the Managerial level -group and 2.77 by the Operational level -group. Total averages of groups were 2.90 and 2.60, respectively. Cases are visualized in figures 4-7 using radar diagrams.

Figure 4: 100 and more people and under 100 people in organization

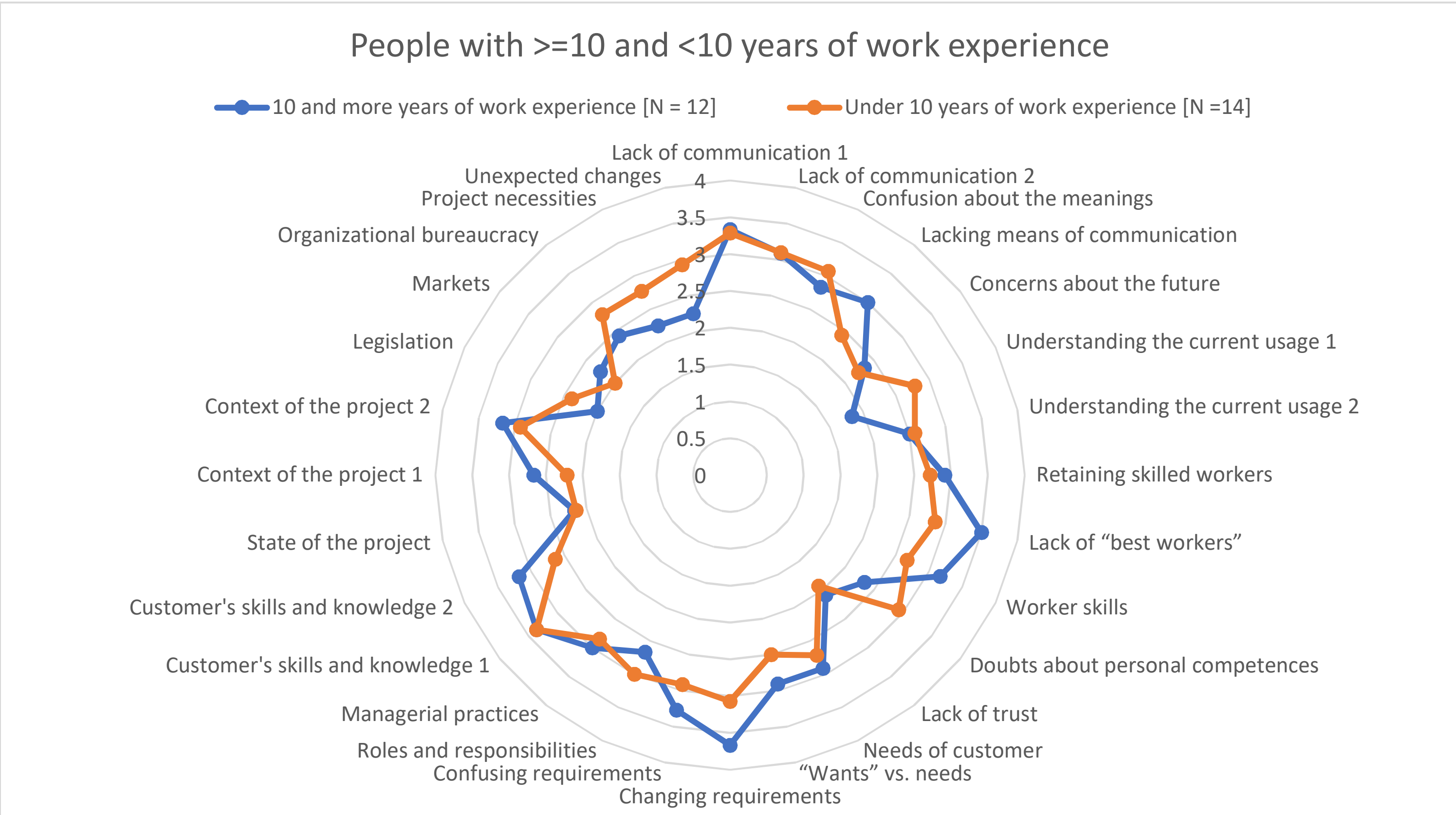

Figure 5: 10 and more and under 10 years of work experience

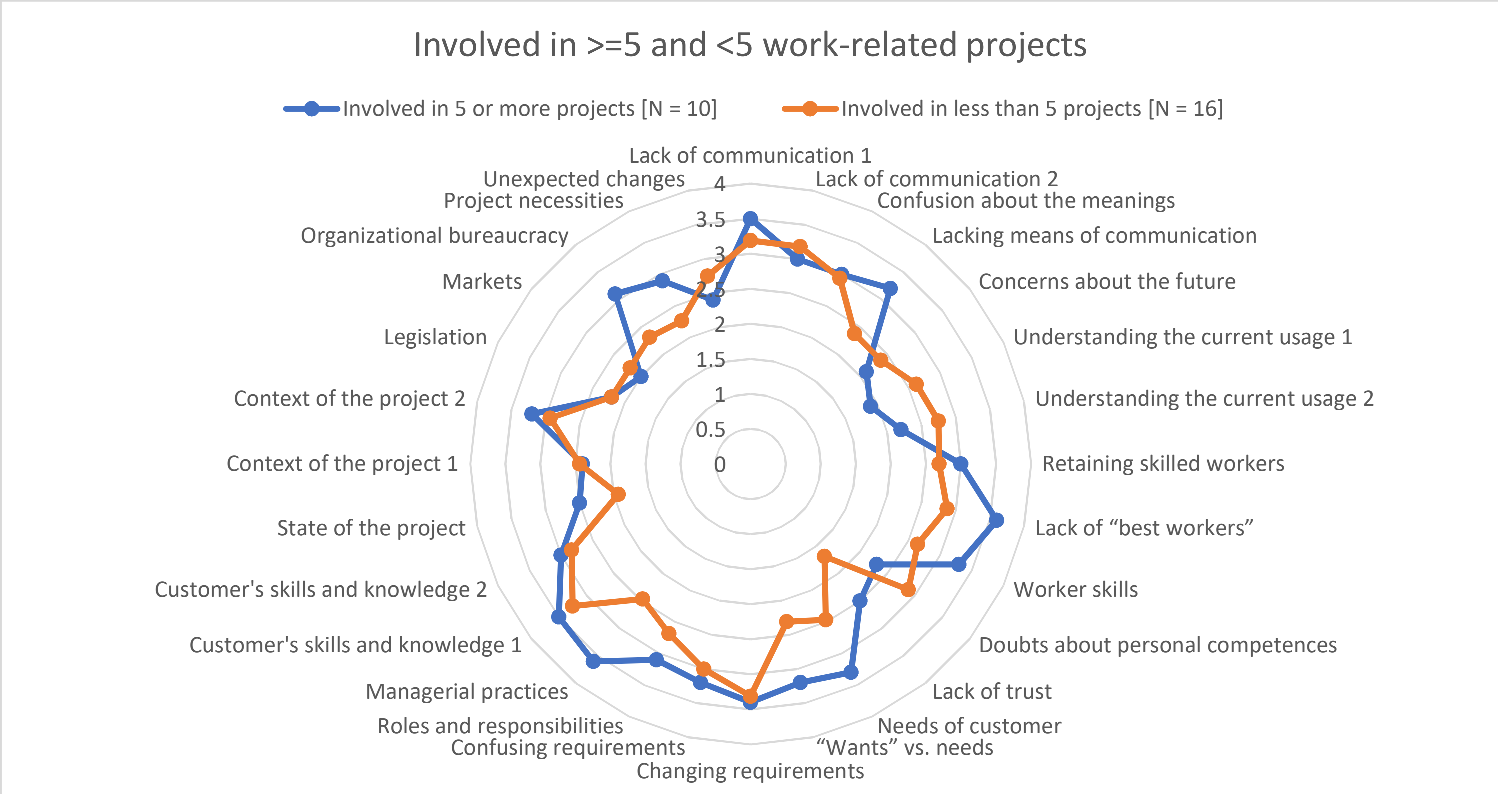

Figure 6: Involved in 5 and more and under 5 work-related projects

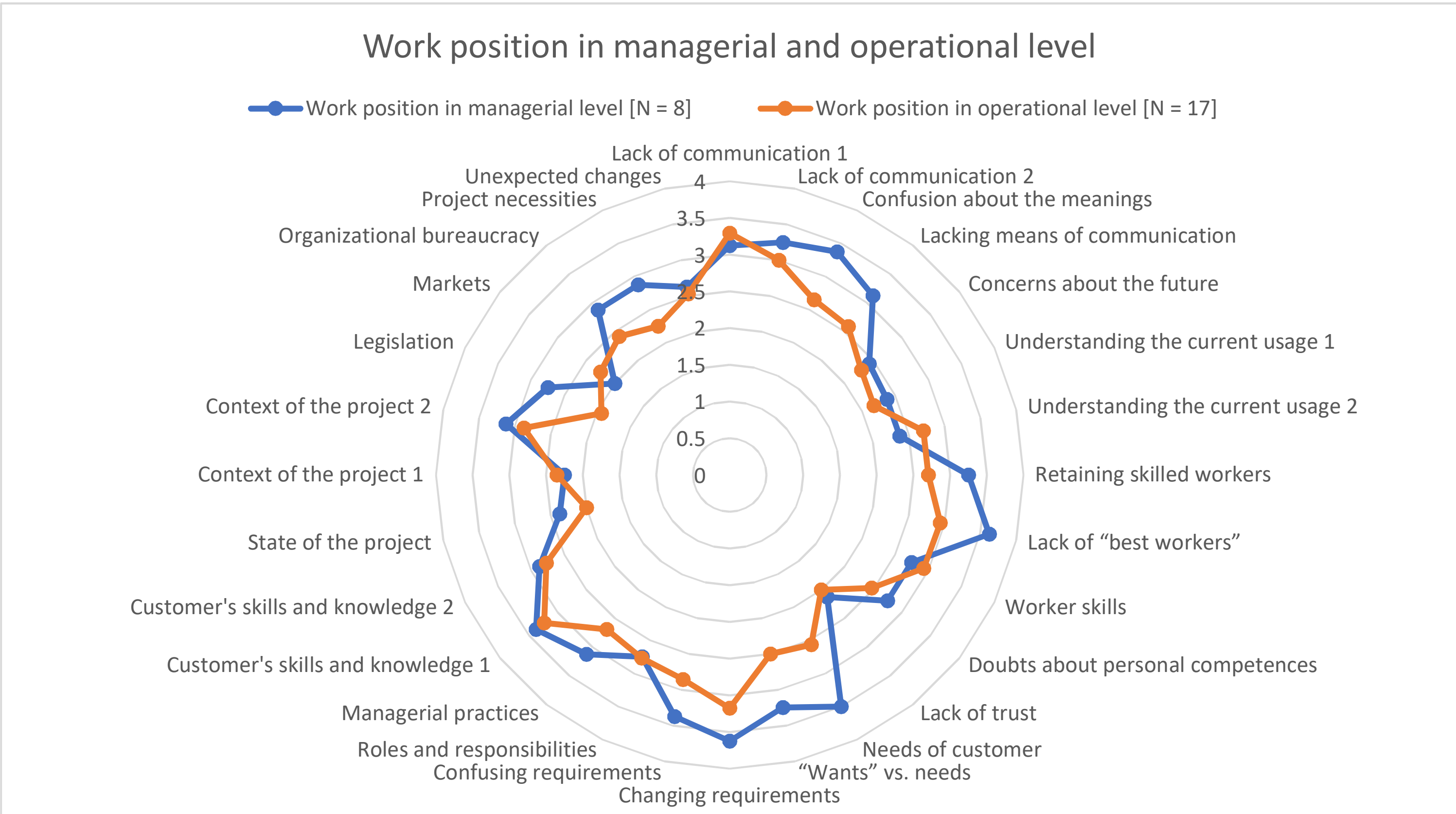

Figure 7: Work position in managerial and operational level

6 DISCUSSION

6.1 Categorization in comparison to prior research

Identified categories were similar to ones found in prior research. Most widespread one was requirement-related categories (e.g. Dönmez and Grote, 2018; Ward and Chapman, 2003; Atkinson et al., 2006). Technologies, management, external uncertainties and internal uncertainties being noticed in multiple occasions (e.g. Jalonen, 2011; Marinho et al., 2014; Petit, 2012). Most common occurrence was partly overlapping categories, e.g. technological complexity -equivocality identified by Sakka et al. (2016) which in turn fit into our more abstract category "Technologies". High variance in understanding what uncertainty is (mentioned in chapter 2.1) is notable in available categorizations, making the direct comparisons challenging. Concepts related to category "Customer's skills and knowledge" were noted in earlier research (Atkinson et al., 2006; Moran, 2014) but only in limited scale. Our categorization was relatively close to findings of Jalonen (2011), both in content and categories. At the same time, three categories identified by Dönmez and Grote (2018), including requirement, resource and task uncertainty, were highly visible in our results.

Our categorization of uncertainties had comparably high fidelity, as it was derived directly from uncertainty codes and described both categories and subcategories used in the categorization. More general, abstract approaches e.g. usage of three major categories by Moran (2014) and two uncertainty categories (combined with two equivocality ones) by Sakka, Barki and Côté (2016) were considered but not utilized. Splitting of uncertainty categories into small parts (only holding in specific conditions) was noted as negative by Grote (2009). In our research this process was required as higher-level, more abstract categories would have been very difficult to turn into questions without large trimming and removal of potentially vital viewpoints. At the same time, results could have benefitted from intermediate results between highly abstract "Core category" and relatively lowly abstract "Uncertainty categories" -levels. Example of this could be the three main categories of uncertainty used by Taipalus et al. (2019, unpublished), including uncertainty causes stemming from within development organization, from the client organization and outside the organizations. Usage of similar "umbrella categories" could benefit the readability and comparability of different aspects of uncertainty.

6.2 Core category

Information was noted as the core category for uncertainties in system development, with the characteristics of participants affecting the formation of uncertainties and being other prominent type of uncertainty. Information as the main, unifying category and identification of information deficiencies as the main source of uncertainty was acknowledged in numerous earlier researches (e.g. Lipshitz & Strauss, 1997; Kolltveit et al., 2004; Johansen et al., 2016). Characteristics of participants, namely knowledge, skill, experience and expertise, were noted to affect multiple information-based uncertainties and sometimes be the main source of uncertainty. The effect was prominent in "Workforce" sub-category "Worker skills" and formed the base for whole category "Customer's skills and knowledge". Characteristics of participants as a major, uniform uncertainty construct wasn't directly assessed in the literature review but still heavily implied, e.g. in task uncertainty ("…knowledge and skills") by Moran (2014) and uncertainty associated with project parties ("…actual skills of anyone involved") by Atkinson, Crawford and Ward (2006).

Identified information-related uncertainty sources followed the outline proposed by Lipshitz and Strauss (1997). Most common source was "Lack of information", comparable to objective "Incomplete information" (you either have or don't have enough required information). Uncertainty source "Information volatility" (e.g. possibility and consequences of sudden, rapid changes in the information or related constructs) was also noted as objective, as its state could be quantified (change from current situation to new one, amount of change). Subjective sources included "Conflicting information" (e.g. having multiple, conflicting cases of information available) and "Noisy information" (e.g. receiving lot of unrequired, "extra" data on top of wanted one). These were comparable to subjective "Inadequate understanding" and "Undifferentiated alternatives", mentioned in chapter 3.1.

Identified uncertainty type "Experience/skill/expertise/experience" differed from "information" type as it was highly person-centric and referred to characteristics of people participating in system development. Two most prominent categories of this type were "Customer's skills and knowledge" and "Worker skills" (sub-category under "Workforce"). These referred to beneficiary of the project and workers on the developer side, respectively. Characteristics of involved people were visible in most categories but rarely emerged as most prominent uncertainty type. Example of this was "Workforce" sub-category "Doubts about personal competences", which was initially noted as being caused by lack of personal skill and expertise. At further inspection, it became evident that the uncertainty was not caused by shortage in personal skills but instead by the lack of information about what the new tasks required from you and not knowing your personal "skill level" (in comparison to future tasks).

Categories coded as "unclear" were noted to not clearly belong to either observed uncertainty type or have no clear source behind uncertainties. Example of this was sub-category "Lack of trust", which had clear uniting theme but individual reasons behind trust issues were unclear. Some could be inferred to be based on lack of information (not being able to ask questions, leading to not knowing things as well as needed), and some caused by lack of skill (poor-quality work of someone affecting your own tasks negatively) but did not form cohesive results. Another example was sub-category "Managerial practices", which included mentions about project manager's lack of skill, problematic distribution of workers into projects and organizing new projects all leading to uncertainty. Uniting theme (difficulties in management of the project) did not clearly signal reasons behind uncertainties.

Distinction of information and knowledge/skill/expertise/experience (of participants) as prominent types of uncertainty in system development raises some considerations. For example, most of the information-based uncertainties can be considered relatively easy to grasp: lack of information caused by poor inter-team communication could be noticed and managed with a short notice, even if the "fix" might not be a perfect one. In comparison, uncertainties stemming from customer's lack of knowledge would have no direct, easy-to-understand and implement -solution. Same problem raises when thinking of the workforce, as concerns about skilled personnel possibly leaving the organization could be controlled through communication or contractual rearrangements, but simply not having wanted expertise available would be much more difficult problem to avert.

6.3 Interview analysis and survey analysis results

Our initial expectations about the perceived importance of uncertainty categories were based on the interview analysis and its results. These expectations were formed based on the number of codes in each category and sub-category and the number of interviews used in sub-category formation (table 1). Some broad assumptions were made: categories and sub-categories with relatively high number of codes and number of used interviews would be perceived as more important by the survey respondents. This included e.g. sub-categories of "Lack of communication" (7/12 and 12 codes), "'Wants' vs. needs" (8/12 and 16 codes) and "Customer's skills and knowledge" (8/12 and 13 codes). Categories with largest number of total codes were expected to be perceived causing more uncertainty by the respondents, including "Workforce" (35 codes) and "Needs of customer" (35 codes).

The results from survey analysis were considerably different than ones from interview analysis. For example, sub-category of "'Wants' vs. needs" (referring to uncertainty caused by differences in mutual understanding with the customer about the goal of the project) was initially thought as a major source of uncertainty but turned out relatively timid (2.70, compared to 2.73 average of all sub-categories). At the same time, sub-category "Changing requirements" was only noticed few times in the interviews but turned out to be one of the major causes of uncertainty for the survey respondents. Some consistency between analyses was visible (number of interviews used in sub-category formation compared to amount of perceived uncertainty), but survey results can be considered as a major improvement over only utilizing interview analysis results.

In the survey, it is notable that respondents agreed with given statements concerning the causes of uncertainty less than we initially thought. This was visible in given ratings, as majority of categories were rated lower than 3 (placing their views between “A little” and “Some amount” -options) with total category average of 2.73. Especially the categories “Development: External uncertainties” and “Technologies” were generally viewed as causing uncertainty less than average. Some exceptions were visible, e.g. “Customer’s skills and knowledge” being rated comparatively highly. Aggregated category results were generally not accurate as the categories included large differences in the ratings of their subcategories, directly affecting the category average.

Comparisons made in the survey analysis based on the respondents’ demographic information gave us some interesting subjects of discussion. For example, respondents in smaller organizations consistently rated their perceived uncertainties lower than respondents in larger ones. Largest separation between groups was noted in “Organizational bureaucracy”-subcategory. Smaller organization size might inhibit the emergence of uncertainty or ease the management of conditions that are perceived uncertain. Latter one might be inferred through the results on “Managerial practices” and “Roles and responsibilities” -subcategories, as both are rated considerably higher as causes of uncertainty by the people in larger organizations. Notable exception to general ratings was sub-category “Markets”, referring to uncertainty caused by the possibility of changes in the market situation. People in smaller organizations perceived more uncertainty from the markets, possibly indicating that market changes affect smaller org. more than established, larger organizations. Size benefits might also make larger organizations not as dependent on a success of a single product or service, making larger organizations more robust to external uncertainties.

Amounts of perceived uncertainty by the respondents with different work experiences were generally close to each other. Notable results included ratings of category “Development: Internal uncertainties” and sub-category “Doubts about personal competences”. People with more work experience experienced less uncertainty from organizational bureaucracy, availability of project necessities and unexpected changes. At the same time, difference in the ratings of “Doubts about personal competences” might suggest that more experienced personnel are not as heavily affected by internal, project-related uncertainties and know their own competences better. Another comparison, being involved in “5 or more” or “Under 5” work-related projects, suggested that being involved in large number of work-related projects makes uncertainties from organizational bureaucracy, management and workforce more prominent. Results might indicate the increase in perceived uncertainties under increasing workload, creating need for better managerial and organizational support for conducting diverse, large-scale tasks.

People working in managerial positions perceived more uncertainty from needs of customer (requirements), skilled workforce remaining in the organization, availability of “best workers” and general communication. On average, uncertainties were also perceived more by the people describing themselves belonging to managerial level than ones in operational level. One reason behind this might be that being involved in broader array of tasks makes encountering, and subsequent perceiving, uncertainties more common. Noted areas of high uncertainties have also traditionally been positioned under managerial tasks (e.g. gathering, analysing and delivering requirements for project team), leading to possibility that uncertainties in those areas are noticed more easily.

Categories had varying scores and perceived uncertainties. Some mentions are presented below, with categories arranged in ascending order based on their category averages. **Development: External uncertainties** consisting of legislation changes and market situation were not perceived as notable uncertainties for people working in the system development. Some differences emerged, but the category was constantly rated not important. **Technologies** were overall not seen as causing uncertainties, including considerations connected to both future and current technologies. **Situational clarity** included mixed results. Uncertainty amounts stemming from lack of knowledge concerning the current state of the project and current tasks of respondent's colleagues were rated low. At the same time, uncertainty from lack of knowledge about project situation outside the immediate project team was rated high. These results might indicate that respondents were comfortable with their immediate surroundings but having a bad situational clarity about changes in the surrounding context (e.g. situation of other systems being developed) lead to uncertainties. **Development: Internal uncertainties**, including organizational bureaucracy, project necessities and unexpected changes were not notable causes of uncertainty. In some cases (e.g. high rating given by people in organizations with 100 or more people) contents of this category were seen causing relatively much uncertainty, but overall the category was considered unimportant. **Workforce** was rated relatively neutral, with exceptions of "Lack of trust" being rated very low, "Doubts about personal competences" as comparatively low and "Lack of 'best workers'" comparatively high. Main uncertainty areas within this category were connected to supply and availability of people with sufficient skills, indicating largest workforce-related uncertainties being caused by uncertain supply and problematic retaining of skilled personnel.

In comparison to other categories, four categories emerged as most important areas of uncertainty. **Management** was rated mostly neutral, with some notable deviations (e.g. high ratings given by the "involved in 5 or more projects" and "100 or more people in the organization" -groups). These results might indicate the failings of managerial practices and role distribution causing uncertainties, increasing with the size of managed organization. **Needs of customer** was overall rated neutral and high, with "Changing requirements" rated highly and "'Wants' vs. needs" comparatively low. Requirement-related uncertainties were prominent throughout the interview analysis and mentioned numerous times in prior research. Changing and confusing requirements were few of the main uncertainty causes identified from the survey results. **Communication** was rated neutral or high, with one sub-category ("Lacking means of communication") rated relatively low. Category itself emerged as being perceived causing more uncertainty than average, with especially "Lack of communication" (… between people I work with) rated high. Communication as a whole emerged as one of the main areas of uncertainty. **Customer's skills and knowledge** was rated neutral and high, with especially "Customer's lack of experience working with system development projects" emerging as causing relatively high amount of uncertainty. The category was almost unanimously scored as being the most prominent cause of uncertainty, indicating the high effect of characteristics of participants (customer, in this case) to uncertainties.

6.4 Implications for research and practice

Usage of multiple research methods were a great help during research analyses. Creation of a survey forced us to transform existing results into question format, which in turn allowed us to identify aspects about the results that were previously unclear (e.g. division of lack of communication into inter-team and customer-related viewpoints). Same result happened with core category creation, as it allowed us to identify characteristics of participants as a major uncertainty type on top of already well-established information-type. Majority of the existing research relied on purely subjective considerations, and introduction of quantitative methods would greatly benefit the results of overall uncertainty research field. Our research provided limited results through categorization and evaluation of uncertainties in system development and demonstrated the possibilities in combination of multiple research methodologies.

This research did not focus on coping with uncertainty, but the literature review provided us some useful notes. Based on the interview analysis and existing literature, it is apparent that uncertainty is distant and sometimes ignored subject with people in system development. At the same time, the existence and effects of uncertainties are noticed through different problems, ambiguities and general feel of unease. Existence of uncertainties should initially be acknowledged, allowing the organizational maturity to grow (Hillson, 1997) from naïve upward. Reaching a normalized level of maturity would require management of uncertainties, including possibilities of reduction, forestalling, reasoning, comparing possibilities and suppression of uncertainties (Lipshitz & Strauss, 1997). One consideration towards general view on removal of uncertainty as the primary management approach is current: Should you? Uncertainty as innovation (Jalonen, 2011) and new business opportunity (Dönmez & Grote, 2018) enabler are only possible through intelligent utilization of uncertain conditions. Some uncertainties in e.g. markets cannot be directly managed, but those which can aren't always best to be completely removed. In general level, organizations should accept uncertainty as a state of affairs, acknowledge where it emerges and choose the best way to manage it. Uncertainty categorization present in this study makes the identification and prioritization of system development uncertainties easier to achieve. Suppression of uncertainty, ignoring it completely, is the worst possible approach for organizations to take.

7 CONCLUSION

Uncertainty in system development is a complex phenomenon that is described, understood and categorized from multiple different viewpoints. Uncertainty itself and its effects are areas with relatively little research. Lists of unclear requirements, technologies and markets are popular but inexhaustive causes for uncertainty, forming a starting point for broader inspection of the research area.

This research explored uncertainties perceived by the people working in the IT industry connected to system development. Literature review investigated the context of the research (system development) and main subject of interest (uncertainty). First part of the study conducted an inductive content analysis for creation of uncertainty categorization and identification of a core category. Second part of the study included a survey based on the earlier uncertainty categorization and provided us some indications about the perceived importance of different categories.

Content analysis allowed us to identify 9 uncertainty categories from the interviews that were perceived as causes of uncertainty. Categories included Communication, Technologies, Workforce, Needs of customer, Management, Customer's skills and knowledge, Situational clarity, Development: External uncertainties and Development: Internal uncertainties. Categories were divided into 22 sub-categories, allowing more detailed results. Sub-categories were inspected through the lens of grounded theory, allowing us to concentrate the findings from categorization. Deficient information was noticed as the main reason for uncertainty emergence, leading to identification of information as core category for uncertainty in system development.

Survey analysis provided us with numerical information about how much uncertainty each sub-category was perceived to cause. Questions allowed us to infer the amount of perceived uncertainty and subsequently the importance of categories created in the content analysis. Four of the categories were rated comparatively high, including Management, Needs of customer, Communication and Customer's skills and knowledge. Three sub-categories were also rated relatively high, inferring lack of inter-team communication, changes in the requirements and customer's lack of experience being major causes of uncertainty in system development.

Study was limited by the high variance in uncertainty itself, leading to numerous different researches using same terminology and reasoning only to speak about totally different subjects. As such, our results from the content analysis of the interviews hold in comparatively limited scale of system development. Results of the survey were not statistically significant but allowed more accurate results than purely qualitative interview analysis. Future research of uncertainty would benefit greatly from quantitative approaches and common terminology to make the results applicable in wider range of situations. Our research extended the growing uncertainty research by utilizing qualitative and quantitative methods in creation of evaluated uncertainty categorization for system development.

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APPENDIX 1: SURVEY QUESTIONS

Demographic question	Response option
Job title (e.g. developer, consultant, designer, project manager, product owner, executive manager)	Open text answer
Work experience in IT sector, including all previous and current positions in years	Open text answer
My work position can be described belonging to my organization's	1 = Managerial level 2 = Operational level 3 = Other (open text)
My employer operates in	1 = Public sector 2 = Private sector 3 = Other (open text)
Number of personnel in my organization is approximately	1 = 1-4 2 = 5-19 3 = 20-99 4 = 100-499 5 = 500-1999 6 = 2000 or over
Number of development-related projects I am currently involved in my work is	1 = 0-1 2 = 2-4 3 = 5 or over
My highest finished diploma	1 = No diploma after primary education 2 = Upper secondary level (High school and vocational studies) 3 = Bachelor or equivalent 4 = Master or equivalent 5 = Doctorate

Category	Sub-category	Question
Communication	Lack of communication	6. Lack of communication between people I work with causes me uncertainty
		7. Lack of communication with the customer causes me uncertainty
	Confusion about the meanings	8. Different understanding about project between different parties causes me uncertainty
	Lacking means of communication	9. Unsuitable communication channels cause me uncertainty
Technologies	Concerns about the future	11. Rapid changes in technology cause me uncertainty
	Understanding the current usage	12. Current technologies cause me uncertainty
		13. Choosing the most fitting technologies for the project causes me uncertainty
Workforce	Retaining skilled workers	15. Concerns about skilled personnel possibly leaving my organization cause me uncertainty
	Lack of "best workers"	16. Concerns whether my organization has enough experienced workforce cause me uncertainty
	Worker skills	17. Doubts about the capabilities of the people I work with cause me uncertainty
	Doubts about personal competences	18. Doubts about my personal competencies to perform in work-related tasks cause me uncertainty
	Lack of trust	19. Lack of trust towards people I work with cause me uncertainty
Needs of customer		21. Customer requirements cause me uncertainty
	"Wants" vs. needs	22. Differences in mutual understanding with the customer about the goal of the project cause me uncertainty
	Changing requirements	23. Changes in the project requirements cause me uncertainty
	Confusing requirements	24. Interpreting the customer's requirements cause me uncertainty
Management	Roles and responsibilities	26. Unclear responsibilities within the project cause me uncertainty
	Managerial practices	27. Organizational management practices (e.g. used methods do not support quick reactions to changes) cause me uncertainty
Customer's skills and knowledge		29. Customer's lack of experience in system development projects cause me uncertainty
		30. Customer's lack of skill and knowledge cause me uncertainty
Situational clarity	State of the project	32. Lack of knowledge concerning the current state of the project cause me uncertainty
	Context of the project	33. Lack of knowledge about the current tasks of my colleagues cause me uncertainty
		34. Lack of knowledge about the project situation outside my team (e.g., the state of other teams involved in the project, or the state of other involved systems being developed) cause me uncertainty
Development: External uncertainties	Legislation	36. Possible changes in the legislation cause me uncertainty
	Markets	37. Possible changes in the market situation cause me uncertainty
Development: Internal uncertainties	Organizational bureaucracy	39. Organizational bureaucracy causes me uncertainty
	Project necessities	40. Availability of project necessities (e.g. budget) causes me uncertainty
	Unexpected changes	41. Unexpected changes during ongoing projects cause me uncertainty