# Uncertainty in Information System Development: Causes, Effects, and Coping Mechanisms

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**Abstract**

Information system development (ISD) projects are an ever-growing field of project management (PM) with their unique features, and project failures in ISD are relatively common. In the broader context of PM, uncertainty is a studied, yet mercurial phenomenon. By contrast, uncertainty in ISD projects has received relatively little attention from scholars, and PM literature has not systematically focused on uncertainty in ISD from a viewpoint other than that of project managers. In order to understand uncertainties in ISD projects, we need to first understand the causes behind them, their effects on everyday ISD work, and share coping mechanisms utilized among industry professionals. In the context of ISD projects, we set out to explore what causes uncertainty, what are the effects of uncertainty, and how software industry professionals cope with uncertainty. We conducted eleven semi-structured interviews with a diverse range of ISD professionals, and analyzed the interviews using conventional content analysis. Our results extend and complement current knowledge on the causes, effects, and coping mechanisms of uncertainty, especially in the context of ISD. Additionally, we present practical considerations on how to implement our findings into ISD industry and education.

*Keywords:* uncertainty, risk, information system development, cause, effect, coping mechanism

## 1. Introduction

Information system development (ISD) projects are characterized by high complexity, uncertainty, conformity, changeability, invisibility, and high chances of failure (Jurison, 1999; Schwalbe, 2010; Rodriguez-Repiso et al., 2007). These are some of the reasons why the success (delivered on time, within budget estimate, with required features and functions) rate of ISD projects is low (Standish Group, 2013). Although success factors and risks in the broader context of project management (PM) have been extensively studied, some aspects of the phenomenon of uncertainty remain untapped.

Albeit uncertainty has received plenty of discussion about its causes, effects, and coping mechanisms (MacCormack and Verganti, 2003; Clarke and O'Connor, 2012; Lindsjørn et al., 2016; Little, 2005) scientific evidence regarding these three concepts is limited. Especially discussion on the causes and effects of uncertainty in ISD is seldom based on scientific evidence, but, often on (nevertheless educated) speculation. It follows that there exists a threat to validity, if such studies are premised on an assumption which is not supported by scientifically acquired results. Furthermore, research conducted on the topic in the field IS (Moynihan, 2000; Madsen and Pries-Heje, 2009) focuses on the project manager's viewpoint, even though uncertainty is something experienced by everyone, regardless of the job description. This is one of the reasons we argue that the phenomenon of uncertainty in ISD is not widely understood, as prior studies focus on specific perspectives. Such perspectives can be social, such as focusing on the perspective of the project manager, business domain perspectives,

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such as supply chain management (Simangunsong et al., 2012; Thomé et al., 2016), or operational perspectives, such as outsourcing (Jun et al., 2011). Although specific and focused research arguably explains phenomena explicitly (Siponen and Klaavuniemi, 2019), generalizability of the results can also be a fundamental goal of IS research (Lee, 1989), and a phenomenon should be understood not only sporadically in depth, but also widely. For example, Simangunsong et al. (2012) extensively summarize both causes and coping mechanisms for uncertainty in the context of supply chains in their secondary study, yet neither of these summaries are generalizable to uncertainty in ISD, because many domain specific aspects of supply chains do not apply to ISD. For these reasons, we believe that exploratory research into causes, effects, and coping mechanisms for uncertainty in ISD is warranted.

In this study, we explore, with the input from a diverse range of ISD industry professionals, *RQ1)* what causes uncertainty in ISD; *RQ2)* what are the effects of uncertainty on ISD; and *RQ3)* how employees working in ISD cope with uncertainty. Our results provide further scientific evidence on the uncertainty coping mechanisms identified in previous studies, and support and complement current understanding on the causes and effects of uncertainty. We present discussion and suggestions on how to incorporate real-world project (as opposed to student project) uncertainties into higher education, and share knowledge on uncertainty coping mechanisms, which may be beneficial to industry professionals as well.

## 2. Background

In this section, we explore previous studies related to uncertainty, and define key terms for this work. We start from the most general theme, uncertainty in PM, and move on to narrower themes of uncertainty in ISD, and, finally, on the research on the causes, effects and coping mechanisms for uncertainty.

Risk management is one of the most important knowledge areas in PM (Project Management Institute, 2013), and a well-studied phenomenon. Although the division of risk and uncertainty in research can be traced back to 1920s (Knight, 1921), uncertainty was often used interchangeably with risk, but a growing interpretation appears to be that risks are merely a subset of uncertainties (e.g., Perminova et al., 2008; Ward and Chapman, 2003). Furthermore, as risk is commonly understood as a chance with negative effects on the project, uncertainties can also have positive outcomes (e.g., Perminova et al., 2008; Dönmez and Grote, 2018), and are thus fundamentally different from risk (Ward and Chapman, 2003; Sanderson, 2012). In contrast, some research suggests that, similarly to risks, uncertainties can have only negative outcomes (Ibrahim et al., 2009; Lipshitz and Strauss, 1997), which may be a different standpoint altogether, or simply a result of a different definition of uncertainty. Finally, an often discussed difference between risk and uncertainty is preparation. Thomé et al. (2016) consider uncertainty as something unseen (i.e., unknown-unknown), which is not something that can be prepared for, and thus not quantifiably estimated (Grote, 2015). Risk, on the other hand, is something that can be predicted, and the possibility of its occurrence estimated (i.e., known-unknown).

Previous research presents various definitions for uncertainty. We adopt the relatively broad definition presented by Taipalus et al. (2018), who, in the vein of Budner (1962) and Chu et al. (2015) present that uncertainty is an emotion caused by ambiguity. Ambiguity, in turn, is caused by either new, complex, or contradictory cues (Budner, 1962). As ambiguity reaches a certain, subjective level, it causes uncertainty.

Later in this study, we discuss uncertainty from a viewpoint of different *organizations*, by which we refer either to the organization that is responsible for the development (i.e., *development organization*) of the system, or the organization responsible for the commission (i.e., *client organization*, or simply *client*) of the system. By *development team* (or simply *team*), we refer to a group of people involved with the development of the system.

In the field of information technology, ISD and *software development* are sometimes used interchangeably. However, the fundamental difference between software development and ISD is scope,

as software development is a subset of ISD, focusing primarily on the technical development of an information system. In this study, by *ISD* or simply *system development*, we refer not only to the technical development, but also to the contextual aspects such as management of an ISD project. This is the main reason why we have approached ISD from PM perspective in this study; the scientific literature relevant to PM subsumes relevant concepts.

In ISD projects, certain aspects of processes, risks, and problems are emphasized when compared to other types of projects. First of the commonly discussed pitfalls in ISD is requirements engineering, as the client seldom has a clear objective, but rather a fickle vision of what kind of system is needed (Na et al., 2004; Zmud, 1980). Second, new feature requests often emerge during the development (Ebert and De Man, 2005), which in turn can cause challenges with time, budget, and prioritization. Third, sometimes innovation and rapid response is needed to sustain the client's business. This is emphasized in rapidly progressing domains such as social media applications.

Partly to respond to this commonly acknowledged phenomenon that uncertainty is always present, the ISD industry has been increasingly embracing more and more adaptive development frameworks. While there is and probably always will be domains for traditional plan-driven development frameworks (e.g., Royce's (1970) so-called waterfall model), more and more extreme alternatives have been gaining popularity in the 2000s. Different agile frameworks (Abrahamsson et al., 2002; Boehm and Turner, 2003) reduce the development cycle of system iterations to weeks (Schwaber and Beedle, 2001), and the continuous development (Jabbari et al., 2016) approach to mere minutes or seconds, as the new system iteration is automatically tested and deployed to the end-users without the need for human intervention. If this development of frameworks can be seen as a trend, it arguably supports the viewpoint that ISD industry embraces uncertainty rather than tries to mitigate it.

Compared to the amount of research concerning risk management, the causes, effects, and coping mechanisms of uncertainty are based on little scientific evidence, especially in the ISD context. Moreover, as summarized by Jun et al. (2011), many IS studies approach uncertainty from a single point of view, rather than taking a wider approach to try to capture the phenomenon in its entirety.

Moynihan (2000) explored causes and coping mechanisms for requirements-uncertainty by analysing interviews of twenty IS project managers in Ireland. The study reports selected 34 constructs, which can be understood as causes for uncertainty, e.g., "we will be using unfamiliar languages/tools", "we've little or no knowledge of the customer's industry", and "we are up against a credible competitor for this project". Based on the interviews, Moynihan (2000) also suggests several coping strategies, e.g., "go bureaucratic", "prototyping", and "detailed implementation planning". Similarly, Madsen and Pries-Heje (2009) interviewed seven students in a project management course. The students also had industry experience in PM. The authors report four types of uncertainty, each with their associated causes, e.g., lack of trust in one's abilities, lack of knowledge about the individuals in the project, and private issues. Furthermore, the authors discuss a number of effects of uncertainty, e.g., stress and panic, and a bad working climate. Finally, the authors propose strategies, e.g., staying calm, role distribution, and worst case scenario analysis. What connects these two studies (Moynihan, 2000; Madsen and Pries-Heje, 2009) is the fact that all interviewees were project managers. Hence, the causes and coping strategies are captured from the project managers' perspective, even though project managers only represent a small vendor side subset of personnel involved in an ISD project. This further propounds the view that uncertainty in ISD projects requires more research.

Finally, not much research regarding uncertainty in ISD education exists. Foregoing, quantitative research seems to agree that uncertainty is perceived as a negative factor for the quality of the process (i.e., the ISD), and the product (i.e., the IS) by both industry professionals (Jun et al., 2011; Na et al., 2004), and students (Taipalus et al., 2018). A set of coping mechanisms for uncertainty among IS students have been identified (Taipalus et al., 2018), yet it remains unclear whether these coping mechanisms can be generalized into industry.

## 3. Methodology and data collection

The methodology and data collections used in this study can be described as a linear, three step process. First, using an online survey, we asked university students what causes uncertainty in an ISD project, and, based on the results, formulated the structure for the semi-structured interviews. Second, we selected and interviewed eleven ISD industry professionals with diverse backgrounds. Finally, using conventional content analysis, we analyzed the interviews three times, once for each research question. Next, we explain these three steps in detail.

### *3.1. Prestudy*

Before answering the survey, the students worked in an ISD project in a university level course, and, in addition to learning about system development, gained experience on uncertainties in ISD. The course was not systematically taught through lectures, but through project work. Based on these experiences, students answered an online survey describing their opinions on what caused uncertainty in ISD. The course subject was information system development encompassing not only software development, but also managerial aspects, such as project management. The 85 students in the course were third year undergraduate students majoring in software engineering, computer science, or information systems. The main learning outcome of the course was to learn to work on a complex information system development project, as opposed to smaller scale programming exercises introduced in previous courses in the curriculum. The course was not mandatory for any of the students.

In the course, the students were instructed to develop a complex information system for a made up client in teams of five to six students. University staff acted as representatives of the client, and gave feedback and insights during the development process, as well as introduced new or revised requirements for the system. During six weeks of effective development, the student teams were forced to prioritize features, as implementing all the features was an excessively laborious assignment by design. After the development project, the students were asked to fill out an online survey. Participation was voluntary and anonymity was ensured. Students were also informed that their answers will be used in scientific research regarding uncertainty in ISD, but reported only as statistical information. Participation had no effects on the student's course grade, and the students were not compensated for participation. The students could withdraw their answers before submitting them, and no personal information such as names were collected. These ethical concerns were communicated to the students prior to choosing whether to fill out the survey, as discussed in Badampudi (2017). Among other questions, the survey contained an open question: *"What caused uncertainty in the course project?"*, and out of the 85 students in the course, 67 chose to participate (response rate 78.8%).

We discovered three distinct and recurring themes as causes for uncertainty in system development among students. First, *intra-team communication failures* were the most common cause for uncertainty. Team members failed to communicate problems and propose solutions for problems. Communication channels were not used enough, or the team chose inefficient ways of communication. Team members felt that work was not delegated properly. Second, *communication with the client* caused uncertainty. Different client representatives provided conflicting requirements, could not answer technical questions, or did not provide sufficient information on the requirements of the system. Third, team members felt that the system required *technical expertise* that was not present in the team, and that the client's other systems were so complex, that the specifics of the integration process were left unclear even after a thorough investigation. The purpose of the prestudy was not to use students as proxies for industry professionals, as discussed in, for example Feldt et al. (2018), but to merely provide a general structure for the subsequent interviews with professionals.

### *3.2. Interviews*

Based on the analysis on the survey answers, we conducted eleven semi-structured interviews with ISD professionals. Semi-structured interview was a natural data collection method, because we were able to meet the interviewees only once (Bernard, 1988), and as we did not want to limit

Table 1: Structure of the interviews

| Question or topic | Purpose |
|---|---|
| Begin the interview; promise anonymity; investigate interviewee background | Orientation for the interview |
| *"What, in your experience, causes uncertainty in information system development?"* | Answer RQ1 |
| *"Have you noticed or experienced causes of uncertainty that are related to [a, b, c]?"* in which a, b, c are concepts identified in the analysis of the survey answers. Repeated for each concept. | Answer RQ1 |
| *"How, in your experience, uncertainty affects information system development work?"* | Answer RQ2 |
| *"How can we cope with uncertainty in information system development?"* | Answer RQ3 |
| End the interview; announce that the interview is ending; *"Is there anything you would like to add, to any of the topics?"*; thank you | Discover additional insights |

Table 2: Interviewees and interview durations

| Industry | Experience (y) | Locality | Personnel | Duration (min) |
|---|---|---|---|---|
| Consulting | 18 | Local | $< 10$ | 88 |
| Social services | 6 | Local | 6,000 | 28 |
| Telecommunication | 7 | Global | 20,000 | 35 |
| Higher education | 17 | Local | 2,500 | 35 |
| Higher education | 13 | Local | 2,500 | 32 |
| Technology | 10 | Global | 350 | 34 |
| Technology | 13 | Global | 350 | 43 |
| Technology | 2 | Global | 44,000 | 30 |
| Technology | 21 | Global | 44,000 | 44 |
| Software | 14 | Local | $< 10$ | 72 |
| Healthcare | 15 | Local | 3,000 | 38 |

the discussion on the causes of uncertainty to topics the students discovered in the survey, but let other causes emerge from the dialogue, as proposed by DiCicco-Bloom and Crabtree (2006). Most of the interviews took place at the university of the authors, and some at the work places of the interviewees. We conducted the interviews face-to-face, and recorded them with the permission of the interviewees. Table 1 describes the general structure of the interviews, but, as is quintessential for semi-structured interviews, we explored interesting motifs outside the general structure. It is worth noting that although we earlier presented a definition for uncertainty, the interviewees each had their own subjective understanding of what uncertainty means.

All the interviewees worked in ISD at the time of the interview. We chose to interview professionals from diverse backgrounds (work experience, past and present titles, line of industry) to gain understanding of a wide range of causes, effects, and coping mechanisms. Table 2 contains the industry the interviewee worked in at the time of the interview, work experience in ISD in years, whether the interviewee's current company has business on a national or international level, the approximate number of personnel the interviewee's company currently employs, and the duration of the interview, with the average of 44 minutes. The interviewees all represent the vendor side of ISD, as opposed to the client side. Concepts *a*, *b*, and *c* listed in Table 1 correspond to *intra-team communication failures*, *communication problems with the client*, and *lack of technical expertise*, respectively.

### *3.3. Analysis*

After we conducted all the interviews, the interview recordings were transcribed, and we analyzed the data using conventional content analysis according to Hsieh and Shannon (2005). We deemed

necessary that the first author, who was the least experienced in the topic of uncertainty in ISD, analyzed the data to minimize the effect of preconception on the results. First, in order to understand the causes of uncertainty, the first author identified key concepts in the transcribed interviews according to the three concepts discovered in the survey, and highlighted the causes of uncertainty with the predetermined codes. When a previously undiscovered cause was found, the first author gave that cause a new code. Next, the first author defined each of the categories with a name that emerged from the data, and with a fitting description. When a category was deemed to encompass significantly more codes than other categories, it was considered whether or not the category should be divided into subcategories. Next, the other two authors reviewed the categories independently of each other, and, finally, all the authors discussed discrepancies, formed a consensus, and revised the categorization accordingly. This whole process was repeated for the effects of uncertainty, and for the coping mechanisms of uncertainty.

## 4. Results

In Section 3.1, we described the three prominent causes for uncertainty in the student survey: intra-team communication failures, communication problems with the client, and lack of technical expertise. Similar themes arose from the interviews with ISD professionals, yet we chose to name them differently. This was done because we set out to study the viewpoints of professionals, and although we found similarities between students and professionals, we feel the hypernyms used in this section better capture the nuances of the themes as they were described by the interviewees.

The 24 causes, 6 effects, and 4 coping mechanisms for uncertainty are summarized in Table 3. The causes are presented as a taxonomy of three levels, for example, the cause *large team size* on the lowest level of the taxonomy belongs to *inefficient conventions* on the middle level of the taxonomy, which in turn belongs to *causes stemming from within the development organization* on the highest level of the taxonomy. Based on the interviews, we have also mapped the middle level causes to their effects, and the effects to coping mechanisms suggested by the interviewees. Connections between causes and effects, and effects and coping mechanisms are both marked with $X$s. Because the word *coping* has a connotation implying *adapting to something negative*, we only marked the connections between negative effects and coping mechanisms.

### *4.1. Causes*

Based on the interviews of the ISD professionals, we formulated a categorization of causes of uncertainty. The highest level of the categorization contains three items: causes stemming from within the development organization, causes stemming from the client organization, and causes stemming from outside the involved organizations. The second level of the categorization contains eight items, which are further divided into a total of 24 themes, each associated with one of the categories. These themes are explained in the following sections, and complemented with direct quotes from interviewees in Tables 4, 5 and 6.

#### *4.1.1. Causes stemming from within the development organization*

*Personal matters* that caused uncertainty were lack of trust (in team member's own abilities, perceived abilities of other team members, the success of the developed system, or the continuation of one's employment), fear (team members were afraid of asking for help, or team members feared for a known risk to be realized), or personal problems outside work (family matters distracting from work, or prior education differing from actual work).

*Inefficient conventions* were characterized by inefficiencies in communication due to large team size, lack of intra–team knowledge concerning the roles of the team members themselves as well as

Table 3: A summary of causes, effects, and coping mechanisms for uncertainty based on the interviews – connections between causes and effects, and between effects and coping mechanisms represent connections suggested by the interviewed professionals

| Causes of uncertainty | | | | Effects of uncertainty: Self–improvement | Innovation | Motivation | Dysphoria | Unnecessary work | Toxic working culture |
|---|---|---|---|---|---|---|---|---|---|
| Causes of uncertainty | Causes stemming from within the development organization | Personal matters | Lack of trust<br>Fear<br>Personal problems outside work | | | | x | | |
| | | Inefficient conventions | Large team size<br>Lack of knowledge concerning roles<br>Unsuitable communication channels<br>Different personal working methods<br>Agile methods<br>Incompetence | | | | | x | x |
| | | Organizational pathoses | Inconsistent resource allocation<br>Organizational complexities<br>Failure handling | | | | x | | x |
| | Causes stemming from the client organization | Lack of interdisciplinary knowledge | Client does not understand software<br>Team does not understand the business domain | x | | x | | x | |
| | | Lack of problem understanding | Lacking initial requirements<br>New features arise<br>Lack of commitment from the client | | | x | | x | |
| | | Conflicts of interest | Authority–involvement discrepancy<br>Prioritization | | | | | x | |
| | Causes stemming from outside the organizations | Technical considerations | Complex technical environments<br>Technology evaluation | x | x | x | x | x | |
| | | Causes outside the scope of influence | Changes in surrounding environments<br>Complexities in surrounding environments<br>Lack of suitable workforce | | | | | x | |
| CMs | Change in attitude | | | | | | x | | |
| | Emphasizing roles | | | | | | x | | |
| | Openness in communication | | | | | | x | x | x |
| | Involvement with the client | | | | | | x | x | |

other team members, and unsuitable communication channels. Intra–team working methods were also perceived as a cause of uncertainty: personal working methods of other team members required other team members to adjust or simply tolerate these working methods. Furthermore, some interviewees described agile methods as a source of uncertainty, as these methods often welcome uncertainty when compared to more linear methods. Finally, actualized incompetence (as opposed to previously discussed perceived inability) or laziness was seen as a cause of uncertainty, as these failures or mistakes affected the work of others in unforeseen ways.

*Organizational pathoses* were caused by intra–organizational discrepancies in resource allocation before and during the development project, bureaucracy, and structural complexities. Finally, some interviewees pointed out the inability to handle failure on organizational level. This results in failure to understand why a project failed, and no lessons are learned on an organizational level.

#### *4.1.2. Causes stemming from the client organization*

*Lack of interdisciplinary knowledge* was perceived as a common source of uncertainty. The interviewees pointed out that this cause stems from the common fact that the client does not understand how software works, how to buy software, or how software can help the business. On the other hand,

Table 4: Causes for uncertainty stemming from within the development organization, a quotation representative of the cause, and the number of interviewees who discussed the particular cause

| Cause | Quotation | $n$ |
|---|---|---|
| Lack of trust | I do not think this system will succeed. | 5 |
| Fear | [...] other team members think I am stupid if I ask this. | 5 |
| Personal problems outside work | This is not what I was used to in the university. | 4 |
| Large team size | Everyone has something to say, but not everything is relevant to everyone. | 4 |
| Lack of knowledge concerning roles | [...] I do not know if I am responsible for this [aspect of development]. | 5 |
| Unsuitable communication channels | I am tired was reading a vast collection of information to find out what I am looking for. | 4 |
| Different personal working methods | Team members have different cultural backgrounds, and I do not know if it is okay to mention about something. | 8 |
| Agile methods | Some people in the team think that agile means that we do not need to plan anything. | 4 |
| Incompetence | We have no expertise on a technology because no one planned that in advance. | 8 |
| Inconsistent resource allocation | We lost team members to another project, and we do not know if we can now meet the deadlines. | 4 |
| Organizational complexities | Organizational structure is complex, and I do not understand why this thing takes so long, or whether it can even be implemented due to some technicality in the legislation. | 4 |
| Failure handling | Another project [in the development organization] failed, but we are nevertheless doing the exact same thing. | 4 |

Table 5: Causes for uncertainty stemming from the client organization, a quotation representative of the cause, and the number of interviewees who discussed the particular cause

| Cause | Quotation | $n$ |
|---|---|---|
| Client does not understand software | In terms of technical development, the client does not understand if [a feature] is a huge matter. Or if it is trivial. | 5 |
| Team does not understand the business domain | I do not think I know enough about how social services work. | 7 |
| Lacking initial requirements | [...] the client failed to communicate what they actually want to accomplish with the system [...] | 10 |
| New features arise | The client wants a new feature, fast, and I do not know if that is possible. | 5 |
| Lack of commitment from the client | The client does not want to see unfinished software which makes reviews quite literally impossible. | 4 |
| Authority–involvement discrepancy | [...] even though the client has a product owner, someone else makes the decisions. | 5 |
| Prioritization | One representative of the client wants things that conflict with another representative [...] | 4 |

the interviewees stated that it is common that the development team does not understand the client's business domain, thus failing to understand why a feature is needed. It follows that, when the *why* is not understood, evaluating a designed or implemented solution is difficult.

*Lack of problem understanding* refers to the client willingly or unwillingly distancing themselves from the development. All the interviewees expressed that a major source of uncertainty is that often the initial requirements are lacking. Furthermore, the client changes their minds, and new features need to be implemented, sometimes with a fast schedule. Finally, some of the interviewees saw lack of commitment from the client side as a source of uncertainty. This manifested in lack of communication, and the client expressing that they do not want to see unfinished software during the project, which in turn caused uncertainty concerning the suitability of the system.

*Conflicts of interest* were relatively uncommon in the interviews, but when they arose, the interviewees pointed out their especially difficult nature. First, conflicts of interest were caused by authority–involvement discrepancy, where the people on the client side making most of the decisions regarding the system were the ones using the system the least. Second, different client representatives intended to use the system in different, sometimes conflicting ways, which resulted in uncertainty within the development team, as which feature requirements to prioritize.

Table 6: Causes for uncertainty stemming from outside the organizations, a quotation representative of the cause, and the number of interviewees who discussed the particular cause

| Cause | Quotation | $n$ |
|---|---|---|
| Complex technical environments | The law dictated that the system needed to comply [to a standard], but the standard was not finalized yet, and the system was supposed to be in production already. | 4 |
| Technology evaluation | [...] will this technology still be relevant in the future? | 9 |
| Changes in surrounding environments | [no one] knows how the legislative considerations are supposed to be implemented [...] and [if the implementation was correct will finally be] decided in the court of law. | 5 |
| Complexities in surrounding environments | [...] that new target country has very different legislation [from ours]. | 4 |
| Lack of suitable workforce | [...] there is no one qualified to hire for this position. | 4 |

#### *4.1.3. Causes stemming from outside the organizations*

*Technical considerations* were a common theme in the interviews. As the clients of the development organization change, new clients introduce new, sometimes complex enterprise architectures, into which the system needs to be integrated. These architectures often span outside the client organization, and are not well understood by the client. Almost all interviewees commented that the evaluation of present and emerging technologies, their applications, suitability, opportunities, and longevity, is a difficult task to assess. Furthermore, such assessments, even at their most accurate, are uncertain.

*Causes outside the scope of influence* increased uncertainty in ways that the development or client organization had little or no way to prevent, only to act on, or simply adapt. First, unforeseen changes in the business, political, or legislative environments caused uncertainty. Most of the interviewees mentioned General Data Protection Regulation (GDPR) in particular, which caused uncertainty, especially with no legal precedent cases at the time. Second, new, especially international clients sometimes introduced legislative or technical standard related complexities to the development team. Finally, two interviewees discussed the lack of suitable workforce in the employee pool, which in turn caused uncertainty whether to train the development team internally, choose already known technologies or methods, or reject or discard a project entirely.

### *4.2. Effects*

As discussed by a number of scholars (e.g., Dönmez and Grote, 2018; Johansen et al., 2016), in addition to negative effects, uncertainty may also have positive outcomes. Based on the interviews, we identified six distinct effects of uncertainty, three negative and three positive. Next, we discuss these effects of uncertainty with quotes from the interviewees representing the effects in Tables 7 and 8.

#### *4.2.1. Positive effects*

Almost all interviewees mentioned that uncertainty has positive effects. The most commonly recognized positive effect was the possibility of *self–improvement*. Uncertainty was seen as a facilitating factor for learning new technologies, faster social bonding with other team members, and autonomous strive to improve current working methods. Additionally, some interviewees had observed that uncertainty may force team members to ask additional questions, consequently making "unknown unknowns known unknowns".

Another positive effect of uncertainty was empowerment of *innovation*. Most of the interviewees recognized uncertain development environments as a seedbed for creativity. New, unknown business domains and technical environments can cause team members to stay vigilant for new solutions and challenge present ones.

Some of the interviewees experienced uncertainty in ISD as a source of *motivation*. This was explained by the common fact that each client brings a new business domain, every development

Table 7: Positive effects of uncertainty, two quotations representative of the effect, and the number of interviewees who discussed the particular effect

| Effect | Quotation | $n$ |
|---|---|---|
| Self–improvement | Uncertainty pushes team members out of their comfort zones, thus facilitating learning and progressing in the trade.<br>We constantly investigate and train in new technologies. | 7 |
| Innovation | [uncertainty] causes team members to innovate for better solutions.<br>Uncertainty leaves room for creativity. | 6 |
| Motivation | Since the industry is not well understood, I will have a job in the future as well.<br>No one has done this before [...] every project is different. | 5 |

Table 8: Negative effects of uncertainty, two quotations representative of the effect, and the number of interviewees who discussed the particular effect

| Effect | Quotation | $n$ |
|---|---|---|
| Dysphoria | [uncertainty] causes stress to those who cannot stand it [...]<br>I cannot feel satisfied of my solutions, because no one knows whether it is a good solution. | 7 |
| Unnecessary work | [...] causes misinterpretation of the requirements [...] technical debt [...]<br>Requirements are misunderstood, then guessed, and then we have built the wrong thing. | 6 |
| Toxic working culture | Project managers pretend that they know everything.<br>Things are not communicated clearly and officially, and that causes unpleasant gossip. | 5 |

project is different, and no one has implemented exactly the same system before, all of which keep the development work interesting.

#### *4.2.2. Negative effects*

All the interviewees recognized that uncertainty has negative effects. The most commonly recognized negative effect was *dysphoria*, a mental state of unease. Many of the interviewees had experienced or observed uncertainty causing unhealthy amounts of stress. Additionally, the feeling of inadequacy affected the ability to perform, as some team members felt that their solutions were not of high enough quality. Finally, uncertainty caused team members inability to feel satisfied by their solutions, because sometimes no one knows whether a solution is a good one.

Uncertainty caused *unnecessary work*. System requirements were misunderstood, wrong features implemented, or two team members implemented the same feature without knowing of the other. Additionally, some of the interviewees had discovered that uncertainty often manifests in technical debt, as features are not understood correctly, and thus implemented negligently.

Finally, uncertainty can lead to a *toxic working culture*, as both the project manager, and the client representatives may pretend that there is no uncertainty, which in turn contributes to misunderstandings, and lack of trust. Uncertainty may also result in unpleasant gossip, and misunderstandings about the state of the project.

### *4.3. Coping mechanisms*

Based on the interviews, we identified four coping mechanisms for uncertainty: *change in attitude*, *emphasizing roles*, *openness in communication*, and *involvement with the client*. Based on the interviews, we recognized connections between the causes and effects of uncertainty, as well as coping mechanisms for the effects of uncertainty. The categorization of causes of uncertainty, themes related to each category, effects and their relation to the causes, coping mechanisms and their relation to the effects were summarized in Table 3. It is worth noting that the positive effects of uncertainty are not connected to any of the coping mechanisms, as *coping* implies a reaction to something perceived as a negative thing. Quotations from the interviewees representing each of the coping mechanisms are presented in Table 9.

#### *4.3.1. Change in attitude*

The first coping mechanism was related to attitudes towards uncertainty. Depending on a team member's background, uncertainty was tolerated to a certain degree. The interviewees described that while attitudes towards uncertainty are usually negative, uncertainty should be viewed as a fundamental element in system development, and that learning new technologies, business domains, and working methods is a constant process. The development organization should encourage team members to experiment, even though failures might be common. Furthermore, these failures need to be discussed and analyzed, not silenced or avoided. Although not explicitly included in the interview structure, most of the interviewees who discussed themes related to this coping mechanism argued that a change in attitude towards uncertainty would alleviate the dysphoria associated with uncertainty.

#### *4.3.2. Emphasizing roles*

Almost all interviewees discussed the importance of roles, and knowledge concerning them. First, it was seen crucial that the team members know who to ask for help in technical and managerial matters. All team members need to know what their role within the development organization is, and what are the roles of other team members related to their work. Second, team members need to know what type of uncertainty they must work with, and what types of uncertainty are the responsibility of someone else. One of the interviewees gave a simple example of a programmer needing to cope with uncertainty concerning an algorithm design, but not needing to know which feature to prioritize. Third, the development organization needs to communicate to the client that the development organization is the expert in system development, and the client is the expert in the client's business. This coping mechanism was also seen to alleviate the dysphoria caused by uncertainty.

#### *4.3.3. Openness in communication*

A coping mechanism that was seen to alleviate all negative effects of uncertainty was openness in communication, both within the development organization, and with the client organization. The interviewees highlighted that trust is a key component in information system development, and trust is facilitated by openly acknowledging problems, weaknesses, uncertainties and failure as early as possible. If problems are left for other team members, or the client to discover, it negatively affects trust between the involved parties.

#### *4.3.4. Involvement with the client*

Almost all interviewees had observed that close involvement with the client, both in the beginning of the development project and during it was crucial in preventing unnecessary work as well as psychological problems. The interviewees discussed that the development team and the client need to allocate time for the initial requirements elicitation, and the client needs to explain the business domain to the development team, so that the team understands why a feature is needed, not only which features are needed. Finally, the development team needs to map the system's largest intended end-user groups, and regularly involve them with the development of the system with, e.g., acceptance testing, or with participatory design.

## 5. Discussion

In this section, we explore the implications of our results to research, industry, and teaching. At the end of this section we discuss threats to validity and limitations of our study.

Table 9: Uncertainty coping mechanisms (CM), two quotations representative of the CM, and the number of interviewees who discussed the particular CM

| CM | Quotation | $n$ |
|---|---|---|
| Change in attitude | We need to acknowledge that uncertainty is a fundamental element of software development.<br>We need to acknowledge that we never stop learning. | 10 |
| Emphasizing roles | Team members, especially developers, need to be able to focus on their work, which is programming [...] team members need to understand what kinds of uncertainties they must deal with, and what types of uncertainties they need not.<br>It needs to be communicated to the client, that the team members are the experts in software, and the client is the expert in their business domain [...] | 9 |
| Openness in communication | Failure, problems, and uncertainties must be communicated early, and they are nothing to be ashamed of<br>[on the concern of punishing for failure] if we must punish team members for something, punish them for not voicing their concerns sooner! | 10 |
| Involvement with the client | [...] team understands why a feature is needed, not just what features are needed.<br>[...] invest in the requirements specification. We always express the requirements with graphics, not just text. | 11 |

### *5.1. Implications for research*

Our study revealed causes, effects, and coping mechanisms, some of which are novel, and some of which have been merely discussed in previous research with no scientific evidence. Next, we present four contributions of our study which may be beneficial for current understanding of uncertainty and for future research. First, our results provide some validation for previous research. Concerning causes and coping mechanisms, Moynihan (2000) presented insights on both the causes and coping mechanisms for uncertainty. Because Moynihan (2000) studied requirements–uncertainty, one–to–one mapping of our results is subject interpretation. On a general level, though, Moynihan (2000)'s reported causes for uncertainty which are similar to ours in the categories regarding causes stemming from the client organization and outside the organizations. Regarding the coping mechanisms, we have summarized similar discoveries in prior research to Table 10. It is worth noting, though, that the referenced studies did not necessarily scientifically discover these coping mechanisms, simply discussed them. Also, the table is not comprehensive regarding previous research on uncertainty coping mechanisms, but merely illustrates that these findings have been discussed in prior research. Finally, the referenced work did not necessarily discuss these coping mechanisms with the same terms, or in the context of ISD, but captured the concepts behind these coping mechanisms, as discussed in Section 4. The coping mechanism of *task switching* (Dönmez and Grote, 2018) was particularly interesting when compared to our coping mechanism of *emphasizing roles*. Dönmez and Grote (2018) suggested that roles within a team should be flexible, yet our interviewees suggested the opposite. Concerning the positive effects of uncertainty, our results support the viewpoints of, for example, Dönmez and Grote (2018) and Perminova et al. (2008), who both argue that uncertainty facilitates innovation.

Second, our study revealed new insights concerning uncertainty in ISD. In addition to the previously discovered positive effect of innovation (Dönmez and Grote, 2018; Giezen, 2012; Perminova et al., 2008), our results suggest that uncertainty may also be a source of motivation and a facilitator of self–improvement, as new projects bring the development organization new business domains and technologies to work with. Furthermore, our study discovered new causes of uncertainty, particularly in the field of ISD, and from a more diverse range of industry professionals than previous studies. This diversity may have revealed additional insights from the multitude of people involved in the vendor side of ISD, as opposed to solely project managers.

Third, we present a perspective for future research in uncertainty management. We agree with Ward and Chapman (2003) that the discipline of PM should consider expanding risk management to uncertainty management, as these concepts are distinct, yet closely related. Furthermore, strategies or mechanisms for working with uncertainty should be considered specifically *management* to capture the phenomenon in it's entirety. The term *coping* (which we also use in the title of our study) has an association with problems or difficulties, yet uncertainty may also have positive outcomes.

Table 10: A comparison of uncertainty coping mechanisms (CM) identified in previous studies

| Previously identified CM | Maps to our CM |
|---|---|
| Go bureaucratic (Lipshitz and Strauss, 1997; Moynihan, 2000) | Involvement with the client |
| Prototyping (Luqi and Cooke, 1992; Moynihan, 2000; Dönmez and Grote, 2018) | Involvement with the client |
| Detailed implementation planning (Lipshitz and Strauss, 1997; Moynihan, 2000; Madsen and Pries-Heje, 2009) | Involvement with the client |
| Incorporating uncertainty in plans (Luqi and Cooke, 1992; Lipshitz and Strauss, 1997; Dönmez and Grote, 2018) | Change in attitude |
| Developing vigilance (Dönmez and Grote, 2018) | Change in attitude |
| Incremental feedback (Lipshitz and Strauss, 1997; Dönmez and Grote, 2018) | Openness in communication |
| Team based task analysis (Dönmez and Grote, 2018) | Involvement with the client |
| Knowledge sharing (Atkinson et al., 2006; Perminova et al., 2008; Madsen and Pries-Heje, 2009; Dönmez and Grote, 2018) | Openness in communication |
| Creating alternatives (Lipshitz and Strauss, 1997; Madsen and Pries-Heje, 2009; Dönmez and Grote, 2018) | *(does not map)* |
| Creating functional roles (Dönmez and Grote, 2018) | Emphasizing roles |
| Stakeholder integration (Dönmez and Grote, 2018) | Involvement with the client |
| Task switching (Dönmez and Grote, 2018) | *(contrary CM suggested)* |
| Delay action (Lipshitz and Strauss, 1997) | *(does not map)* |
| Support for speaking up (Grote, 2015) | Openness in communication |
| Trust between parties (Atkinson et al., 2006) | Change in attitude |
| Ownership of uncertainty (Atkinson et al., 2006; Madsen and Pries-Heje, 2009) | Emphasizing roles |

Therefore, we present that coping is merely a subset of management, and, by design, we did not consider mechanisms for the positive effects of uncertainty in our study, as can be observed in Table 3.

Giezen (2012) puts forward the view of disadvantages of reducing uncertainty. If uncertainty is reduced by reducing the complexity of the project, the resulting simplicity may be helpful in understanding the project, but may also lead to subpar solutions, and diminish innovation. Grote (2015) also points out that increasing uncertainty may be beneficial to the project in, e.g., safety considerations, as more information does not implicitly result in less uncertainty, and coping with uncertainty does not equal to increasing knowledge about everything related to the project. On the other hand, as Lipshitz and Strauss (1997) mention, collecting information to reduce uncertainty is not always possible or feasible. These things considered, and as the fourth contribution, we present that uncertainty management covers four dimensions. We present these dimensions with examples of situations in ISD these dimensions may manifest in Table 11. These dimensions share some similarities with the ones presented by Marinho et al. (2014) with the fundamental difference that their study focused on minimizing uncertainty with different methods. In their systematic literature review, Marinho et al. (2014) summarize that uncertainty in software projects can be minimized with strategies and techniques, immediate responses to uncertainties, identifying uncertainties before they are realised, understanding the sources of uncertainty, and adapting management style to the project at hand.

It is worth noting that the definition for coping presented in Table 11 is not in line with what we have discussed previously in this study. For future research we propose that the results presented in this study should be used in quantitative research (e.g., by means of a survey) to further explore which causes, effects, or coping mechanisms are most widespread among professionals in ISD in particular, or in PM in general. Even though our interviewees frequently pointed out technical considerations as a source of uncertainty, another study on uncertainties in project portfolio management (Petit and Hobbs, 2010) discovered that technology is, in fact the least prominent source of uncertainty, which raises the question of how much of the results of our study may be generalized from ISD to PM.

### *5.2. Implications for industry*

In addition to providing additional, general knowledge on the causes, effects, and coping mechanisms for uncertainty, we put forward some considerations for industry, specifically for the field of ISD. As discussed in an earlier study (Luqi and Cooke, 1992), prototyping can bridge the gap between informal terms in communication and formal structures of software. To enable and facilitate

Table 11: Four dimensions of uncertainty management

| Dimension and description | Example |
|---|---|
| *Coping with uncertainty*: uncertainties that exist and cannot be reduced | There will be unforeseen changes in technologies. The occurrence of these changes must simply be acknowledged and reacted to. |
| *Decreasing uncertainty*: uncertainties that should be reduced for better project outcome | Team does not understand the client's business domain. This knowledge is relatively easy to obtain, and will benefit the project. |
| *Increasing uncertainty*: uncertainties that must be increased in order to reduce them | The success of the project is largely related to a chosen technology. The weaknesses of the technology should be discussed, and concerns voiced, even if it will increase uncertainty regarding the technology's suitability, and trust in it. Alternatives should be explored. |
| *Exploiting uncertainty*: uncertainties that invite innovation, motivation, and self–improvement | The solution is the first of its kind in terms of, e.g., scope, business domain, technology or user-base. The development organization should facilitate a culture of fast prototyping, innovation and constant learning. Failure should be considered a lesson learned. |

prototyping, however, we argue that the development organization must adopt an attitude towards uncertainty as a positive and natural environment. This change in attitude would arguably help team members who have a naturally low tolerance for uncertainty, as noted by Madsen and Pries-Heje (2009). Additionally, stakeholder involvement early in the project and frequent communication has been emphasized earlier (Grote, 2015), and our results support these guidelines.

Personnel responsible for an ISD project should consider how much uncertainty can be tolerated. Grote (2015) argues that different business domains invite different types and levels of uncertainty. We add that, even though some positive effects, such as motivation, are arguably always welcome, encouraging innovation in, e.g., a strictly plan-driven ISD project, may have negative effects. The same applies for technologies as well, as some business domains may embrace tested and accepted solutions, others thrive in environments where there exist no technological precedents. Regarding the effects of uncertainty in our study, some of the interviewees mentioned that uncertainty facilitates social bonding between team members. Surprisingly, however, the results of a study by Mehta et al. (2014) suggest that increase in uncertainty leads to decrease in communication between team members. This, in turn, might suggest that team members feel bonded when they try to cope with a common adversary, but this bond does not facilitate work related communication.

Finally, with Table 11 in mind, we emphasize that while coping and reduction of uncertainty have received the bulk of the scholarly attention, these two dimensions seem to be only half of uncertainty management. In applicable business domains, increasing and exploiting uncertainty should be included in the project management considerations. This change in attitude does not necessarily require a strenuous organization wide cultural shift, but can reorient and relieve stress on team level with a relatively simple orientation.

### *5.3. Implications for teaching*

As we mentioned earlier, uncertainty has not been studied extensively in IS education. Taipalus et al. (2018) used a problem based learning (Bell, 2010) approach in an ISD course, and simulated uncertainty with various constructs, e.g., high system complexity, ambiguous domain description, and changes in surrounding environments. Their study reports three strategies students used to cope with uncertainty. *Obedient* teams followed the development framework (which in that case was Scrum),

trusting the method to guide them to the best system quality. *Determined* teams followed their intra-team expertise, trusting their skills, and focusing on aspects they were certain of. Finally, *versatile* teams followed the ever-changing situation, trusting their intuition, and relinquishing both Scrum roles and personal areas of expertise if the situation demanded. The results of their study showed that, based on the product quality, obedient teams performed the best, and versatile teams the worst. These coping mechanisms seem very different to our results, and, combined with the data from both students and professionals concerning the causes of uncertainty presented in Section 4, suggest that students and professionals view uncertainty differently. However, our results suggest that while the causes behind uncertainty are somewhat similar among students and professionals, students focused on general themes, while professionals were able to reflect the causes in more detail.

One of the interviewees stated that *"prior education accustoms employees to static problems, whereas problems in system development are dynamic and chaotic"*, which is an opinion we can agree with. Taipalus et al. (2018) discuss that while it is difficult to teach uncertainty through lectures, which intrinsically strive to minimize uncertainty, teaching approaches like problem based learning enable an environment in which uncertainty is not taught, but simulated. This accustoms students to uncertainty, which may be helpful for the students in their future work environments. We propose that, by complementing the uncertainty causing constructs presented by Taipalus et al. (2018) with the ones we discovered, uncertainty can be simulated in a way that more accurately mimics the uncertainties in industry. Naturally, it is not necessary or even possible to simulate all causes of uncertainty in education. Finally, we propose that IS education should consider teaching the four coping mechanisms, and the four dimensions of uncertainty to students, with the intent of changing attitudes toward uncertainty, and communicating the potential positive effects to future professionals.

### *5.4. Limitations and threats to validity*

Concerning the interviews, the rather small sample size ($N = 11$) may be perceived as a limitation. However, even though all of us participated in conducting the interviews, similar themes recurred with eleven interviewees, and at least four interviewees discussed all causes, effects, and coping mechanisms. Furthermore, most of the themes are in line with what previous studies discuss.

Hsieh and Shannon (2005) summarize some threats to validity regarding content analysis. First, there is a risk that the researchers fail to understand the whole context, and thus missing key categories. As we deemed that the phenomenon of uncertainty in ISD is not widely understood, we took it as our primary objective to approach the subject with as open a mind as possible, and mitigate the threats to validity with investigator triangulation, rather than reversing these priorities. We tried to minimize this risk with investigator triangulation (one author categorized the causes, effects, and coping mechanisms, while the others reviewed the findings) (cf. e.g., Thurmond, 2001) as well as prolonged engagement and persistent observation (one of the authors has extensive background in PM in IS, both with students and industry professionals). Second, Hsieh and Shannon (2005) caution not to use preconceived categories, but to allow the categories to flow from the data. This was fundamentally difficult to conform to, because all the authors had experience and knowledge about project uncertainties. We tried to minimize this threat with two means. First, we conducted the literature review only after the data analysis. This approach naturally posed a risk that our study would yield no new insights to the field. Second, the researcher with the least experience in uncertainties in ISD and PM formulated the categorization. However, since this is a qualitative and explorative study, another group of researchers might probably arrive to at least slightly different categorization.

## 6. Conclusion

In this study, we set out to investigate causes, effects, and coping mechanisms for uncertainty among a diverse range of industry professionals in ISD projects. The results show an extensive list

of 24 themes behind uncertainty, which we categorized into eight categories such as unsuitable communication channels, lack of commitment from the client, and technology evaluation. Additionally, our results revealed six effects of uncertainty, namely dysphoria, unnecessary work, toxic working culture, innovation, self–improvement, and motivation. Finally, we identified four coping mechanisms for uncertainty, i.e., change in attitude, emphasizing roles, openness in communication, and involvement with the client, all of which are in line with previous research on industry professionals, but differ from the perceptions of ISD students. Based on our results, we suggest several research considerations, practical implications for industry, and adjustments to teaching.

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