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Uncertainty in the Early Phase of a Municipal Building Refurbishment Project—A Case Study in Finland

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Abstract: Municipal building refurbishment projects are carried out under conditions of high uncertainty and complexity, which often result in unsatisfying outcomes. In this research, a case study approach is used to provide a holistic presentation of the sources of uncertainties in the early phase of a municipal school refurbishment project in Finland. The study also explores how these sources are treated in the case project. It is considered that the uncertainty in the case study originated from three key sources: from the project due to the characteristics of existing buildings; from the organization due to the separately operating municipal units; from the municipal environment due to the municipal policy, and decision-making process. This study shows that more emphasis should be laid on the sources of uncertainty in the early phases of a municipal building refurbishment project for reaching proper decisions. In addition, the study presents suggestions for improving the municipal process.

Keywords: uncertainty; risk; refurbishment; renovation; early project phase; municipal property; case study

1. Introduction

Challenges in the management of building refurbishment projects have been identified in several countries. Unsatisfying project outcomes, and budget and schedule overruns are common problems, especially in many municipal building refurbishment projects [1,2]. Typically, these negative outcomes are associated with the project complexity [3,4], whereas complexity is strongly related to uncertainty [1,3–6]. Commonly, building refurbishment projects are carried out to fulfill new technical, physical or technological requirements [7]. Recently, an increasing number of renovation scenarios, typically characterised by high levels of complexity and uncertainty, have also been carried out because of a grown importance of the energy efficiency of existing buildings [8,9].

Building refurbishment projects include more uncertainties than new building projects because of the circumstances and limitations that the existing building imposes, as well as due to the social, technological and legislative aspects. The project costs and duration of time are more inaccurate due to the uncertainties associated with the existing building. Furthermore, a lack of "as built" data and defective drawings cause design changes and impromptu decisions on site. The projects also have a number of stakeholders and contracts between the parties, and the conditions and environments vary in every refurbishment project. Additionally, the nature of a public environment and political issues cause uncertainties and difficulties for a public construction project, including differing interests among the various public sector parties, as well as a hurried start and poor preparation of projects as the project needs to be implemented before the next elections [10–12].

Building refurbishment risks and sources of uncertainties are confronted in each phase of a project, from the project planning phase to the end of the project [13]. The Finnish standards [14] for a building project, including refurbishment projects, are roughly divided into eight stages: feasibility analysis; project planning; schematic design; design development; detailed design; construction; commissioning; guarantee period. This study focuses on examining the sources of uncertainty that need to be identified and analysed before setting project targets. These targets, such as the specific scope, budget, quality and schedule of the project, are set in a project planning phase. The phase is a critical stage in project management, since the most significant decisions are made in the project planning phase. Uncertainties that have not been identified and prepared for can then cause serious consequences at later phases, such as failures in realisation and project delays, accidents or health hazards or massive financial losses. As presented above, uncertainty has a high impact on project outcomes and success. These outcomes are eminently substantial in projects characterised by a high complexity, such as municipal building refurbishment projects. However, the uncertainties are not typically considered at a broad level in construction projects [15,16]. To address these aforementioned problems, this study presents an analysis of the sources of uncertainties identified in the early phase of a refurbishment project of a publicly owned school. As the risks are project-specific and depend on the project targets, uncertainties come from more general sources and arise from ignorance. This study also demonstrates how some of these sources of uncertainty are transferred into risks as more information and knowledge are gathered. The identification of uncertainties and transferring these sources into risks, as well as processing these sources, avail a project team to determine a more informed decision regarding the alternative approaches of providing a healthy and functional campus. Furthermore, the authors suggest improvements to the early phase of municipal refurbishment projects.

Multiple descriptions are provided to describe the term "refurbishment", and the meaning of the term has become blurred to an extent [17]. In this study, refurbishment encompasses the series of work parcels, including the renovations, alterations, modernizations, demolitions and extensions carried out on the case campus. That description is rather similar to the definitions Ali and Rahmat, Quah, and Egbu et al. [18–21] have provided. In addition, the term "renovation scenario" is used in this study to describe the combination of "renovation approaches", such as the replacement of a natural ventilation system and building envelope implementation. This terminology follows Kamari et al. [7].

2. Uncertainty and Risk

In the literature, the terms risk and uncertainty are defined and linked with each other in multiple ways. A large group of scholars define uncertainty as risk or risk as uncertainty [22,23], but more often these are classified into two different concepts. The practical difference between these concepts is that the outcomes of the risks are known, while the outcomes of uncertainty are unknown [24]. Relationships among uncertainty, risks and outcomes are presented in Figure 1.

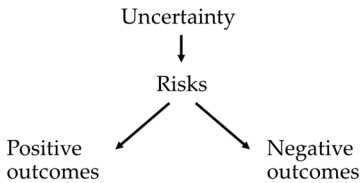

Figure 1. Relationships among uncertainty, risks and outcomes. Adapted from [25].

The ISO standard 31,000 on risk management defines risk as "the effect of uncertainty on objectives" [26]. Risk is also considered to be an uncertain event or the presence of a potential or actual threat or an opportunity that has a negative or positive impact on the project's success [27]. Often, risk is attributed to uncertainty [25,28]. In turn, uncertainty is referred to in the ISO standard as "the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequences or likelihood" [26]. Aven [29] has defined it in a simpler way: "uncertainty means

that we do not know if a specific event occurs or not, and what the consequences of the activity will be". Uncertainty is often also defined as the difference between the amounts of information required to perform the task and the amount of information already possessed by the organisation [30]. In the construction project field, uncertainty is also referred to as a "lack of certainty" or "lack of knowledge" considering the current and future information and circumstances [16,27]. It is also defined to as "ambiguity" with regard to the project participants, lack of data and lack of knowledge, as well as ignorance of the issues that should be known when dealing with the project, and ignorance of the level of knowledge [16]. The former US Secretary of Defense, Donald Rumsfeld, famously categorised the understanding in three levels: known-knowns, known-unknowns and unknown-unknowns [31]. This categorisation is a simplified version of the Johari window, which presents, in addition to these three levels, a fourth level, "unknown-knows". The Johari window was created to help people understand their relationship with themselves and others [32], but it can also be used for explaining the level of uncertainty. These four levels can be divided and explained as follows:

- Known-knowns: things we know that we know.
- Known-unknowns: things we know we do not know.
- Unknown-knowns: things we do not know we know.
- Unknown-unknowns: things that we do not even know that we do not know.

Project risk management tends to detect the unknown-knowns and decrease uncertainty so that all the risks can be transferred into known-knowns [33]. As risks are usually considered as events, uncertainty tends to be examined in a broader perspective and based on more general sources. In project management, uncertainty is traditionally seen as causing only negative effects. Thus, the tendency is to eliminate it as far as possible. However, especially in more recent studies, uncertainty is also viewed from positive perspective by emphasising its opportunities and possibilities [27,34,35]. Risks are generally considered as having both negative and positive effects. However, risk management also typically focuses on the potential threats for successful project implementation instead of opportunities [35,36].

The level of uncertainty can be determined by defining knowledge about the likelihoods and outcomes [37]. The more the knowledge is lacking, i.e., the indeterminacy, the deeper the uncertainty becomes [38], whereas uncertainty is low in a situation where the likelihoods and outcomes are roughly known [39].

Uncertainties may be divided into two categories: aleatory uncertainties, also known as variability, and stochastic and epistemic uncertainties, also known as ambiguity [39–41]. Aleatory uncertainty results from the variability and represents the randomness in natural systems, thus it cannot be eliminated [40]. However, it can be quantified by using the classical frequentist methods [41] or by an expert opinion [40]. Epistemic uncertainties come from a lack of knowledge about phenomena [41]. It can be reduced by more research [38] and quantified by expert opinions, but it cannot be measured [40]. Typically, uncertainty management requires a combination of the measures of both the aleatory and epistemic uncertainties [41], and the most common way to measure it is through probability [29].

Based on the origin, sources may be divided into external and internal uncertainty. These largely correspond to epistemic and aleatory uncertainties, as external uncertainty is defined as a lack of information that may affect the project performance related to external factors, whereas internal uncertainty is related to a project's internal factors [42]. Typically, external uncertainties are more challenging to manage since these sources can seldom be changed. Instead, the project team can influence the sources of internal uncertainty by making decisions [42].

3. Uncertainty Management in Construction Projects

In building refurbishment projects, the sources of uncertainty are unique in every project, and thus more challenging to identify and manage. However, multiple common sources exist in these projects, as presented in Table 1.

Table 1. The sources of uncertainty of building refurbishment projects.

Source of Uncertainty of Building Refurbishment Project	Authors
Unforeseen site conditions, lack of drawings, lack of design information	[43–51]
A tight budget, a lack of funds	[21,44–46,48,52,53]
A lack of predictability of costs	[53]
A tight schedule	[44–46,48,49,53]
A lack of availability of materials	[21,50,52]
Occupants in the building during the refurbishment work	[21,49]
A lack of availability of working space on site	[21,49]
A lack of involvement of key participants in a project and poor communication among project participants	[3,45,47,48,54]
A lack of precise definition of what is required	[45–47]

As current risk management processes are generally well-known and used in projects, practitioners are relatively unfamiliar with uncertainty management [55]. However, uncertainty management is essential since risk management practices and tools alone are inadequate and useless, especially in complex projects with a high level of uncertainty [16,56]. The aim of the project risk management is to improve a project's performance by decreasing the probability and impact of negative events and increasing the probability and impact of positive events [56,57]. In addition, risks tend to be reduced or maintain the assumed level. The aforementioned targets can, also, be set for the uncertainty management.

Typically, project risk management is divided into separate processes, phases or steps. A simple risk management process includes the following key phases:

1. Risk identification;
2. Risk analysis;
3. Risk response.

However, often more steps or processes—such as risk assessment; risk estimation; risk mitigation; risk monitoring—are involved in the process [13,27,36,55,57–59]. As a process, uncertainty management is partly similar to project risk management, and the similar methods and steps used in traditional risk management can be used for uncertainty management [42]. However, the process of uncertainty management should involve risk and opportunity management as well as identifying and managing the sources of uncertainty in a broad sense [16,60]. In contrast to risk management, in uncertainty management the tendency is to understand where and why uncertainty is important and unimportant in the project context [16].

A typical project risk management process can be modified into project uncertainty management by modifying the process and shifting the emphasis. This approach might include, e.g., revising terminology, such as from risk management into uncertainty management [56]; putting more emphasis on the origins of uncertainties [16]; emphasising some aspects of project-related uncertainty outside of the project context [56]; advancing the process, since uncertainties can be identified with less information than risks [56]; reflective learning and sensemaking, enabling flexibility [61]; classifying uncertainties into various types on the basis of the potential effects and estimating which types are the most important [62].

From an economical viewpoint, the uncertainty can be evaluated by making a tradeoff between the cost of mitigating the uncertainty and that of the damage likely to be caused to the project [63]. Thus, the limits of the zone of an affordable uncertainty protection can be set [63]. However, it must be noted that not all uncertainty can be addressed via analytical approaches, and some uncertainty will always remain in a project [63]. Systematic risk management has been shown to have a positive effect on a construction project's success. Several authors [64,65] have found a strong relationship between the implemented risk management efforts in a project and the level of the project's success. According to Smith et al. [13], each building refurbishment project should be divided into a number of

separate phases, and each phase should contain risk assessment and risk management. Thus, the risk management leads to a continuous process that spans the entire project [13]. Regular risk assessment and management is important because the risks of a building refurbishment project differ, and new risks arise at every phase. Additionally, the nature of managing the risks changes during the project. In the early phases of the project, the range of the possible options is very broad, but in later phases the range of the risks narrows [13]. This corresponds with uncertainty, as during the project uncertainty gradually shrinks since more knowledge is obtained [66].

Despite the multiple efficient tools and models that can be used in risk and uncertainty management, as well as the encouraging results of project management methods, various problems concerning risk and uncertainty management in practice are identified. Many project managers consider the tools to be difficult to use in complex projects and the quality of their use to be poor [67]. Additionally, the effectiveness of the tools is perceived as quite low, which reduces the interest towards risk management [67]. In addition, Ehsan et al. [68] posit that most of the risks are perceived subjectively and are related to contacts or construction processes; thus it is better to deal with them on the basis of previous experience. Despite the wide variety of risk management tools, the project managers use only some of them [67], and the studies of Mansfield [69] and Ehsan et al. [68] reveal that most of the practices do not use any formalised risk identification method. Several authors [15,16,56] have criticised the project risk management process as having an excessively limited focus as the norm and paying too little attention to uncertainty. According to Ward and Chapman (2003) and [56], the focus is often on threats which may result in a lack of attention to many areas of uncertainty, such as the variability arising from a lack of knowledge. Paté-Cornell [41] states that a full analysis of uncertainties is a complex and costly procedure to exercise. Cleden (2012) concurs, and states that "the goal is containment of uncertainty, not elimination".

4. Methods and Materials

As this study aims to identify the sources of uncertainty and examine the treatment of these sources in the early phase of a refurbishment project of a publicly owned building, a participatory case study was chosen as the research method. This approach is used to gain greater insights into the studied issue or community [70]. Besides, the participatory research method allows researchers to obtain new knowledge, and the studied community often benefits from the research process [71,72]. In this research, the approach was employed to develop a comprehensive understanding of the studied project. In qualitative research and participant observation, the influence of researchers and the chosen sources of information play an important role in the results. The authors participated in the project planning meetings where the potential actions of a publicly owned school were considered. The research data collection method was through participant observation in the project meetings. In addition, the authors scrutinised the documents and minutes concerning the project and conducted site visits. The first project planning meeting was organised in February 2018 and the last one that the authors attended was in March 2019. The original project planning schedule was delayed; thus, the authors were not involved in the project planning in its final stages. The authors actively attended a total of 21 meetings, and observed, made suggestions and asked questions through the process. The number of participants at the meetings ranged from 6 to 18. The participants of the meetings are listed in Table 2.

This research is part of the "Management of Complex Building Refurbishment" project, which aims to develop tools and practices to improve the management of complex building refurbishment projects. The project team selected the case study school as the pilot project. Details concerning the condition and investigation of the buildings, as well as the decision-making process and alternative solutions, are presented in earlier publications [73,74].

Table 2. The participants of the meetings.

Project Stakeholder	Participant
Authors of this article	Three university researchers
Municipal employees	Representatives of the Real Estate Centre The chief of the maintenance department The representative of a renovation contractor The representative of a school committee Kitchen expert Cleaning expert The chief of early childhood education
Condition assessment consultants	Five condition assessment consultant the project leader purchased
Users	The head teacher and the deputy head teacher

Case Study

The case study concerns a school campus composed of three buildings: a white building built in 1997; a brick building built in 1955; a pavilion built in 2001. In addition, a day nursery was operating in the white building. The campus, presented in Figure 2, is located in Southern Finland, in the city of Vantaa.

Figure 2. The school campus is composed of a (1) white building; (2) brick building and (3) pavilion.

The number of children and pupils in the surrounding area of the campus increased. Therefore, there was a need for additional places for over 160 children in the day nursery, and approximately 150 pupils. In addition, lunches were prepared on the campus and also served in the surrounding schools. The number of pupils also increased in said schools, resulting in an increased requirement for lunches. Therefore, major kitchen modifications were required in the campus.

The pupils and the staff of the white building have suffered from various building-related symptoms. The municipal employees have tended to solve the problems by commissioning multiple investigations. However, any clear source causing the symptoms had not been identified. The white building had also sustained multiple hazards, including several water leaks from the roof. These hazards tended to be repaired. However, any larger-sized renovation scenarios had not been made in the building.

Since the technical systems, some materials and structures of the brick building had come to the end of their useful life, the building was in need of major renovation approaches. The natural ventilation in the building was considered challenging since the number of pupils in the classrooms is nowadays greater than was designed. Additionally, during summer, the temperature in the classrooms was considered too high, while during winter it was too low.

The alternative solutions for organising the facilities were examined in the feasibility analysis. On the grounds of the analysis, the city council had decided that the project planning would be advanced on the basis of a solution that contained renovation scenarios of the white building and the brick building: an extension and alteration considering the kitchen, and the demolition of the pavilion. However, other alternatives were not ruled out.

5. The Sources of Uncertainty in the Case Project

Multiple sources of uncertainty were identified in the meetings, by scrutinizing the minutes and documents concerning the campus, and by observation in the meetings. These sources are divided into three main areas: uncertainty from the project, including the characteristics of the existing buildings and campus; uncertainty from the organisation; uncertainty from the operational environment. As the uncertainties were discussed in the meetings, respectively, these are presented in this chapter in the previously mentioned order. The project team also processed and tended to create methods for responding to some of the uncertainties and risks in the meetings. However, the approach was casual and informal as the project team did not have a risk management plan for the project, nor did they handle risk and uncertainty management in a structured way.

5.1. The Process of Identification and Treatment of Uncertainties

The process of identification and treatment of the sources of uncertainties, in the project meetings, is presented in Figure 3. The participants in the meetings did not generate the sources of uncertainty deliberately, instead, the sources arose from discussions. The process started by examining the sources of uncertainties considering the existing buildings, such as the building condition and indoor air problems. The meetings were particularly focused on these sources. In addition, uncertainties concerning the project needs and requirements, measurement data, and design were discussed in the meetings. In the early planning phase, the project team also showed a higher level of competence and acquired more knowledge after hiring consultants. As the project planning phase progressed, the team noted several sources of uncertainties arising from the municipal environment. However, these uncertainties could not be reacted to.

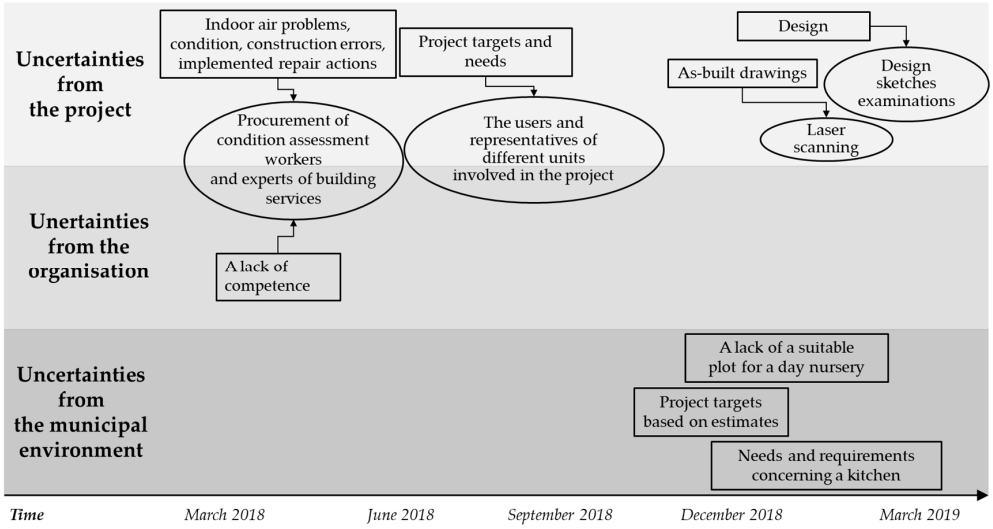

Figure 3. The identification and treatment of the sources of uncertainty considered in the project meetings.

5.2. Uncertainty from the Project

In the beginning of the project planning phase, there was a high level of uncertainty concerning the circumstances of the existing buildings due to a lack of initial data and lack of knowledge of the initial state. During the project planning phase, the project team focused most on these sources of uncertainty. The municipal employees were neither conscious of the repair needs nor of the origins of the building-related symptoms, even though they had sought the reasons for the symptoms for several years by commissioning multiple investigations. In addition, they did not know how the buildings had been studied and repaired over the years. Besides the uncertainty concerning the existing buildings, project uncertainty was also arising from the design, project targets and costs.

This uncertainty, related to the existing buildings and campus, tended to decrease and transfer into risks by gathering more information. First, the authors tended to create an overall view of the condition of the buildings and the identified potential sources of the building-related symptoms by scrutinising all the reports concerning the condition of the buildings. Even though the results of the reports presented multiple potential factors that have affected the development of the building-related symptoms, the scrutiny also found some omissions and a lack of knowledge considering the condition of the buildings. To respond to this shortage, the municipal employees commissioned consultants to survey the buildings more accurately and extensively during the summer and autumn of 2018. The consultants' findings provided a more accurate overall picture of the condition of the buildings, as well as an increased knowledge of the location of the microbes and faults.

Several sources of uncertainty were decreased or transferred into risks after more information was gathered and processed. For example, there was a high uncertainty concerning the condition of the structure of the white building due to the complaints of the building-related symptoms, water leakages and noted construction errors. The scrutiny revealed missing drainages under the white building and high values of relative humidity measured from the slab-on-ground floor. Additionally, the composition and quality of the soil under the white building was unknown in the beginning of the project. This brought out a risk of a capillary suction from the underlying ground into the structures. The uncertainty concerning the ground floor was reduced by examining the composition of the capillary break drainage layer from the test pits on the side of the building, by cuts on the ground floor and by measuring the moisture from the concrete slab. These actions exposed a soil with a high capillary rise, which may cause capillary suction from the underlying ground. The wet soil may cause water to rise up to the base floor, causing it to stay constantly wet. The exceptionally high values of relative humidity were measured in several places of the slab-on-ground floor. Thus, there is a risk that the moisture load would lead to moisture damage in structures such as partition walls. The scrutiny of the investigations also revealed damaged materials in multiple places in the white building that were outside the locations of recorded damage. The project team aimed to reduce the uncertainty concerning the damaged materials and microbes by investigating the structures. The condition survey investigators implemented structural openings and took samples from the materials. Thus, the potential damaged areas tended to be located. Several damaged materials were found; however, the samples were not taken in such a large scale that all the damaged structures could have been found with certainty. In addition, it must be noted that a completely reliable comprehension of the location of damaged materials is only possible by investigating all the structures and materials of the building, which, in practice, is impossible. Thus, all the uncertainties could not be eliminated.

The project team tended to respond to some of the identified project risks. For example, an unpleasant smell and high values of relative humidity in some of the structures were noted in the basement of the brick building. A former condition assessment investigator suspected that the structures contained harmful microbes. Due to the potential health hazard, pupils and staff were banned from using the rooms in the basement. Since the renovation of the structures of the basement is relatively challenging and expensive to implement, the project team discussed the reduction of the risks related to the microbes instead of risk elimination. The project team discovered some methods for reducing the risks, such as not placing the rooms for educational use in the basement; locating

the bottom floor of the new elevator on the first floor instead of the basement; installing a ventilation machine, separated from other ventilation, in the basement.

When implementing a building refurbishment, accurate measurement data are important for producing a proper detailed design. The project team did not have confidence in the accuracy of the measurement data of the existing buildings as they comprised old drawings and some pictures in .dwg format. Therefore, laser scanning covering the white building and the brick building was conducted in order to gather more accurate and detailed measurement data. Thus, a risk related to the errors in measurements, such as faults in design, tended to be reduced.

The uncertainty was also related to the feasible repair actions of the brick building, since there was a need to increase the number of pupils in the rooms, which creates a requirement to increase the ventilation rate. A change from natural ventilation into the other systems may cause changes, e.g., in air pressure, which may present difficulties, such as microbes spreading into the indoor air. The project team decreased this uncertainty by commissioning ventilation experts to compile a draft of potential ventilation alternatives. The experts presented four potential solutions, involving threats, opportunities and the number of pupils that the solution enables, for organising the ventilation procedure. The decision of the implemented ventilation was deferred to the later project phase.

A high level of uncertainty was related to the project targets, even the preliminary project objects, set in a feasibility analysis. These targets are closely connected to the project but are presented more specifically in Section 5.3, as the primary reasons for uncertainty are considered to arise from the operational environment instead of from the project.

The uncertainty also concerned the design task implemented in the project planning phase. In this phase, the preliminary design focused on the outlines of the facilities and the extension. The uncertainty concerning that task tended to decrease and transfer into risks by sharing information between project stakeholders. The risks concerning the design faults tended to be reduced and responded to by purchasing several design sketches and evaluating these informally in the meetings. Thus, some design errors, such as mistakes regarding the number of required rooms for the day nursery, were noticed early on and corrected. In addition, the attention paid to the project requirements and the targets of the design could be followed up, leading to the right direction in terms of project management.

The investment costs of the alternative solutions regarding demolitions, extensions and a new building were roughly estimated in the feasibility study. However, the costs concerning the alternative solutions of refurbishment actions and an extension were not evaluated in the project planning phase. Thus, the project team neither knew the cost difference between the alternative solutions nor the rough estimate of the costs of the potential actions. The standard procedure in the municipality is to calculate the costs after the final design is completed. Therefore, there was high uncertainty with regard to the potential project costs. Even if the cost was calculated later, reducing the costs would have been challenging since the design solutions were already decided.

The sources of uncertainty concerning the project, as well as the potential outcomes, are summarised in Table 3.

Table 3. The sources and the potential outcomes of the uncertainty concerning the project.

Key Source of Uncertainty	Contributing Factors	Potential Outcomes
The existing buildings	Unknown repair needs Lack of as-built data Ignorance of the implemented repairs Lack of knowledge of how the buildings are studied Ignorance of the results of investigations Unknown origin of the building-related symptoms	Inappropriate scope of the work, failed actions, construction errors, cost overrun, prolonged duration of the project, unhealthy and unsafe facilities, decreased quality of the work
Project targets	Ignorance of the project targets	Unsatisfying outcomes, financial losses
Design	Ignorance of the requirements and the design targets Ignorance of the scope of work	Unsuitable facilities for the purposes, additional costs, delayed schedule
Costs	Ignorance of the budget Ignorance of the costs of different actions	Unnecessary expenses, poor use of the municipal finances, stillborn project

5.3. Uncertainties Related to the Organisation

Some sources of uncertainty were identified in the organisation's structure. The municipality has a number of separate units administering different municipal activities. These units operate rather independently and have their own responsibilities. The Real Estate Centre is responsible for purchasing and developing the municipal facilities and real property with the city's customer departments: the City Planning Unit, and Financial Planning. The Maintenance Unit is responsible for the maintenance and minor repairs of the municipal facilities and real property. The case project was initiated by the Real Estate Unit.

In the early project planning phase, the project team found out that multiple repair actions would be implemented in the white building during the summer and autumn of 2018. The Maintenance Unit commissioned several actions, such as sealing the gaps between the floor and wall, to decrease the users' building-related symptoms. However, the implemented repair actions somewhat conflicted with the actions the condition assessment workers had proposed in the project planning phase. This may have resulted from the divergent time spans regarding the two units. The Maintenance Unit tended to respond to users' complaints quickly and within the limits of their administrative district. Therefore, the unit paid for the actions to be taken, which were estimated to last about five years. In contrast, the project team took a much more long-term view when examining the campus and thus required the appraisal of refurbishment actions with a long-term perspective. Since these two units operate separately, the project leadership becomes more complex. The project team cannot conclude advisable long-term decisions as some project limitations have already been created in other municipal units. In addition, the information flow between the units was deficient. This increases the project uncertainty, as not all the existing information and knowledge considering the project was available to the project team.

The final major refurbishment decisions were concluded in the city council one project at a time. However, the municipal employees prepared the proposals for the council. Thus, they have a remarkable role in the decision-making process. In the project meetings, the project stakeholders tended to ensure the implementation of the needs and requirements of the spheres of authority they represented. Thus, it was challenging to find the order of priority of the project targets as well as the compromises. This increased the uncertainty towards the validity of the chosen solutions.

The sources of uncertainty concerning the organization, as well as the potential outcomes, are summarised in Table 4.

Table 4. The sources and the potential outcomes of the uncertainty concerning the organisation.

Key Source of Uncertainty	Contributing Factors	Potential Outcomes
Separately operating units in the municipal organisation	Lack of common project targets Lack of prioritising of the requirements Ignorance of the actions of the other units Projects limitations Lack of information concerning the project	Inappropriate facilities, poor solutions, challenges in project leadership, financial losses, cost overrun

5.4. Uncertainties Originating from the Operational Environment

A high level of uncertainty is related to the operational environment, including the municipal structure, a service network analysis, land use planning and estimates of the population growth. There was ambiguity considering the targets and the requirements in the project, such as the need of the extension premises in the service network analysis. The conclusions the analysis provides are based on prognoses, including the estimates of migration, population growth and the use, condition and refurbishment needs of the publicly owned school buildings. However, an estimate always contains uncertainty. In the beginning of the project planning phase, it was estimated that there was no need to increase the number of pupil places in the case campus. However, during the project planning, a new analysis was published, and the estimate of the requirement of the places for the pupils in

the school increased by 150. As the estimates changed so significantly, it can be assumed that a high uncertainty concerns the actual need of the pupil places in the campus. In addition, the estimates are more inaccurate the longer the term. Therefore, it is hard to estimate if the increase of 150 pupil places in the campus is sufficient or excessive over the coming decades.

The primary project targets were examined and finalised in the feasibility analysis, which was gathered up approximately five months before the beginning of the project planning. As some of the needs presented in this analysis had been changed, the project targets should have been redefined. However, the precise project targets were not set in the meetings, instead, the discussions focused on the needs and the requirements at a vague level. Additionally, another problem was connected with the targets, as it was unclear if the targets are realistic to implement or conflicting. For example, the size of the case site is rather small, and thus locating all the required operations and rooms there is challenging. In addition, the project team did not know if some of the space requirements could be revised, or if these requirements could be satisfied in other locations. If some project targets or requirements cannot be modified, there is a risk that the new campus will be compromised by many poor solutions.

Uncertainty was caused by a lack of knowledge about the municipal policy. The decisions to be made in the case project should follow municipal policy. However, there were several issues that were not yet decided at the upper municipal level. For example, there was uncertainty related to the meal servicing and food preparation in the campus. The network service analysis states that the new municipal food production solutions should be established and evaluated by the Real Estate Centre, i.e., the decisions considering the municipal food production are not concluded yet. As the overall outline is not set, it is hard to discover a proper solution for organising food preparation and meal servicing, including the size of the kitchen and location, in the case campus. There is a high risk that the selected solution will only be a short-term one, in addition to being unsuitable.

The Real Estate Centre tends to follow the policy which states that the new municipal service buildings should be larger than the earlier ones. According to the service network analysis, the larger-sized school buildings are economically more profitable than the smaller-sized buildings, in addition to the larger-sized building enabling more opportunities for education. However, the service network analysis highlights a lack of large-sized plots in expedient locations. Therefore, it is practically impossible to build a new school campus or day nursery in an unbuilt plot. A large-sized campus or day nursery can only be provided by building extensions in an existing campus. In the case project, this policy causes uncertainty considering the possibility of finding a feasible solution, as it was challenging to enlarge the day nursery in the rather small-sized site. According to the representative of early childhood education, there were no available free plots for the day nursery nearby. Therefore, the increased number of children need to be located in the case campus. However, a closer examination proves that the municipality has a number of unutilised plots nearby, but these are planned for other uses or are leased out. Other studies have shown that the strategy of enlarging campuses may have unfavourable consequences, including decreased learning results [75], noise [76] and congestions [76].

Usually, the decision-making process of implementing a major municipal refurbishment project lasts a long time, since the decisions are made in different municipal levels and phases. This time lapse causes uncertainties in the project as the initial data, the targets and the needs are advanced during that time.

Appropriation also caused uncertainty in the project. The project planning of the campus was already implemented twice before, but the actions were not enforced because of a lack of appropriation. There is a risk that this time, too, an appropriation is granted to the other projects. Major municipal refurbishment projects are included in the municipal long-term investment plan. The projects are prioritised on the basis of the plans, and the viability of the projects is evaluated. However, since the refurbishment needs of municipal buildings are high and exceed the appropriation, some of the buildings with an urgent repair need must have their repairs postponed. In addition, the municipal refurbishment decisions are usually based on investment costs as operating and maintenance costs

are ignored. These running costs are often challenging to estimate, which increases the uncertainty concerning the lifecycle costs of different solutions, as well as uncertainty concerning the accuracy of the decisions.

The sources of uncertainty concerning the municipal environment, as well as the potential outcomes, are summarised in Table 5.

Table 5. The sources and the potential outcomes of the uncertainty concerning the operational environment.

Key Source of Uncertainty	Contributing Factors	Potential Outcomes
Municipal policy	Lack of knowledge about the municipal policy Ignorance of the feasibility of the project targets Ignorance of the appropriation	Inappropriate facilities, short-sighted decisions, financial losses
Decision-making process	Prolonged decision-making process	Decisions are based on outdated information, poor decisions, prolonged duration of the project
Estimates and service network analysis Municipal employees and decision makers	Uncertain estimates of migration Unclear project requirements and needs Ignorance of the required competence Uncertainty of the employees' and decision makers' skills and competence	Unsuitable facilities for the purposes, financial losses Inappropriate decisions, financial losses

6. Discussion

The project team tended to find proper solutions for providing suitable and healthy spaces for the pupils, children and staff in the publicly owned school and the day nursery. In the project planning phase, multiple sources of uncertainty that might affect the project were identified. Generally, at the early phase of a project, the field of uncertainties is broad since the project does not yet have many limitations; the targets are set but only a few decisions are made.

The origins of the uncertainty of the case project are divided in this study into three categories as follows:

- The project, such as the existing buildings and campus, project targets, design and costs;
- The organisation, such as separately operating units;
- The municipal operational environment, such as the municipal policy, decision-making process and estimates.

This categorisation is relatively similar to the key sources Martinsuo et al. [77] presented regarding portfolio uncertainty. The first two categories can be considered internal uncertainties, whereas the third one is mainly an external uncertainty, since the sources originate from outside the project and are thus much more complicated to manage.

The management of uncertainty and risks was left uncompleted in the studied project deliberately. Nevertheless, some common phases of risk and uncertainty management could be identified. The case project features of the management process involved identifying and responding to uncertainty and risks. In addition, the project team emphasised the origins of uncertainty, which is considered a characteristic of uncertainty management rather than risk management [56]. Of the four commonly used risk response strategies, avoidance, mitigation and acceptance were used in the case project, but not transference [78]. The majority of the risks and uncertainties were not prioritised or evaluated, and the probability and the potential outcomes were not processed to a large extent. This is a significant difference from the typical process of risk management. Since the risks and uncertainties were not prioritised, the potential of serious risks and uncertainties were not discerned from the risks

and uncertainties with minor outcomes. This might significantly affect the reliability of the project decisions made.

Discussions, site visits, brainstorming, past experiences and reviews from similar projects were the methods used for uncertainty identification and treatment concerning the existing buildings and the campus. The use of these methods for identifying the risks and uncertainties of construction projects is in accordance with the other studies [79–81]. In the early project planning phase, the project team became aware of their lack of competence and knowledge regarding some technical issues. Therefore, they sought to reduce the uncertainties related to inadequate knowledge and skill by hiring experts to produce an analysis and share their experiences and knowledge in the meetings. In line with other studies [35,36,42], the uncertainty was considered only as a negative perspective as all the identified uncertainties were seen as threats, with the outcomes of uncertainties causing negative risks, in the case project. Since the targets of the project were rather accurately defined, the potential possibilities are harder to find as well as more challenging to utilise.

The existing buildings produced multiple sources of project uncertainties. The unknown condition of a building and the lack of a proper site survey for existing conditions are commonly recognised sources of risk which cause uncertainty in refurbishment projects, as reported in several other studies [44,46,49,50,82]. The project team focused especially on the striking technical sources with serious outcomes as noted in the beginning of the project planning phase. Some of these sources were transferred into risks as more information was gathered by scrutinising existing data, conducting condition assessments and implementing site visits. As more information was obtained, the sources became more manageable and predictable and the potential outcomes of these sources could be discovered. By enforcing this process, the uncertainty was reduced and the threats could be managed easier.

A significant challenge in this project was indecision, especially at the higher municipal level. The project team had to make a great amount of decisions and choices affecting the other projects, with only a little amount of information. The decision-making process should proceed progressively, from major lines into the more detailed levels. However, this study shows that sometimes the municipal decisions are concluded in reverse. The issues that have a major influence on the municipal operations are made at the project level as the upper level policy is not finalised yet. In addition, a high level of uncertainty was related to the project targets. Most of the sources of uncertainty essentially arose from the municipal environment and a deficient decision-making process as well as from financial sources. As the project targets were not well-defined early in the project, each project participant utilised the opportunity to contribute to the direction of the project during the later project planning phase. However, the interest and views concerning the targets varied between the project parties, because they were representing different municipal departments and units. The project planning process would become more simplified and easier to manage if the main lines had been finalised before, and if the project targets were clear in the beginning of the project planning phase. Thus, a project team could follow the municipal policy with the major lines and focus on more detailed decisions in the project's context. If the decisions that have a major impact on municipal operations are made at the project level, there is a high risk that the optimal solutions are not found as the big picture is not observed regarding the issues.

In addition, estimates concerning migration increased uncertainty as the project requirements were based on these prognoses. It has been reported that unclear or changing requirements in municipal construction projects have also caused difficulties in other studies [10]. The municipal building and refurbishment project is challenged by the rigidity of the process. The decisions are made at several levels in many phases. As the municipal decision-making process is a long-lasting one, uncertainty will increase; the initial situation and data, original project targets and needs will be modified as time passes. This also causes overlapping work, as the project targets and data need to be reconstituted in the later phases of the project. In addition, e.g., changing a town plan is a long-term process. Even if

the changes were worthwhile, the process would probably delay the project so much that it would not be undertaken.

As multiple sources of uncertainty initially arose from the municipal environment, increasing uncertainty at the organisational and project level, the authors submit suggestions to modify the current process. The modified process is presented in Figure 4.

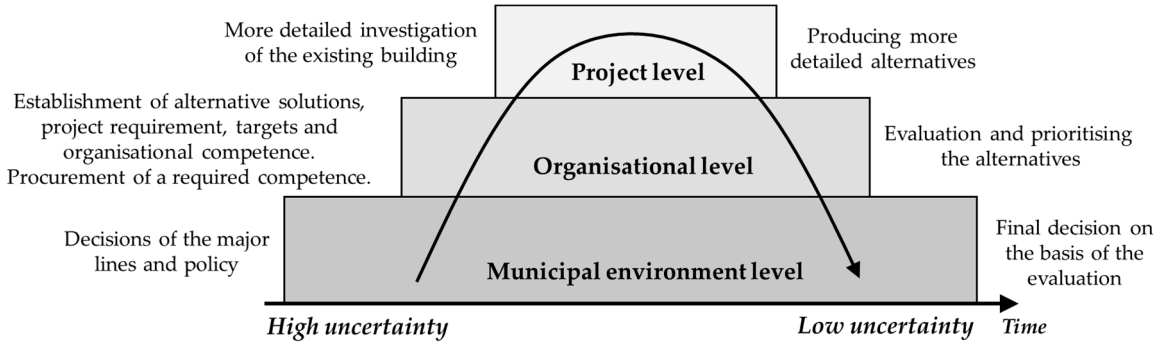

Figure 4. The proposal of a process for decreasing the uncertainty in an early phase of a municipal building refurbishment project.

The process of decreasing uncertainty in a refurbishment project starts at the municipal level, since there are multiple sources of uncertainty affecting individual projects. The major lines considering the projects should first be determined at that level. Then, the organisation describes more specifically the requirements and targets of the project, and settles the competence of the organisation. If needed, a higher level of competence is achieved through the hiring of experts. In addition, alternative solutions for satisfying the project targets are investigated. At the project level, the existing buildings, as well as the details of the targets and needs, are detected more accurately. Additionally, the implementation of the alternatives are discovered more precisely. As information and knowledge increases, some sources of uncertainty can be transferred into risks at this stage. After being carefully established, the alternatives are evaluated at the organisational level. Eventually, the final decision of implementation is concluded at the higher municipal level, on the basis of the evaluation and suggestions that the project organisation has made.

A notable finding in this study was the lack of the project targets in the project planning phase. The project budget was hardly discussed in the meetings, and even the targets concerning the facilities were rather unclear. The target of the project completion date was set, and the project schedule prepared. However, the project planning phase was behind the schedule. Additionally, a curious consideration in this project was starting the preliminary design even before the targets were clear. This was probably a result of a lack of information, and an aim to stay on schedule. Rarely, the decisions can be made with full information, therefore, the choices must be of limited rationality. In this project, multiple decisions were made in chaos as the project was complex and contained high levels of uncertainty. The project participants' approach for decision-making largely followed Herbert Simon's [83] famous decision-making concept, as they did not look for the best solution but rather a satisfying one. For example, the approach to organise the facilities as presented in the feasibility analysis and recommended by the city council, can be considered as a satisfying solution, as other solutions were not further examined during this phase. Thus, the search for further information concerning other alternatives was cancelled. Appropriate solutions were probably missed because of this approach. However, it saved human and financial resources, in this phase of the project.

7. Conclusions

This case study provides a holistic picture of where uncertainty originates from in municipal building refurbishment projects in the early project phase. In addition, the research presented how

some of those uncertainties were transferred into risks after more information was gathered. It also presents the approaches to the uncertainties and risks and the responses to them in this project.

The study divided the main sources of uncertainties, identified in the case project, into three categories:

- Uncertainty from the project, including the sources of uncertainty considering the existing buildings and the campus, the project targets, schedule and costs;
- Uncertainty from the organisation, including separately operating units, and the project stakeholders' competence;
- Uncertainty from the operational environment, including the municipal policy, estimates, needs and decision-making process.

The identified uncertainties impact the decisions regarding refurbishment actions of the school building and need to be confronted by the project parties to ensure the appropriate decision is made. In this project, most of the identified sources of uncertainty or risks were not evaluated, which is typically an important step for achieving a proper overall picture of the situation before the final decision. The interesting finding of the study was that a municipal environment provides many sources of uncertainty in refurbishment projects. In the municipal decision-making process, in particular, indecision and separate administrative units can cause project threats.

This study demonstrated how the project team focused on managing the project uncertainties that can be transferred into risks by gathering more information, whereas the external uncertainty and the organisational sources of uncertainty were mainly ignored. In addition, the features of risk and uncertainty management of the project focused on pinpointing the potential threats for successful project implementation instead of opportunities.

As this study demonstrated the process of transferring uncertainties into risks by gathering more information, it can provide value for practitioners involved in a complex building and refurbishment project. In addition, the authors' suggestions to modify the municipal building refurbishment process may help municipal employees develop their refurbishment projects. The findings may also provide practical value for the client's representatives regarding the decision of whether to undertake some refurbishment works.

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