Construction method selection based upon the clients' preferences

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PREFACE

This thesis provide an insight in the factors that are related to the construction methods that are used in The Netherlands. This is done based on the clients' perspective. Not only are the factors related to the construction methods discovered, also the degree of important factors has been revealed. This has been accomplished by an extensive literature review, interviews and questionnaires that have been held.

After an intensive period of five months, the time has come to complete the Master: Construction Management & Engineering at the Technical University of Eindhoven. With these words of gratitude I put the finishing touches to my thesis. It was a period in which I have learned a lot, scientifically, but also on a personal level. I would to thank my graduation company Plegt-Vos for the opportunity for carrying out my graduation project within the company. They provided input that was useful for the completion of this thesis. Within the company of Plegt-Vos I would like to thank the department of B&U and in particular my external advisor Dennis Baas for his practical input and guidance during my graduation process. In addition, I would like to thank the Technical University of Eindhoven for making my graduation possible. Within the university I would like to thank in particular my supervisors Bauke de Vries, Gamze Dane and Theo Arentze for their scientific inputs, critical thinking and guidance. Besides, I would like to thank especially Gert Regterschot for the time and effort he has put in helping me to complete my Master. I also want to express my appreciation for my partner Mariam Al-Saqaff who has beared with me during the long months of writing, even when I retreated to long days working on my computer. They all have been a valuable addition to overcome the bridge between the theory and practise and eventually finishing this thesis.

The results of this thesis could not have been produced without the help of the people who I have interviewed and who completed the questionnaires. I would like to show my appreciation for their help and inputs.

I hope that you enjoy reading my work!

Brian van Hamond
July 2019, Utrecht

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SYNOPSIS

The construction industry is a complex sector with a variety of concerns that the industry has to overcome. To name a few; on the one hand the construction industry has to deal with the growing shortage of housing, productivity problems and labour shortage, and on the other hand the industry has to deal with the reduction of the Green House Gas emissions by improving the climate issues. These are some important aspects that must be taken into account, when choosing a particular construction method. Since construction companies need to decide which construction method they should apply best for its type of client and their project, the decision making process contributes to the discussed variety of concerns. The choice for one particular construction method over the other is not made randomly, therefore it is interesting to examine this topic.

The purpose of this thesis is to investigate and uncover all reviewed factors related to the construction methods that are applied in the Netherlands from the perspective of the client.. For this thesis it is important to know the clients' preferences of factors related to the construction methods. This could help construction companies in their choice of using a particular construction method to realize a construction project. Working with the Fuzzy Delphi Method discovered what the most important critical factors are.

In this thesis a literature review was performed to determine the set of construction methods that are used in the Netherlands. In addition to this, the client types and building types were explored. It turned out that there are four main construction methods applied in the Netherlands: the conventional construction method, prefab construction method, conceptual construction method and the modular construction method. The conventional construction method refers to a construction method that has a linear process of building and is labour intensive from the early design phase on the building site. The prefab construction method is the practise of creating building elements in a factory which are later assembled on-site. The conceptual construction method is a method that uses a standardized way of constructing a building by means of a standardized process. It is characterized by its dry-stacking principle and its parallel process of construction. In terms of the modular construction method, module sections are constructed at an off-site factory were only the assembly will be done on-site. When the modules exit the factory, they are fully furnished and made install-ready. The client types that were researched in the literature review of this thesis are the following ones:

- Governmental body;
- Healthcare body;
- Educational body;
- Housing corporation;
- Developer;
- Investor.

After the literature review had been conducted, fifteen factors related to the construction methods in the Netherlands from the clients' perspective were found. With the factors and the information gathered from the literature review, interviews were conducted with clients to give a first indication of which factors, construction methods and building types the clients prefer; correspond with factors derived from the literature review; why clients hold certain

opinions about this research topic; and more importantly to gain information about new factors that are mentioned by clients that will be added to the already discovered factors, derived from the literature review. Results from interviews showed that six new factors have been mentioned by the interviewees. In total twenty-one factors related to the four construction methods were found.

In this thesis, two rounds of questionnaires were conducted to reveal the preferred factors and reach consensus among the results from both questionnaires in line with the criteria of the Fuzzy Delphi Method. In line with the theory described by Aliev et al., (2004) and Rahimianzarif & Moradi (2017) the results of questionnaire (I) served as input for questionnaire (II). Questionnaire (I) had one hundred and forty-six respondents, whereafter the results have been analysed and calculated using the Fuzzy Delphi Method. Six factors were considered to be important, as they scored higher than proposed threshold of $\alpha = 0.70$. The factors that scored below the threshold, were excluded from the list of factors. Questionnaire (II) had seventy-two respondents and on its turn, the results from questionnaire (II) are also calculated by the Fuzzy Delphi Method. Again, the factors needed to meet the same threshold. The repeating process of using multiple questionnaires ensures consistency in answers and leads to consensus of the results. In both the results of the questionnaires, the respondents' profile was described. The respondents' profile showed similarities and differences, those are scientifically elaborated by working with the chi-square goodness of fit test. With the results of the second questionnaire on the factors, a final rank order towards the most important critical factors could be composed. These results are depicted in a tree-diagram that gives an overview of the distribution on the client's response and building type. The tree diagram shows the distribution on the clients' response and building type. It also shows the preferred attributes among the construction methods and factors. As could be seen in the tree diagram, most respondents who filled in both questionnaires came from the housing corporations. All respondents included the building type: *residential* in their portfolio. Besides the *residential* building type, the building types *commercial, specialty* and *infrastructure* were managed by the six client types – depending on the type of client. The clients who managed the *residential* building types the most, are the housing corporations. The prefab construction method and the conceptual construction method are both the most preferred construction methods. Thereafter the modular construction method is preferred, followed by the conventional construction method. When all the crisp values of factors from questionnaire (II) – derived from the Fuzzy Delphi Method calculation – are combined together, it gives the following ranked list of most important critical factors. As should be noted: this is an overall view, the rank order differs per client type.

Factors	**Crisp value (S_j)**
1. Quality	(0.79)
2. Costs	(0.78)
3. Exploitation / operating (cost related)	(0.77)
4. Sustainability	(0.75)
5. Safety	(0.73)

SAMENVATTING

De bouwindustrie is een complexe sector met een verscheidenheid aan uitdagingen die ze moeten zien te overwinnen. Om er een paar te noemen; aan de ene kant heeft de bouwindustrie te maken met het groeiende tekort aan woningen, productiviteitsproblemen en arbeidstekorten. En aan de andere kant heeft de bouwindustrie te maken met de vermindering van de uitstoot van broeikasgassen door de klimaatproblemen tegen te gaan. Dit zijn enkele belangrijke aspecten waarbij rekening mee moet worden gehouden, bij de keuze van een bepaalde bouwmethode. De keuze voor een bepaalde bouwmethode draagt op verschillende manieren bij aan deze uitdagingen. Om ervoor te zorgen dat bouwbedrijven aan haar type opdrachtgevers en hun projecten de beste bouwmethode naar behoefte kunnen voorschrijven, zou een overzicht een belangrijke bijdrage kunnen leveren. Het besluitvormingsproces kan bijdragen aan de besproken verscheidenheid van uitdagingen. Sinds de keuze voor een bepaalde bouwmethode niet iets is dat willekeurig bepaald wordt en de factoren die leiden tot de keuze ervan niet nader onderzocht zijn, is hiermee de interesse ontstaan om dit onderwerp te onderzoeken.

Het doel van deze scriptie bestaat uit het kwantificeren en onderzoeken van de factoren gerelateerd aan bouwmethodes die er in Nederland worden toegepast. Dit gebeurd vanuit het oogpunt van opdrachtgevers van grote aannemers. De geïnterviewde opdrachtgevers hebben geleid tot nieuwe factors en onderliggende redenen om de ene methode verkiezen boven de andere. Voor deze scriptie was het belangrijk om de voorkeuren van opdrachtgevers gerelateerd aan de bouwmethodes te achterhalen. Dit kan bouwbedrijven helpen bij het maken van hun keuze voor een bepaalde bouwmethode. Ook kan er zo beter maatwerk geboden worden en efficiënter worden gewerkt. Door gebruik te maken van de Fuzzy Delphi Method zijn de belangrijkste kritieke factoren ontdekt.

In deze afstudeerscriptie is een literatuuronderzoek uitgevoerd om de diversiteit van de gebruikte bouwmethoden in Nederland te achterhalen. Daarnaast werden ook de type opdrachtgevers en bouwtypes onderzocht. Uit het literatuuronderzoek van deze afstudeerscriptie blijkt dat er in Nederland vier soorten bouwmethodes worden gebruikt: de traditionele bouwmethode, prefab bouwmethode, conceptuele bouwmethode en de modulaire bouwmethode. De traditionele bouwmethode verwijst naar een bouwmethode dat een lineair bouwproces heeft en al vanaf de start van de vroege ontwerpfase op de bouwplaats erg arbeidsintensief is. De prefab bouwmethode is een proces welke bestaat uit het maken van bouwelementen in een fabriek of werkplaats, waarna deze op de bouwplaats worden verwerkt. De conceptuele bouwmethode is een methode dat bestaat uit een gestandaardiseerde manier van bouwen door middel van een gestandaardiseerd proces. Deze bouwmethode wordt gekenmerkt door zijn droogstapel-techniek en zijn parallelle manier van bouwen. Bij de modulaire bouwmethode worden er kant-en-klare units gebouwd in een gecontroleerde omgeving (fabriek), waarbij de units worden getransporteerd naar de bouwplaats zodat er alleen nog maar geassembleerd moet worden. Wanneer de units de fabriek verlaten, dienen deze volledig te zijn ingericht en afgewerkt. Uit de literatuur van dit

onderzoek zijn de volgende opdrachtgevers naar voren gekomen, deze zijn nader onderzocht in het empirische gedeelte:

- Overheidsinstanties;
- Zorginstellingen;
- Educatieve instanties;
- Woningcorporaties;
- Ontwikkelaars;
- Investeerders.

Nadat het literatuuronderzoek was uitgevoerd, ontstonden er vijftien factoren die betrekking hadden op gebruikte bouwmethoden in Nederland vanuit het perspectief van de opdrachtgevers. Met de factoren en informatie verzameld uit de literatuurstudie, werden er interviews met klanten afgenomen om een eerste indicatie te geven van welke factoren, constructiemethoden en bouwtypen de klanten prefereren; overeenstemming te vinden met factoren afgeleid vanuit de literatuurstudie; te ontdekken waarom opdrachtgevers bepaalde meningen hebben over dit onderzoeksthema; en nog belangrijker, om informatie te verkrijgen over nieuwe factoren die door opdrachtgevers worden genoemd in de interviews. Deze factoren zullen worden toegevoegd aan de reeds ontdekte factoren, afgeleid van de literatuurstudie. Uit de resultaten van de interviews bleek dat er zes nieuwe factoren werden genoemd door opdrachtgevers. In het totaal maakt dit dat er eenentwintig factoren gerelateerd aan de vier bouwmethodes onderzocht zijn in dit onderzoek.

In deze scriptie zijn er twee rondes van verschillende vragenlijsten afgenomen om de geprefereerde factoren te onthullen en zo consensus te bereiken tussen de resultaten van beide vragenlijsten. Hierbij werd er voldaan aan de gestelde criteria van de Fuzzy Delphi Method. In overeenstemming met de theorie beschreven door Aliev et al., (2004) en Rahimianzarif & Moradi (2017) dienden de resultaten van de vragenlijst (I) als input voor de vragen gesteld in vragenlijst (II). Vragenlijst (I) had honderdzesenveertig respondenten, waarna de resultaten werden geanalyseerd en berekend met de Fuzzy Delphi Method. Zes factoren werden als belangrijk beschouwd, omdat ze hoger scoorden dan de voorgestelde grenswaarde van $\alpha = 0{,}70$. De factoren die onder de grens scoorden, werden buiten gesloten van de lijst met factoren. Vragenlijst (II) had tweeënzeventig respondenten en op zijn beurt werden de resultaten van vragenlijst (II) ook berekend met de Fuzzy Delphi Method. Ook hier weer moesten de factoren voldoen aan de zelfde voorgestelde grenswaarde. Het repeterende proces van meerdere vragenlijsten die werden gebruikt, zorgt voor consistentie in de antwoorden en leidt tot consensus van de resultaten. In beide resultaten van de vragenlijsten is het profiel van de respondenten beschreven. Het profiel van de respondenten vertoonde overeenkomsten en verschillen, die wetenschappelijk zijn onderzocht door te werken met de chi-square goodness of fit test. Met betrekking tot de resultaten van de factoren uit vragenlijst (II), kon een laatste rangorde van de belangrijkste kritieke factoren worden samengesteld. Deze resultaten worden weergegeven in een boomdiagram dat een overzicht geeft van de verdeling van de responspercentage van de opdrachtgevers en het percentage bouwtypes dat de opdrachtgevers beheren in hun portfolio. Daarnaast toont de boomdiagram de voorkeurskenmerken van de constructiemethodes en factoren. Uit de boomdiagram valt af te leiden dat de meeste respondenten, die beide vragenlijsten hadden ingevuld, afkomstig van de woningbouwcorporaties. Resultaten laten zien dat alle respondenten woningbouw

beheren in hun portfolio. Afhankelijk van het soort opdrachtgever kwamen commerciële bouw, bijzondere bouw en infrastructuur ook voor in de portfolio van alle zes type opdrachtgevers. De opdrachtgevers die de woningbouw het meest beheren in hun portfolio zijn overduidelijk de woningbouwcorporaties. De prefab bouwmethode en de conceptuele bouwmethode zijn beide de meest geprefereerde bouwmethode. Daarna is dit de modulaire bouwmethode, gevolgd door de traditionele bouwmethode. Wanneer alle crisp waardes van factoren uit vragenlijst (II) - afgeleid van de Fuzzy Delphi Method berekening - samen worden gecombineerd, geeft dit de volgende gerangschikte lijst met de belangrijkste kritieke factoren. Opgemerkt moet worden is dat dit een totaaloverzicht is, de rangorder verschilt per type opdrachtgever.

Factoren	**Crisp waarde (S_j)**
1. Kwaliteit	(0.79)
2. Kosten	(0.78)
3. Exploitatiekosten	(0.77)
4. Duurzaamheid	(0.75)
5. Veiligheid	(0.73)

ABSTRACT

The construction industry is a complex sector that has to deal with a variety of concerns; Growing number of housing shortages, productivity problems, labour shortages, reduction of Green House Gas emissions and many more. These are some important aspects that must be taken into account. Since construction companies need to decide which construction method they should apply best for its type of client and their project, the decision making process contributes to the discussed variety of concerns. The choice for one particular construction method over the other is not made randomly, therefore it is interesting to examine this topic.

The purpose of this thesis is to investigate and uncover all reviewed factors related to the construction methods that are applied in the Netherlands from the clients' perspective. In order to fulfil this purpose, this thesis focused on selecting the most important critical factors related to the construction methods – by using the Fuzzy Delphi Method.

To fulfil the purpose of this thesis, a literature review was conducted that gave insight into the related client types, building types, construction methods and factors. According to the literature review, for large construction companies these client types were considered to be the most interesting: the governmental bodies, healthcare bodies, educational bodies, housing corporations, developers and investors. Furthermore a distinction was made between six different building types, four different construction methods and fifteen factors. After the literature review has been made, interviews were conducted among the six client types to give a first indication of which factors, construction methods and building types the clients prefer. More importantly six new factors derived from the interviews that sums up the total list to twenty-one factors.

To specify the important levels of the twenty-one factors and the relation between the client type, building type and construction methods, two questionnaires have been held whereby results of questionnaire (I) served as input for questionnaire (II). Results of both questionnaires on the respondents' profile were compared to each other and scientific elaborated with the chi-square goodness of fit test. Among the clients mostly the *residential* building type was managed. The prefab construction method and the conceptual construction method are both the most preferred construction methods. Thereafter this is the modular construction method, followed by the conventional construction method. When all the crisp values of factors from questionnaire (II) – derived from the Fuzzy Delphi Method calculation – are combined together, it gives the following ranked list of most important critical factors. However, the rank order differs per client type.

Factors	**Crisp value (S_j)**
1. Quality	(0.79)
2. Costs	(0.78)
3. Exploitation / operating (cost related)	(0.77)
4. Sustainability	(0.75)
5. Safety	(0.73)

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LIST OF ABBREVIATIONS

MMC	Modern Methods of Construction
FDM	Fuzzy Delphi Method
ZZP	(Zelfstandige Zonder Personeel) Freelancer
CBS	Central office of Statistics
FT	Fuzzy set Theory
DM	Delphi Method
AHP	Analytic Hierarchy Process

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1. INTRODUCTION

The introduction explains the research problem and its context. Hereby the importance of the problem becomes clear. In the paragraph that follows, the main research question is defined and divided into multiple sub-research questions. The next paragraph includes the research design which provides an overview of the set of methods and procedures used in collecting and analysing measures of the research problem area. Thereafter, the practical and scientific relevance and the project boundaries will be described whereas lastly the reading guide for the further chapters will be given.

1.1 Problem background

The building industry has two major concerns to care for: *climate issues* and *the lagging productivity*. The building industry is responsible for approximately 40 percent of the total global energy consumption. The World Business Council for Sustainable Development (WBCSD) (2009) argues that the building industry is also a sector that contributes to a major part of carbon- and GHG emissions in the world. Tam, Tam, Zeng & William (2006) state that construction activity generates approximately 20 – 30 percent of all wastes deposited in Australian landfills; 29 percent of the solid-waste stream in the USA is construction waste. More than 50 percent of the waste deposited in a typical landfill in UK comes from construction waste. Therefore, uncollected construction solid waste has become a major health hazard (Tam et al., 2006, p. 3643).

Besides the waste of the construction industry, the global construction industry has a chronic productivity problem. Woetzel, Sridhar, & Mischke (2017) state that the productivity in the construction industry over the past 20 years only has grown annually with one percent. This amounts to just one-third of the rate of the world economy and only around one-quarter of the productivity rate in manufacturing. In comparison: between 1947 and 2010 the agricultural sector in the United States had seen a cumulative real growth of 1510 percent in its production and had achieved a 760 percent growth in its manufacturing. With only a six percent growth for the construction industry, it is noticeable that there is a considerably large difference between the sectors (Woetzel, Sridhar, & Mischke, 2017). Poor productivity in the construction industry is the result of many varying factors, such as regulatory measurements, little investments in technology, lack of innovation, labour shortage and too much standardization.
According to Woetzel et al. (2017) the biggest leap in productivity can be achieved by using more prefabrication and standardization with buildings largely manufactured in factories and assembled quickly on-site. Use of standardized components in China's 10,000-kilometer high-speed-rail network, largely manufactured offsite, help to keep costs per kilometre about 65 percent lower than if they would have been manufactured in the United States and around 80 percent lower than if they would have been manufactured in the United Kingdom (Wang, 2016; Woetzel, et al., 2017)

Construction methods have a direct relation with the two major concerns of the building industry; climate issues and the lagging productivity. More specific, these two concerns are influenced by the choice of one particular construction method over the other. A majority of buildings is still constructed using traditional technology (i.e. timber, masonry and concrete). However, in the last few years there has been an increasing use of *Modern Methods of Construction* (MMC) for housing, driven by a range of factors including demands for faster construction, skill shortages, and sustainability. The term, MMC, originates from the United Kingdom as a common name for off-site and on-site methods of construction. Off-site MMC has predominantly been manufactured and assembled in a factory-controlled environment. On-site MMC brings together systems or components that are predominantly assembled on

site. Some potential benefits of using the MMC are: faster construction, fewer housing defects, and reductions in energy use and waste (Parliamentary Office of Science and Technology, 2003; Mesároš & Mandičák, 2015), all of which offer significant potential to minimize both construction waste (WRAP, 2007) and construction safety risks (Kyjaková & Bašková, 2016, p. 36).

In the construction sector a distinction is made between different construction methods: Conventional (= traditional), prefabrication, conceptual and modular. The conventional way of constructing a building is by far the oldest method (Proveniers, Crijns, & Eldonk, 1989). It is characterized by its labour intensive work, constructing work on-site and its linear process. Since all work is done on-site and is made specifically for that one non-rehearsal project, it has proven to be most flexible construction method. Prefabrication is a mix of factory-made elements and labour work on-site to construct a building. Although conceptual is quite similar to prefabrication, an important difference is that conceptual includes working with standardized processes using prefabricated elements (Ji, Li, Liu, Shrestha, & Jing, 2018; Coster, 2010). The method is characterized by its fully off-site prefabrication process and dry stack principle whereby only assembly will be done on-site. Modular is the far opposite of conventional, since this method uses a predetermined way with predefined measurements. Here the project is completely thought out in advance and made off-site, which makes that the preparation time is long. This construction method is commonly used when multiple 'same like' units are repeated that eventually forms a total building.

These four construction methods each have their own advantages and disadvantages. The chosen construction method often differs between projects and clients. Naturally, clients of construction companies need something and this translates itself in certain buildings: specialty buildings which could be prisons or universities, residential buildings which could be high-rise buildings or low-rise buildings such as row-houses or unique stand-alone houses. There is also a variety of clients to take into account, such as housing corporations, investors, healthcare industry and project developers. To conclude, there are many building types, different clients and aspects to take into consideration when looking at the choice of construction method.

1.2 Research Objective

As has been mentioned earlier: construction methods have a direct relation with the two major concerns of the building industry; climate issues and the lagging productivity. Choosing one construction method over the other depends among others on the type of client and its preferences. Therefore is it valuable to know which factors, related to the construction methods, clients prefer. To name a few factors: sustainability, costs, time and production speed. These factors address to the recalled climate and productivity concerns, but contain many more facets: Safety issues in the building sector also affect the project's schedule and may cause budget overspending. Also, investing in practises such as management programs (e.g. Lean management), software or the use of advanced prefabrication like conceptual or modular construction reduce safety risks. (McGraw Hill Construction, 2013; Jones, 2018;

Coubau, 2018). More (underlying) factors are coming forth from the literature review that will be listed in the end of chapter two. The following research objective is central to this thesis:

*"*The purpose of this thesis is to investigate and uncover all reviewed factors related to the construction methods that are applied in the Netherlands from the perspective of the client. Interviewing clients leads to new factors and underlying reasons for choosing one method over the other. For this thesis it is important to know the clients' preferences of factors related to the construction methods. This could help construction companies in their choice of using a particular construction method to realize a construction project. Working with the Fuzzy Delphi Method (FDM) should discover what the most important critical factors are*."*

In this thesis the researcher will conduct an extensive literature review and use the FDM to clarify invertible fuzziness in questionnaires, filled in by experts, to obtain more reasonable and proper results. Critical factors related to the construction methods are derived from the literature review and interviews with clients. Thereafter, the FDM is used to select the most important critical factors. With this, construction companies such as Plegt-Vos (i.e. contractors) that are specialized in a particular construction method, can improve their method by improving the factors. Doing this can help persuade clients and extending the network of construction companies.

1.3 Research questions

To achieve the desired research objective, the following main question and sub-questions are asked in this research:

Main research question

Which (underlying) factors related to conventional-, prefabrication-, conceptual- or modular construction methods in the Netherlands, are of importance for construction companies when choosing a construction method in light of the clients' preferences?

Sub-research questions

SQ1. What are the definitions of the four construction methods: conventional-, prefabrication, conceptual and modular way of constructing buildings?

SQ2. What does the inventory of potential clients for the construction industry look like (i.e. top 5/10)?

SQ3. What are the (underlying) factors related to the construction methods?

SQ4. In terms of the different construction methods, which factors do clients find important in realizing a project?

1.4 Research Design

Despite the fact that no research on the topic of (underlying) factors on construction methods on the clients' preferences has been done before, similar research on the methodology does exist. There has been research done by Rahimianzarif & Moradi (2017) in which they used interviews, set up questionnaires while performing the FDM and determined the weight of the measured factors. They compared different methods with each other whereby eventually the combination between Analytic Hierarchy Process (AHP) with the FDM was chosen (Rahimianzarif & Moradi, 2017, p. 4). More research on a similar approach was performed by Boeters (2018) about factors causing delays in the execution phase of utility construction projects in the Netherlands. Here the FDM was also applied for both conducting questionnaires and setting the weight. In extension to his research he applied the Bayesian Belief Network (BBN) (Boeters, 2018, p. 28), which differs from the research angle in this thesis. In the following two paragraphs the research design is explained more in detail. In addition to this, a graphic has been made of the research design to give the reader a clear overview of the steps used to conduct this research. This is shown in figure 1.

As the research design shows, this research consists of two phases. One phase includes the qualitative part and the other phase includes the quantitative part. Next, the two phases will be explained in more detail.

1.4.1 Phase one: Qualitative part

The purpose of phase one is to extract all factors that are related to construction methods from the literature review. In order to understand these factors, the construction methods need to be explored first. By unraveling each construction method, the first sub-research question will be answered: Thereafter, an inventory of the different types of clients in the Netherlands needs to be performed. A client data base of Plegt-Vos will be used to give an insight in the type of clients. Additional sources will be used to extent the information obtained from the database, to get a more holistic view. The information from the database of Plegt-Vos and from the literature review will be mixed into one final database. This will be used to answer sub-research question 2. A combination of qualitative and quantitative research methods will answer sub-question 3. The mix will consist of conducting a literature review and by holding interviews with clients. This refers to a qualitative research approach: qualitative research provides in-depth information by discussing the underlying motivations, opinions, wishes and needs of the research group (Graauw, 2018).

1.4.2 Phase two: Quantitative part

In order to give a proper answer on sub-research question 4, the FDM will be applied and weights will be determined by a Likert-scale and setting a certain alpha threshold. According to Rahimianzarif & Moradi (2017), most typical Delphi studies start with a questionnaire designed by a small team and sent to a larger group of specialists. Once the questionnaire is returned, the research organizers summarize the outcomes, including all different answers

and causes for their responses, before sending this summary back to the specialists. The experts have the opportunity to change their responses based on the results, and organizers re-evaluate these second-round results. This process goes on until consensus has been reached or it becomes apparent that there is no chance of consensus (Rahimianzarif & Moradi, 2017, p. 20; Logan & Starr, 2005).

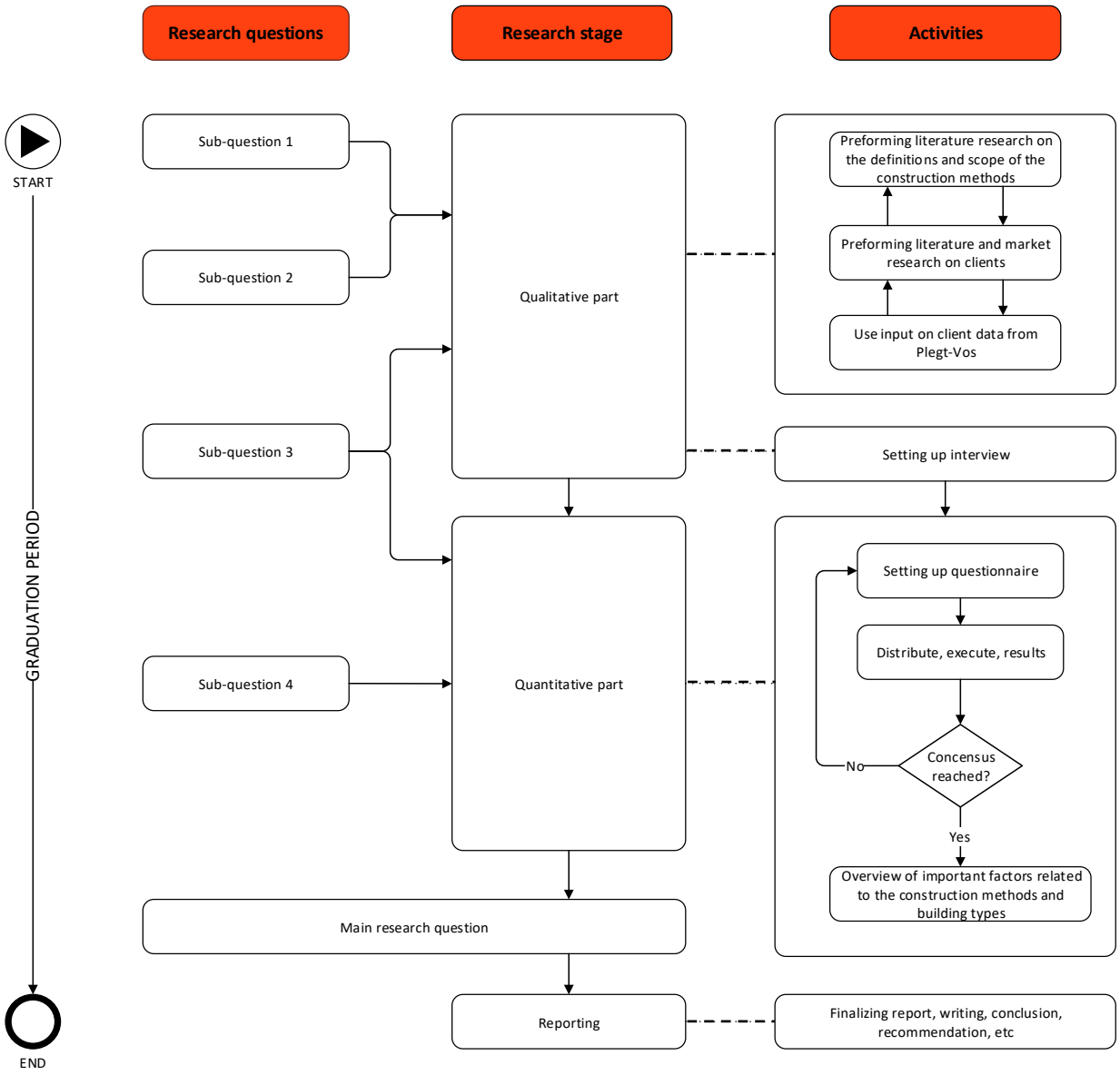

Figure 1 | Conceptual research model

1.5 Plegt-Vos

This graduation project focuses on different construction methods used in the Netherlands and exposes factors that clients tend to find important. The researcher has collaborated with Plegt-Vos. They provided the access to data of clients and helped arranging interviews. They

delivered necessary input for this thesis. Besides input of the clients, also documents with information of construction methods can be used. Plegt-Vos is a medium-sized construction company in the Netherlands, which started as a family business and has grown into a national construction company with four offices in the Netherlands over the past 115 years. Their main office is located in Hengelo. The company employs approximately 400 people and the turnover is €160 million. With this, Plegt-Vos belongs to the top twenty-five largest contractors of the Dutch construction sector (Klok, 2013, p. 45). An important note to consider is that this research will be carried out in the interest of the student, who wants to contribute to the scientific literature.

1.6 Practical and Scientific Relevance

There are many national -and international researchers, such as Hurlimann, Browne, Warren-Myers, & Francis (2018) and Snyman & Smallwood (2017), that conducted research to improve the climate issue or productivity but there remains a scarcity in research when it comes to investigating the construction methods. Generally, research on construction methods only provides stand-alone papers or articles where just one single construction method is described with some advantages and disadvantages. This thesis shows a comprehensive study on all the used construction methods in the Netherlands and indicates the importance of all factors related to it (Hurlimann, et al., 2018; Snyman & Smallwood, 2017). Thus, this research contributes to a larger body of knowledge concerning the choice of the construction method and their (underlying) factors.

Moreover, construction companies specialized in certain construction methods benefit from this research if they want to improve a certain method. When improving a certain construction method, emphasis can be laid on the factors that have the most impact for the process of choosing for clients. This thesis provides a practical and scientific relevance because this is the first study that uses a mix of literature and client's perspectives to expose all relevant factors, for choosing a construction method, with their degree of importance. Furthermore, it shows which factors are preferred by the client.

1.7 Reading Guide

This research focused on revealing the (underlying) factors related to the construction methods used in the Netherlands based on the clients' perspective and what critical factors they find most important. This thesis mainly consists of five chapters. The following chapter contains the literature review. It formed the qualitative part of this research and was used as input for answering the theoretical questions. The third chapter contains the results that were obtained from the interviews with different clients. The results of these interviews gave a first insight in the opinions of clients towards the building types, construction methods and preferred factors. Also new factors were discovered during the interviews with clients. The

fourth chapter is about the methodology and performing the FDM. The chapter consists of the results gathered from the different rounds of questionnaires, whereby the discussion of each questionnaire was ended with a (sub-)conclusion. Chapter five provides a final conclusion whereby an overview of the investigated factors with their level of importance is shown. In addition, a conclusion about the construction methods, building types and client types was made. Hence, an answer to the main research question of this thesis will be given. This final and last chapter also includes limitations, relevance's and recommendations for further research. References and appendixes are added in the back part of this thesis.

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2. LITERATURE REVIEW: SEARCH FOR CONSTRUCTION METHOD FACTORS

This chapter focuses on the literature of the different construction methods in the Netherlands. Previous in this thesis is mentioned that there are four construction methods were to be dealt with: conventional, prefabrication, conceptual and modular. Additional to this, inventory on the type of clients and building types needs to becomes clear. A literature review will provide the theoretical framework for this thesis. The purpose of this literature review is to give a proper answer on sub-research question 1: "What is the definition of the four construction methods: conventional-, prefabrication, conceptual and modular way of constructing buildings?". Here the construction methods need to be explored very thoroughly, and also which building fits best with its method. Thereafter, research about the factors related to the construction methods and the diversity of clients and is needed. Input of Plegt-Vos about her clients will be gathered and prepared for chapter 3. Research about this subject will lead to answering sub-research question 2: "What does the diversity of clients and their target market look like and how can they be rated (i.e. top 5/10)?". This literature review also provides useful information for answering sub-research question 3. However additional research in needed in order to complete answering sub-research question 3. This will be done in chapter 3.

2.1 Key problems in the building industry

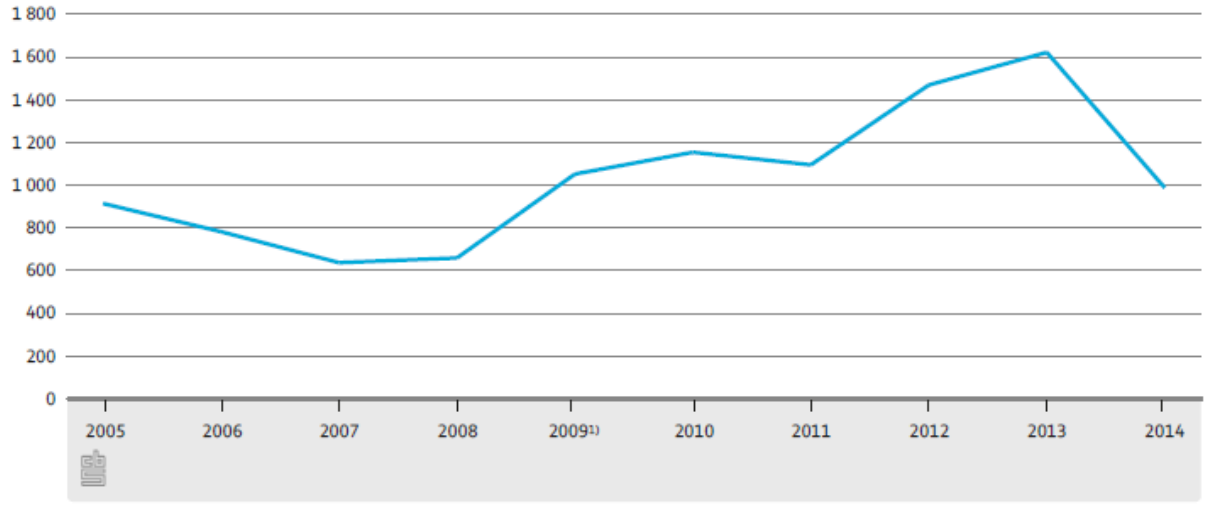
2.1.1 Fiscal crisis

It is a changing time for the building industry. Since the early 21 century new techniques and ways of working has been developed. Between 1997 and 2000 the 'Dot.com bubble' arose. During this boom the values of shares of internet companies (and dependent companies) rose rapidly, as a result of the (expected) growth of these companies. In the spring of 2000 the rates finally collapsed and the bubble snapped. What was typical for this period of time was the rapid development and bankruptcy of the small internet companies. When the internet-bubble collapsed in 2000, it caused a global light recession which especially last several years in the Western countries. In the Netherlands this recession happened simultaneously with the adjustment of the economy to the new European monetary union by the introduction of the euro, in which the share of the guilder was too low, which suddenly ended a period of over-spending and overheating of the economy. In addition of the beginning of 2001, a new tax system was introduced by Minister of Finance Gerrit Zalm, which first caused an inflow of consumer capital, but then aggravated the recession by simultaneously creating a cyclical budget system for (Ofori, n.d.; USA Today, 2017)

The second economic crisis was unleashed in 2008 and special to this crisis was the uncertainty among the population. Lot of people in America could not pay their mortgage anymore which means that a lot of banks, including the larger banks in America, went bankrupt. A big and powerful America, which formed the engine of the world economy, brought the rest of the world into an economic rut. Later, the government spent extra money on saving a few larger banks which lead to the end of uncertainty and in 2009 to a moderate growth of the economy in America and Europe (InfoNu, 2015).

Like many other sectors, the crisis was the turning point of the construction sector. According to the CBS (2015), who dedicated a report on the construction sector and its crisis, the scale of construction in the period before the crisis is rose by an average of 4.4 percent, whereas after 2008 there was an average contraction of 4 percent. Where the Dutch economy was recovered as before in 2014, the scale of construction was still 22 percent below. This was among others due to lack of development in the construction sector. Whereas countries such as Belgium and Germany performed a positive influence on the construction industry, Spain and Greece saw further declination of the construction industry – 62 percent declination (Notten, 2015). CBS (2015) further state that the number of bankruptcy of construction companies and one-man businesses rose from 659 in 2008 to 1600 companies in 2013 (figure 2) . Despite many losses of companies, the number of small companies in 2013 grew. CBS (2015) further state that the number of jobs for self-employed workers in construction rose between 2008 and 2014 with only four thousand, up to 211 thousand. The decline in the number of jobs in the construction industry came almost exclusively on behalf of the employees. In 2014 there were only 306 thousand jobs for employees, nearly 100 thousand less than six years earlier. This decline of the amount of jobs was mainly in general civil and

non-residential building, and the specialized construction (i.e. plumbers, plasterers and painters).



Bron: CBS.
[1)] In 2009 is overgegaan op een nieuwe methode. Het verschil tussen de oude en nieuwe methode is echter gering.

Figure 2 | Number of bankruptcy in the construction industry (Notten, 2015, p. 8)

2.1.2 Labour shortage

As the construction industry suffers from the recovery of the crisis, there is still a labour shortage to be mentioned. According to Jones (2018) many workers either retired or were laid off and found employment in other industries. As the recovery continued, it was clear that these workers, now in new careers, were not coming back. It is to be found that the construction industry is not attracting enough talent to meet the demand. Recent research performed by AGC found that 75 percent of firms expect to add headcount in 2018 and that 78 percent of firms are having trouble finding qualified workers. In addition, 82 percent of firms expect it to remain difficult, or get harder, to find and hire qualified workers in 2018 (Jones, 2018). About 21 percent of the employees that are working in the construction industry is older than 55 years old compared to just 9 percent that are 24 or younger. When the retiring age is hit, lot of quality is and knowledge is lost as well as only young people are left behind (Jones, 2018).

2.1.3 Productivity Levels

The productivity levels in the construction industry are remaining constant while the productivity in other sectors are growing. Jones (2018) cites that this can be due to inadequate planning and scheduling, lack of collaboration and communication between stakeholders on the project, idle time wasted by having to wait on materials and supplies to be delivered or for prior work to be completed. Furthermore there is an absence of skilled employees because a lot of people will go on retirement. Besides, construction methods have been the same for years as technology or a particular mind-set holds back innovation and therefore productivity (Jones, 2018). The NVM (2018) explains that productivity is inherent to the high demand of houses which on its turn is caused by the previous years of low production and the increasing population of the last few years (NVM, 2018).

2.1.4 Safety

Another aspect to look at is safety in the built environment and management that comes with it (Goubau, 2018). Terwel et al. (2014) mentioned that structural safety is of main concern in the construction industry and that incomplete permanent structures are a threat for the safety of persons. Based on data from Dutch Labour Inspectorate this study concluded that approximately 20 percent of the fatalities during construction are related to structural failures. The total number of fatalities during construction exceeds (disputable) acceptability limits in the Netherlands. Structural failures were especially influenced by motivation of employees, available equipment and procedures. Improvement is needed, which can start with an increase of safety awareness, such a safety management (Terwel, Mud, & Frjiters, 2014). Safety management not only refers to what is going on at the building site, but is also connected to the construction methods and productivity. According to research performed by Berstein et al. (2013) contractors experience strong productivity improvements due to the adoption of safety (see figure 3). Also related to safety management is the improved reputation, ability to contract new work and project quality. Furthermore BIM and training have a positive impact on safety (Bernstein, Russo, & Laquidara-Carr, 2013). In a study performed by McGraw Hill Construction's 2011 Prefabrication and Modularization SmartMarket Report prefabrication and modularization is rising. In terms of safety, the Modular Building Institute reports the benefit of workers as they are not exposed of out-door elements because everything is made off-site in a factory. This makes it easier to monitor safety. Further is stated that despite the overall trend for improving safety, installation of large prefabricated or modular components can present unique challenges. Proper training on-site is still essentials as workers need to careful assemble these elements. However, it is clear that the rise of these construction methods has a strong implication for improving the overall improvements in site safety (Bernstein, Russo, & Laquidara-Carr, 2013).

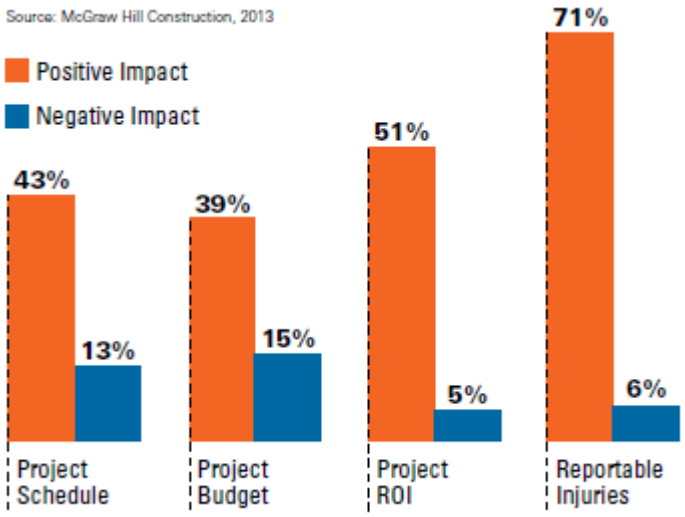


Figure 3 | Positive and Negative Impacts of Safety Programs on Projects (Bernstein, Russo, & Laquidara-Carr, 2013).

2.1.5 Environment

The building industry is responsible for approximately 40 percent of the total global energy. WBCD (2009) argues that the building industry is also the sector which provides a major part of its carbon- and GHG emissions. Chang et al. (2018) discussed in their paper about unlocking the green opportunity for prefabricated buildings and construction in China, that buildings consume more than 35 percent of the total primary energy and account for significant

fractions of the demand for energy and resource-intensive construction materials (UNE and IEA, 2017). Increasing of population means that the demand of housing rises, which means that this will exert substantial resource and environmental pressures on the country (Chang, et al., 2018). Tam et al. (2006) state that construction activity approximately generates 20 – 30 percent of all wastes deposited in Australian landfills; 29 percent of the solid-waste stream in the USA is construction waste. More than 50 percent of the waste deposited in a typical landfill in UK comes from construction waste. Therefore, uncollected construction solid waste has become a major health hazard (Tam, Tam, Zeng, & William, 2006, p. 3643). What is seen in both developing and developed countries is that the construction sector consumes up to 60 percent of all raw materials extracted from the Earth (Lombera and Aprea, 2010). According to Lachimpadi et al. (2012) research that is conducted by World Watch Institute has shown that the raw material used for building construction consumes up to 40 percent of stones, sand and gravel; 25 percent of timber and 16 percent of all water used annually around the world (Dimoudi and Tompa, 2008). Based on the quantities of raw materials used by the construction industry, it is therefore, responsible for generating a significant portion of construction waste in the world (Kourmpanis et al., 2008; Wang et al., 2004; Lachimpadi, Pereira, Taha, & Mokhtar, p. 97 2012). A lot of these raw materials return, or sometimes immediately, go to the waste piles. Globally significant waste is generated annually: 323 million tons of construction and demolition waste in the USA, in Australia construction and demolition waste accounts for 16 – 40 percent – and in Hong Kong this amount is estimated around 3158 tons of construction waste per day (US EPA, 2004; Bell, 1998; Hong Kong EDP, 2007). These environment challenges contribute to promote reuse and recycling of construction waste in order to reduce inflow of construction waste (Lachimpadi, Pereira, Taha, & Mokhtar, 2012).

Like is described above, the construction industry faces problems and challenges which affect the productivity and efficiency. According to Wambeke et al. (2011), 58 percent of the construction projects exceed the scheduled time and 15 out of 20 projects exceed their original approved budgets. Kamali et al. (2018) and Ren et al. (2011) found that different construction methods influence project performance in various ways and impact on the productivity of construction projects; deficient methods decrease the productivity of projects. Furthermore, Forbes & Ahmed (2010) posed that the choice of construction method significantly impacts on the cost, time, and quality of buildings, and adopting inappropriate methods increases the cost and duration of projects, as well as decreasing the quality and lifespan of buildings (Moghayedi & Windapo, 2018). In terms of safety, elements and components that are made off-site are presented safer for the employees. The degree of safety varies between the different construction methods. This also account for the environmental part and the above mentioned key problem. In the next paragraphs the different construction methods that are used in the Netherlands will be examined whereas in the end of each paragraph the explored factors are documented.

2.2 Conventional construction method

One of the most common construction method worldwide is called the conventional or traditional construction method. In this thesis the term conventional will be applied to refer to this construction method. The reason for this is that traditional is derived of something that is done for a long time which becomes a habit over the years, whereas conventional is considered to be traditional but not vice versa and therefore in this thesis there will be rather spoken of conventional instead of traditional. According to Designing Buildings wiki (2018) the term conventional is often used to describe the types of linear construction, where each individual step is not only constructed entirely (or largely) on site, but also needs to be completed before the project can move on to the next phase (Designing Buildings wiki, 2018). Focussed on the Netherlands, the conventional construction method entails that employees mainly build with brick, working with a timber frame construction, steel construction and/or pouring concrete (figure 4).

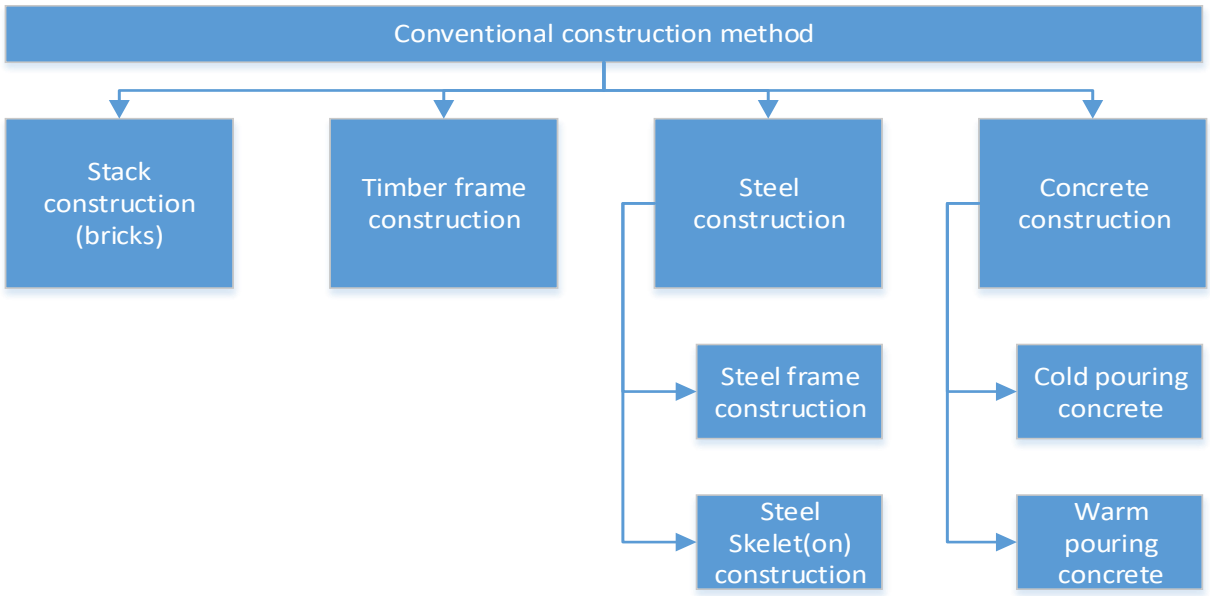


Figure 4 | Types of conventional construction methods

2.2.1 Types of methods

According to Groothuis Bouw (2019) a house built with brick on the outside and build with silk stone on the inside is called stack construction. Typically, this stack construction consists of hand masonry facades, cavity space, foil, insulation and silk stone. For the stories, concrete (poured) floors are used. Factors of working with the conventional brick construction method are (Groothuis Bouw, 2019):

- Labour – intensive
- Openings must be carried by a lintel
- Short preparation time;
- On-site labour

A timber-framed house, on the other hand, is supported by a wooden construction of beams and styles. Although the skeleton of a house built according to wooden frame construction

consists of wood, the outer walls in the Netherlands are often provided with masonry (Groothuis Bouw, 2019). However it could be the case that the outer walls, just like the timber frame construction, also is made out of wood. Is this the case, then a timber frame construction wall consists of styles and battens work with 15mm construction plates aligned to the inside. After the ventilation battens and pest grilles will be placed, the space between the styles will be filled with insulation and finished with water-repelling vapour-open wood fibre boards. On top of this the cladding will be placed. On the inside of the 'typical timber frame construction' the cracks and crevices will be taped airtight and battens are placed for the plasterboards and finishing layer (Passief Huis Markt, n.d.). Factors of working with the conventional timber construction method are (Finnlogs, 2019):

- Flexible;
- Insulation integrated between trusses;
- Dry construction method (no water is used during fabrication);
- Cost saving;
- Environmentally and energy friendly;
- Fast building time.

A steel construction consists of two different ways of constructing a building. It is possible to work with a steel frame construction or to work with a steel 'skelet(on)' construction. In both ways there will be worked with steel, but with the steel frame construction each separate frame is a framework of structurally bearing styles and rules in which each supporting part is limited in section and thus its weight. This system spreads its vertical loads, since the point loads remain limited. In case of working with a steel 'skelet(on)' construction, the dimensions are larger which leads to larger span widths. The disc-forming elements that forms the frame are in this case only used as filling (Be-Steel, 2019). Any outer walls or materials can be used in combination with a steel construction. For a lot of residential projects most times eternit, trespa, wood or brick is used for finishing the outer walls. In terms of industrial projects sandwich cladding is used, which consists of two steel or aluminium panels with a layer of insulating material in between. Factors of working with the conventional steel construction method are (QBusbouw, 2018; Bouwen met Staal, 2018):

- Steel constructions can be made in-situ and off-site;
- Accurate dimensions;
- Less sensitive to climate influences;
- Pest resistant;
- Large span widths and cantilevers;
- High safety in the off-site creation;
- Rapid assembly on the construction site;
- Light weight possibilities;
- High degree of flexibility;
- Reusable.

According to De Vree (n.d.) the casting method is a construction method where concrete mortar is poured into a mould with a cubic or concrete pump at the construction site. Together with steel reinforcement this results into carrying floors and walls (Vree, n.d.). Typical this method is used for forming the hull of the building. Also here, lot of outer walls materials can be used for finishing. Factors of working with the conventional casting (concrete) construction method (Betonhuis-Betonmortel, 2013):

- Pipes are easy integrated in the floor;
- No residual waste;
- Low CO_2 emissions;
- Can be poured into a variety of different shapes.

In general by making use of a conventional construction method, span widths are possible without having too much limitations and houses made with this made are unique based. The conventional construction method consists of a high degree of flexibility because spaces can be adjusted easily with the help of non-load-bearing walls (Liebregts, 2013). In the following table, the factors of the conventional construction method are listed (table 1):

Table 1 | Conventional construction method factors

Conventional construction method - Factors	
Factors	**Derivatives of the factors**
Labour intensity:	on-site labour, fast building time
On-site construction time:	weather conditions
Preparation time:	short preparation time,
Safety:	high safety in off-site construction,
Flexibility:	openings must be carried by a lintel, flexible, light weight possibilities
Sustainability:	environmentally and energy friendly, reusable, low CO_2 emissions, no residual waste
Costs:	cost saving
Accuracy:	accurate dimensions
Uniqueness:	can be poured into a variety of different shapes, large span widths and cantilevers

2.3 Prefabrication construction method

In order to reduce carbon emissions Ji et al. (2018) state that many strategies have been adopted to improve the efficiency of building construction. Such strategies generally involve innovative methods such as design for disassembly, lean construction and waste management. Besides these approaches, off-site prefab construction – just like Kyjaková & Bašková (2016) called out, are gaining more popularity. Literature carried out by Chang et al. (2018) state that prefabrication has some important advantages: prefabrication needs fewer job site workers, providing a solution to the nationwide workforce shortage as well as the soaring labour prices, in-plants manufacturing facilitates more quality control because of lower error rate and re-works, no affection of the weather, less waste of materials, movement and storage on construction site, well defined material recycling processes, higher safety issues, less material use for on-site, less cause of injuries, illnesses, less congestion of people and materials on-site, less dusty and noisy (Chang, et al., 2018; Kyjaková & Bašková, 2016).

The next figure is giving a more represented image to see how prefabrication is divided (Ji, Li, Liu, Shrestha, & Jing, 2018). Precast in-situ construction is a combination of two words. In case of precast, pre-made elements are made in a factory and are transported to the construction site (prefab way of working). In case of in-situ, labour work on the construction site (traditional way of working) will be done. So precast in-situ contains a mini-factory or workplace nearby the construction site where elements are made and transported to the construction site. Off-site construction is fully dependent of making all the components in a large factory were only the assembly-part takes place on the construction site.

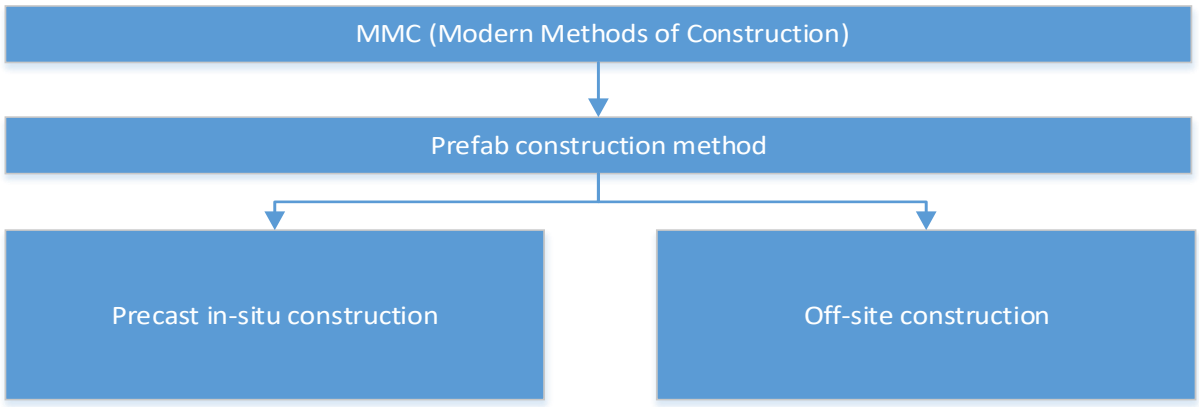


Figure 5 | Types of prefab construction methods (Ji, Li, Liu, Shrestha, & Jing, 2018, p. 125)

Parliamentary Office of Science and Technology (2003) state that prefabricted housing in the United Kingdom has made its entrance arround 1960. After World War II, many houses were destroyed and there was a need of high demand on houses. The Parliamentary Office of Science and Technology (2003) called prefabrication MMC which refers to a new term which intented to reflect technical improvements in prefabrication, encompassing a range of on- and off-site construction methods. They state that MMC houses typically have less defects and can be built quicker. This suggests that a higher productivity can be reached with MMC compared to the conventional way of constructing a building. Also prefabricated houses are more energy efficient as they may involve less transport of materials and produce less waste. Besides they state that there may be fewer accidents and less impact on local residents during construction (Parliamentary Office of Science and Technology, 2003, p. 2; Kyjaková & Bašková, 2016, p. 37).

According to Kyjaková & Bašková (2016) everything what is made in a factory is called MMC. This also applies for modular systems. A number of factors that refers to the prefabrication part of MMC are: safer working environment at the off-site production of building components; faster construction over labor costs, fewer design errors and better quality in the manufacturing of components, easier quality control at the factory, less waste on the construction site and less environmental pollution during construction easier quality control at the factory.

Research that is performed in a case study by Ji et al. (2018) showed that the amount of GHG emissions in precast in-situ construction method was 3.1 percent lower than for conventional buildings. The most dominant source in both constructions that was leading for the most GHG emissions was embodied emissions of building materials.

Tam et al. (2006) preformed a research towards adaptation of prefabrication in construction. During the set-up of a feasibility analysis in adopting prefabrication on construction activities advantage's and hindrances are explored. They state that the application of prefabrication reduced construction costs, shorten construction time and needed limited space on the construction site when it arrived. However, it is to be noted that prefabrication has a higher preparation time than the conventional construction method, is considered uniform in aesthetics and is inflexible for design changes (Tam, Tam, Zeng, & William, 2006, p. 3645). In the following table, the factors of the prefab construction method are listed (table 2):

Table 2 | Prefab construction method factors

Prefab construction method - Factors	
Factors	**Derivatives of the factors**
Labour intensity:	Fewer job site workers
On-site construction time:	Shorten construction time
Preparation time:	Easier quality control at the factory, in-door
Safety:	Higher safety issues, less material use for on-site, less cause of injuries, illnesses, less congestion of people and materials on-site, less dusty and noisy.
Flexibility:	Inflexible for design changes
Sustainability:	Less waste of materials, less transport waste, less GHG emissions.
Costs:	Higher initial construction costs, lower labour prices,
Accuracy:	Monitored in factory, better supervision, less defects, fewer design errors
Aesthetics:	Monotone in aesthetics
Construction site:	Limited site space, Less movement on construction site
Productivity:	Provide a solution to workforce shortage
Weather:	No affection of the weather

2.4 Conceptual construction method

The conceptual construction method assumes that a certain construction company has a number of concepts from which the client can choose. Think of a metaphor of choosing a car, which is not built on customer specifications but where the manufacturer has a series of models for certain target groups. In the conceptual construction method, therefore, it is not the client who define the solution, but more the provider (i.e. construction company). Conceptual building has been developed to allow the construction industry to function as the ordinary consumer market (Vree, 2019; Huijbregts, 2008).

According to Coster (2010) the conceptual construction method is focusing on two perspectives: On the one hand "product" and on the other hand "process".

Explaining the perspective on *product*, Coster (2010) states that it is about mass production. This implies that the customer chooses a product that has been developed in advance that is subsequently adjusted to his individual wishes. In case of conceptual construction, the customer chooses a reference house (a home concept) in which he/she can implement his/her own wishes by means of a number of options. The elements of the standard home, such as a façade or a wall, are made in the factory. Those elements then only need to be placed on the construction site together (Vrijthoef, 2008). This is a big difference with conventional construction method, where the construction of the house is completely done on the building site. Since the production process is all done in the factory instead of at the construction site, there is a lot saved on time and costs.

Taking the *process* perspective into account, streamlining of the building process will be done by making use of Building Information Modelling (BIM), permanent co-makers and involvement of all parties (architect, contractor, consultants) in the preliminary phase. In practice, the product and process approach are often combined (Vrijthoef, 2008).

While choosing the conceptual construction method to realise an apartment complex or a number of houses, this method uses a different approach on the construction site than others. The foundation and ground floor are made prefab by using dry elements that are connected with each other through pen and shaft connections. The walls, floors and roof are also all prefabricated, but in an off-site factory, were on-site assembly will be applied. The bathroom and technical room is placed completely as a unit whereby only the installations need to be linked with each other. In other words: This construction method is on-site characterized by its dry stack construction (Vrijthoef, 2008). However, on-site, some connections (i.e. gluing, finishing) and customizations (i.e. walls, cladding) are remaining goods (figure 6).

Conceptual construction method has many advantages: it is more efficient and the outcome is more certain through the standardization of products and processes. Clients have the advantage to have more insight into the end product, more certainty about the quality, a greater delivery reliability and a better price-quality ratio.

The main disadvantage of using conceptual building is the freedom of choice the client has in making his own layout. This is inherent to a previously developed product (Vrijthoef, 2008).

Conceptual building will always be less flexible than traditional construction where the customer can choose everything himself in consultation with the architect. The art of using the conceptual construction method is therefore finding the maximum threshold in giving the customer the freedom of choice (Coster, 2010, p. 17).

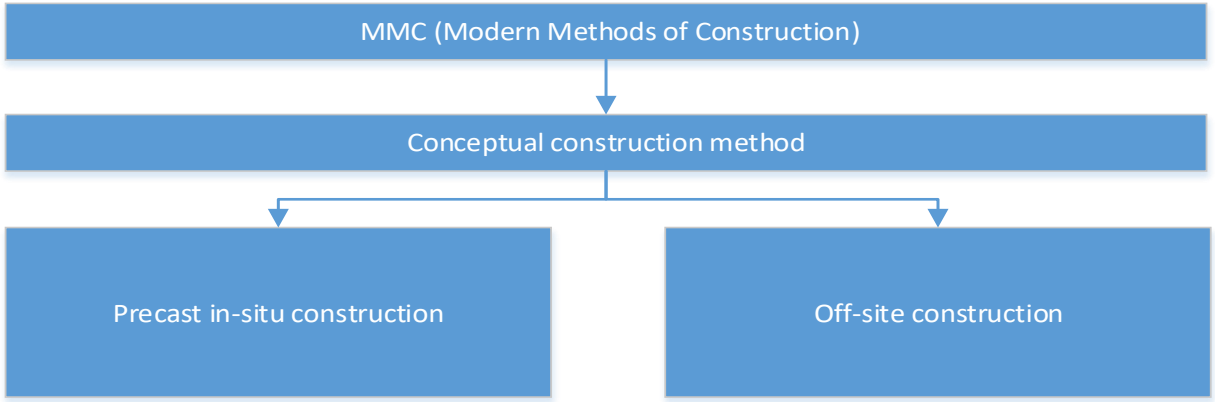


Figure 6 | Types of conceptual construction methods

Be that as it may, the conceptual construction method is a standardized way of constructing a building with a standardized planning. Plegt-Vos is a contractor who is specialized in using this construction method and has two perfect examples of what this construction method entails: *Huisvanu Woning bouw* and *Huisvanu Appartementen*. Appendix A shows insights of the principle with its standard measurements that are used in the conceptual construction method for the housing and apartment concept. In the following table, the factors of the conceptual construction method are listed (table 3):

Table 3 | Conceptual construction method - Factors

Conceptual construction method - Factors	
Factors	**Derivatives of the factors**
Diversity / flexibility	Different concepts, design freedom is limited
Off-site construction	Production process is all done in the factory
Time	Factory made, no weather influence, streamlined process
Costs	Less costs because of mass production of standardized elements, collaboration with fixed parties
Digital collaboration	BIM usage, more insight into the end product
Process	Involvement of all parties in the preliminary phase
Efficiency	Standardized non-linear process
Accuracy	More certain about quality

2.5 Modular construction method

Cities in the world are faced with growing numbers of the population. According to statistics in 2005 every third habitant of a city lived in unfavourable conditions. To satisfy the world needs in urban housing, it is required to build about 35 million apartments a year (approximately 95 thousand apartments a day) (Lawrence, 2009; Demographia, 2015). This can be done with the use of MMC. Just like prefabrication, modular buildings are also part of MMC (Kyjaková & Bašková, 2016).

"Virtually all high quality products are built in factories around the world. Cars, planes, ships, computers, printers, cell phones – even the pen you write with – are built in factories. In addition, even homes built on site use many components that are produced in factories"
- (Precision Structural Engineering, 2018)

More specific modular construction combines various technologies of rapid construction principles. According to Kamali & Hewage (2017) modular construction is known as one of the primary methods of off-site construction, in which different modules are built in a manufacturing centre (85 – 90 percent) of the project work which are later transported to the final project location to form a building (Kamali & Hewage, 2017, p. 3593). As Gereralova et al. (2016) describe in their article, two main directions can be distinguished: the use of separate elements of a frame system (beams, columns, floorings, wall panels, etc.) that are produced offsite and assembled onsite AND the use of 3D elements (block containers) including necessary internal engineering facilities, interior and exterior finishing and built-in furniture and equipment (figure 7) (Gereralova, Generalov, & Kuznetsova, 2016, p. 168).

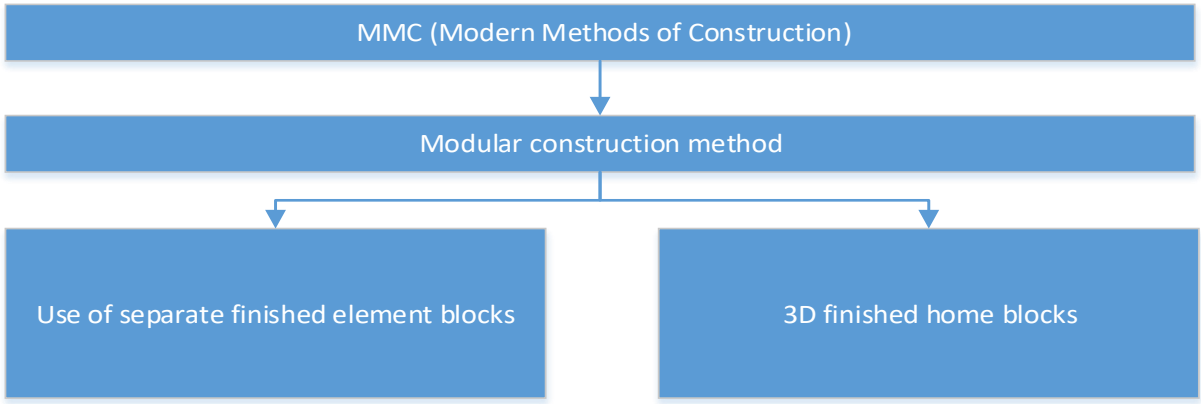


Figure 7 | Types of modular construction methods (Gereralova, Generalov, & Kuznetsova, 2016)

Due to the prefabricated units that are made in a factory the mechanization, quality and construction safety increases; construction wastes are minimized; and the level of noise and air pollution at construction sites decreases (Gereralova, Generalov, & Kuznetsova, 2016, p. 168). Modular construction can be used in low-rise and in high-rise and in new projects or

renovation projects. In the paper of Kyjaková & Bašková (2016) an extensive number of (dis)advantages are discussed (Kyjaková & Bašková, 2016, p. 40):

- Assembling speed;
- High quality control at a plant;
- Work safety as the time of high-altitude works shortens;
- Testing and rapid introduction of new technologies at the plant;
- Decrease of noise level and the amount of construction waste at a construction site that has a good impact on the environment;
- A parallel way of constructing;
- Environmental responsibility in terms of logistics ;
- Limited flexibility in the design of one module;
- Standardized work process;

Among the paper of Tam et al. (2006) the adoption of prefabrication and modular construction addresses one important advantage – to provide a better solution to the problem of huge waste generation on site activities (Tam, Tam, Zeng, & William, 2006, p. 3653). A thesis from Overbeeke (2013), about comparisons in opportunities between conventional and modular way of constructing hospital real-estate, explains that for two similar projects a comparison has been made for costs. In the structural design of a reference project in München, conventional seems to be cheaper in costs than modular. This is due to the fact that some elements; such as floors or walls, are double engineered for modular construction. By working with the conventional construction method, this is not the case. Here the structural parts consist of only one element. Looking at the installations, according to Overbeeke (2013), it can be concluded that modular construction is cheaper. This is a larger cost item and therefore modular construction makes the difference (Overbeeke, 2013, p. 43).

In the following table, the factors of the conceptual construction method are listed (table 4):

Table 4 | Modular construction method - Factors

Modular construction method - Factors	
Factors	**Derivatives of the factors**
Productivity	To meet the demand of the growing population, assembling speed
Accuracy	High quality control at a plant
Safety	Waste at the construction site is minimized which lead to a safer work environment, Work safety as the time of high-altitude works shortens,
Environment friendly	Construction wastes are minimized, noise and air pollution is minimized, environmental responsibility in terms of logistics,
Efficiency	Parallel way of constructing
Costs	High standardization leads to low costs
Off-site construction	Production process is all done in the factory

2.6 Definition of factors

Table 5 shows a list with the factors that are derived from the literature review about the construction methods. The ambiguity is filtered to reduce the number of factors. While definitions still remain unclear, paragraph 2.6 is assigned to reduce the degree of fuzziness and vagueness of these factors to come with consensus. First different authors express their opinions about the definitions of the discovered factors whereas in the conclusion the definition is made final.

Table 5 | Description of factors derived from the literature

Factors from literature		
Factors	**Source**	**Definition**
1. Labour intensity	(Bamfo-Agyei, Didibhuku Thwala, & Aigbavboa, 2019, p. 515)	The construction industry is labour-intensive and relies heavily on the skills of its workforce. Noted that the workforce is the industry's most valuable asset, which, at the very least, accounts for over a quarter of the total project cost (p. 515).
	(McCutcheon, 2008, pp. 3-4)	… operation in which proportionately more labour is used than other factors of production (p. 3). Labour-intensive construction may be defined as the economically efficient employment … of labour as is technically feasible, ideally throughout the construction process including the production of materials, to produce as high a standard of construction … labour-intensive construction results in the generation of a significant increase in employment opportunities per unit of expenditure (p. 4).
	(Kenton, Labor Intensive, 2018)	Labour intensive refers to a process or industry that requires a large amount of labour to produce its goods or services. The degree of labour intensity is typically measured in proportion to the amount of capital required to produce the goods or services; the higher the proportion of labour costs required, the more labour intensive the business.
	(Pettinger, 2018)	Labour intensive refers to a production process where labour costs are the largest component. Labour intensive implies that capital (machines/factories) are a small percentage of the final cost.

		Labour intensity is the percentage of labour which is used in the production process.
2. Safety	(Terwel, Mud, & Frjiters, 2014)	Structural safety is defined as the absence of unacceptable risk associated with failure of (part of) a structure (p. 3).
	(Bernstein, Russo, & Laquidara-Carr, 2013)	Safety management is the procedure used to recognize H&S risks and implement actions to decrease the possibility of a risk materializing and to diminish or eliminate the potential consequences of identified project Health & Safety risks.
	(Safeopedia, 2019)	Construction safety aims to ensure that a construction site or the industry as a whole is not the cause of immediate danger to the public around a construction site, or the workers at a construction site, as well as making sure that the finished product of construction meets required safety standards.
	(Cooney, 2016, p. 68)	Safety relates to how individuals are protected from physical harm in the course of executing their duties and responsibilities (p. 68).
3. Flexibility	(Designing Building Wiki, 2017)	Flexibility might include active flexibility, such as moveable partitions …. such as multi-use spaces, open plan offices, large floor-to-ceiling heights and high-capacity service voids …. a room's ability to expand or to use a range of different energy sources, de-constructability, and so on. However when define flexibility, it can be split into three broad types: adaptability, transformability and convertibility.
	(Thomas, 2013, p. 3)	Capacity of buildings of buildings to undergo drastic physical changes in such a way that the purpose and the function of the building can be completely altered whatsoever the original intend was (p. 3).
	(Shahu, 2017, p. 1; (Upton 1994; Shashu, Pundir & Ganapathy, 2012, pp. 192-193)	Flexibility can be defined as the ability to change or react with little penalty time, effort, cost or performance (p. 1).
	(Gosling, Naim, Sassi, Iosif, & Lark, 2008, p. 117)	A building that has been designed to allow easy rearrangement of its internal fit out and arrangement to suit the changing needs of occupants (Addis and Shouten, 2004) (p. 117).

4. Sustain-ability	(Kenton, Sustainability, 2018)	Sustainability focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs.
	(HEC Global Learning Centre, 2009)	A process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.
	(Morelli, 2011, p. 6)	Meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them, interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity (p. 6).
	(Glavic & Lukman, 2007, p. 1885; Brundtland, 1987)	…development that meets the needs of the present without compromising the ability of future generations to meet their own needs (p. 1885).
5. Costs	(Business Dictionary, 2019)	Expense incurred by a contractor for labor, material, equipment, financing, services, utilities, etc., plus overheads and contractor's profit. Costs such as that of land, architectural design, consultant and engineer's fee are not construction costs.
	(Merriam-Webster, 2019)	The amount or equivalent paid or charged for something.
	(Averkamp, 2019)	In accounting, cost is defined as the cash amount (or the cash equivalent) given up for an asset. Cost includes all costs necessary to get an asset in place and ready for use.
	(Designing Buildings Wiki, 2018)	Construction costs will be those costs incurred by the actual construction works themselves.

6. Accuracy	(Russo, 2014, p. 36)	The extent to which a given measurement agrees with the standard value for that measurement (p. 36).
	(Selvik & Abrahamsen, 2017)	The term 'accuracy' often associate with systematic errors and 'precision' with random errors.
	(California Surverying & Drafting Supply, 2017)	The correctness or truthfulness of something. You are accurate when your precise measure-ments align or correspond with a standard (or datum).
	(English Oxford Living Dictionaries, 2019)	The quality or state of being correct or precise. The degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard.
7. Uniqueness	(Page, 2014)	The uniqueness of construction projects also mean that the external influences and constraints would be different, yet subject to change throughout the project timeline.
	(Vocabulary, 2019)	A noun used to describe that certain something that makes a person or thing uncommon or singular.
8. Process	(Business Dictionary, 2019)	Sequence of interdependent and linked procedures which, at every stage, consume one or more resources (employee time, energy, machines, money) to convert inputs (data, material, parts, etc.) into outputs. These outputs then serve as inputs for the next stage until a known goal or end result is reached.
	(Burhanuddin & Mohamad, 2011, p. 7)	A process is defined as a system of operations in the design, development, and production of something, such as a project (p. 7).
	(Nelson, et al., 2017, p. 1; Davenport's, 1993)	A process is simply a structured, measured set of activities designed to produce a specified output for a particular customer or market.
	(Ireland & Iceland, 2002)	A process is a series of actions, changes, or operation that bring about an end result – cost, schedule, technical performance objective.

9. Aesthetics (variety)	(Markovic, 2012, p. 1)	… as a special kind of subject-object relationship in which a particular object strongly engages the subject's mind, shadowing all other surrounding objects and events (p. 1).
	(Melchionne, 2013, p. 1)	Objects that are not art or nature (p. 1).
	(Desiging Buildings Wiki, 2018)	Aesthetics is a branch of philosophic study that relates to the nature and expression of beauty and taste; in other words, the appearances of things.
	(Philosophy basics, 2019)	Aesthetics is the branch of philosophy concerned with the nature and appreciation of art, beauty and good taste. It has also been defined as "critical reflection on art, culture and nature".
10. Time	(Alvele, 2019)	A dimension in which events can be ordered from the past through the present into the future, and also the measure of durations of events and the intervals between them.
	(Desiging Building Wiki, 2018)	Time management is the process of organizing and implementing a strategy related to the time required for work activities on a project.
	(McGraw-Hill Encyclopedia of Science and Technology, 2012)	The dimension of the physical universe that orders the sequence of events at a given place.
	(Duke & Carmen, 2018)	In a construction contract, the concept of time is not the mere elapse of time from execution of the contract itself — rather, it is the period for performance of the construction obligations.
11. Production speed	(Business Dictionary, 2019)	A measure of the efficiency of a person, machine, factory, system, etc., in converting inputs into useful outputs. Productivity is computed by dividing average output per period by the total costs incurred or resources (capital, energy, material, personnel) consumed in that period.

	(Robbins, n.d.)	"making certain choices in certain ways" that moves us from being "merely busy" to "genuinely productive".
	(Kenton, Labor Productivity, 2018)	Labour productivity measures the hourly output of a country's economy. Specifically, it charts the amount of real gross domestic product (GDP) produced by an hour of labor.
	(International Labour Organization, 2019, p. 1)	Productivity represents the amount of output per unit of input (p. 1).
12. Collaboration	(ThoughtFarmer, 2018)	Two or more people working together towards shared goals.
	(Business Dictionary, 2019)	Cooperative arrangement in which two or more parties (which may or may not have any previous relationship) work jointly towards a common goal.
	(Koutsogiannis, 2018)	Well-established strategic collaboration appears to be the way forward, otherwise 'No commitment = no relationship = no innovation = no gain'.
13. On-site	(Kyjaková & Bašková, 2016, p. 36)	On-site MMC refers to modern methods of construction which brings together systems or components that are predominantly assembled on site (p. 36).
	(Legmpelos, 2013, p. 33)	On-site activities is called construction and off-site activities is called manufacturing (p. 33).
14. Off-site	(Desiging Buildings Wiki, 2019)	Off-site construction refers to the completion of elements or components of a construction project at a different location to where they will be permanently installed. The completed item is then transported to site and assembled in place.
	(Kyjaková & Bašková, 2016)	Off-site MMC refers to modern methods of construction which has predominantly been manufactured and assembled in a factory-controlled environment.
	(National Institute of Building Sciences, 2019)	Off-site construction is the planning, design, fabrication and assembly of building elements at a location other than their final installed location to support the rapid and efficient construction of a permanent structure.

15. Innovation	(Business Dictionary, 2019)	The process of translating an idea or invention into a good or service that creates value or for which customers will pay.
	(Sexton and Barrett, 2003)	New ideas should be followed by effective implementation and must improve overall organisational performance.
	(Morledge, n.d.)	The successful introduction of new technologies or procedures into industry.
	(Kulatunga, Amaratunga, & Haigh, 2006)	…. the implementation of significantly new processes, products or management approaches in order to increase efficiency of an organisation.

2.7 Inventory of clients

Clients in construction can differ greatly from each other (e.g. professionalism). BrandVeilig (2013) state that the project size widely differs. This could vary between a private person who, once in his life, wants to build a house to a professional organization where the development of real estate is one of the core tasks. The preference of a contractor for a type of client depends, of course, on the set of clients in which the contractor works. Generally, apart from specializations, the larger the contractor, the greater the diversity of the set of reachable clients and the larger the projects on which the contractor will focus on. However, even if a small contractor wants to focus on large projects, the selection criteria of the client will often be an insurmountable obstacle. This is why the set of clients differs between the different contractors and their size – which also means there are different preferences between the contractors among their clients. According to the CBS (2009) there were in the first of January 2008 around 405 construction companies with 100 or more employees and 620 companies with 50 – 100 employees (Rijt, Hompes, & Santema, 2010, p. 35). The newest results in CBS StatLine (2019) show that there are 515 construction companies with 50 – 100 employees (CBS StatLine, 2019). However, there are no numbers of 2019 with more than 100 employees the comparison of 2008 is been calculated which shows that there is a declination of 17 percent between 2008 and 2019 in the category 50 – 100 employees. Using the same declination number of percentage for 100 or more employees, this results from 2008 to 2019 in approximately 337 construction companies. According to a publication of BrandVeilig (2013) the preferences of small contractors in terms of clients are the private persons (81%). Almost half of small contractors likes to work for these types of clients. Larger contractors (>19 FTE, Full time Employees) prefer the type of clients related to firms. However besides firms, large contractors also have clients who are related to housing corporations, healthcare and educational bodies, governments and private persons (BrandVeilig, 2013).

From a report about 'ZZP-markt in beeld' from BouwKennis (2016) the top three type clients of ZZP'ers are private persons (95%), firms (67%) and contractors (48%). ZZP'ers barely have projects from bodies, housing corporations and governmental institutions (Dijk, 2016).

Another report studied the types of clients in the construction industry and divided the clients into two groups: large regular clients and small non-regular clients. Large regular clients exists of governmental institutions on national-, provincial- and governmental level, water boards (governmental bodies charges with managing water treatment), large housing corporations and large firms. The second group exists out of the same clients but are smaller in size. Besides these clients, the small non-regular clients also consists of project developers (Regieraad Bouw & EIB, 2006, p. 7). Co-Paybouw cite that in addition also large investors (i.e. pension funds, insurers and / or banks) could be a potential client for contractors (Co-Paybouw, n.d.).

With aforementioned information of the different clients we can say that there are five types of main clients for large contractors with more than 100 employees: developers, housing corporations, investors, healthcare- & educational bodies and governmental bodies. Private persons are not taken into account because it is not considered to be interesting for the "large" construction companies. The market segment in the Netherlands is classified in the subsectors: public sector, semi-public sector and private sector. The governmental bodies are part of the public sector, housing corporations and healthcare- & educational bodies are part the semi-public sector and investors and developers are part of the private sector.

Considering the governmental bodies, the CBS categorized these as the central government (National level and other central government instances), the local government (Provinces, Municipalities, Water boards and other local government instances) and the Social Security Funds. A list of institutions is published through CBS statistics and this list contains 354 institutions within the central government, 2096 institutions of local government institutions and 5 institutions within the Social Security Funds. Together with the client database of Plegt-Vos the total amount of governmental bodies is numbered at 2258. Here, a lot of ambiguous clients have been deleted (Chi, 2016, p. 6; CBS, 2018; Plegt-Vos client database, 2019).

According to the association of housing corporations Aedes (2016) and Woningcorporaties (2019) the number of housing corporations in the Netherlands in 2016 is 352. Together with the actual data of housing corporations of Plegt-Vos, the number is modified to 421 (Aedes, 2016; Woningcorporaties, 2019; Plegt-Vos client database, 2019).

Platform Groenbeleggen (2015) state that largest part of the investors in the Netherlands exist of Pension companies and Insurers companies (Platform Groenbeleggen, 2015). According to Pensioen Federatie (2019) there are 199 pension funds that are member of the Pension Federation. These are general, corporate, occupational and industry pension funds (Pensioen Federatie, 2019). In case of insurers companies the number is declining. In the year of 2000 there were over 600 insurers companies which slinked towards 188 insurers companies in the year of 2016 (Statline.cbs, 2017; Verbond van Verzekeraars, 2016, p. 24). Together with the

actual client database of Plegt-Vos, the total amount of investors are 452 (Plegt-Vos client database, 2019).

Healthcare- & educational bodies belong to the semi-public government. Healthcare bodies counts 195 institutions in the Netherlands and educational bodies counts 1413 institutions in the Netherlands. This amount includes the clients of the database from Plegt-Vos. So the total amount of healthcare- & educational bodies in the semi-public sector is equal to 1608 (CBS, 2018). Of course there are also healthcare- & educational bodies that are active in the private sector. For the healthcare this amount is 127 and for the educational bodies these numbers cannot be found (Patiëntenfederatie, 2019). This brings the total number of clients of the healthcare- & educational bodies to an amount of 1735.

Most major Dutch developers are members of the Association of Dutch Project Development Companies (NEPROM). This association was established in 1974 and wants to promote cooperation between government and developers in the realization of real estate projects. The development companies of large and medium-sized Dutch construction companies, real estate investors, housing corporations and niche players join the NEPROM. Since 2018, NEPROM contains over 60 members and together they realise over more than half of all newly built houses, renovation and new construction of office space or shopping centres (NEPROM, 2018). Together with the client database of Plegt-Vos the total amount is equal to 389.

The next figure shows an overview of the main target group of clients that is of importance for "large" contractors (figure 8). Here it is shown that the focus will be laid on five type of clients (see yellow blocks and the merged red block). The actual numbers of clients are visible in the figure. A shortened part of the merged client database of Plegt-Vos with the rest of the Netherlands about the client itself can be seen in Appendix B.

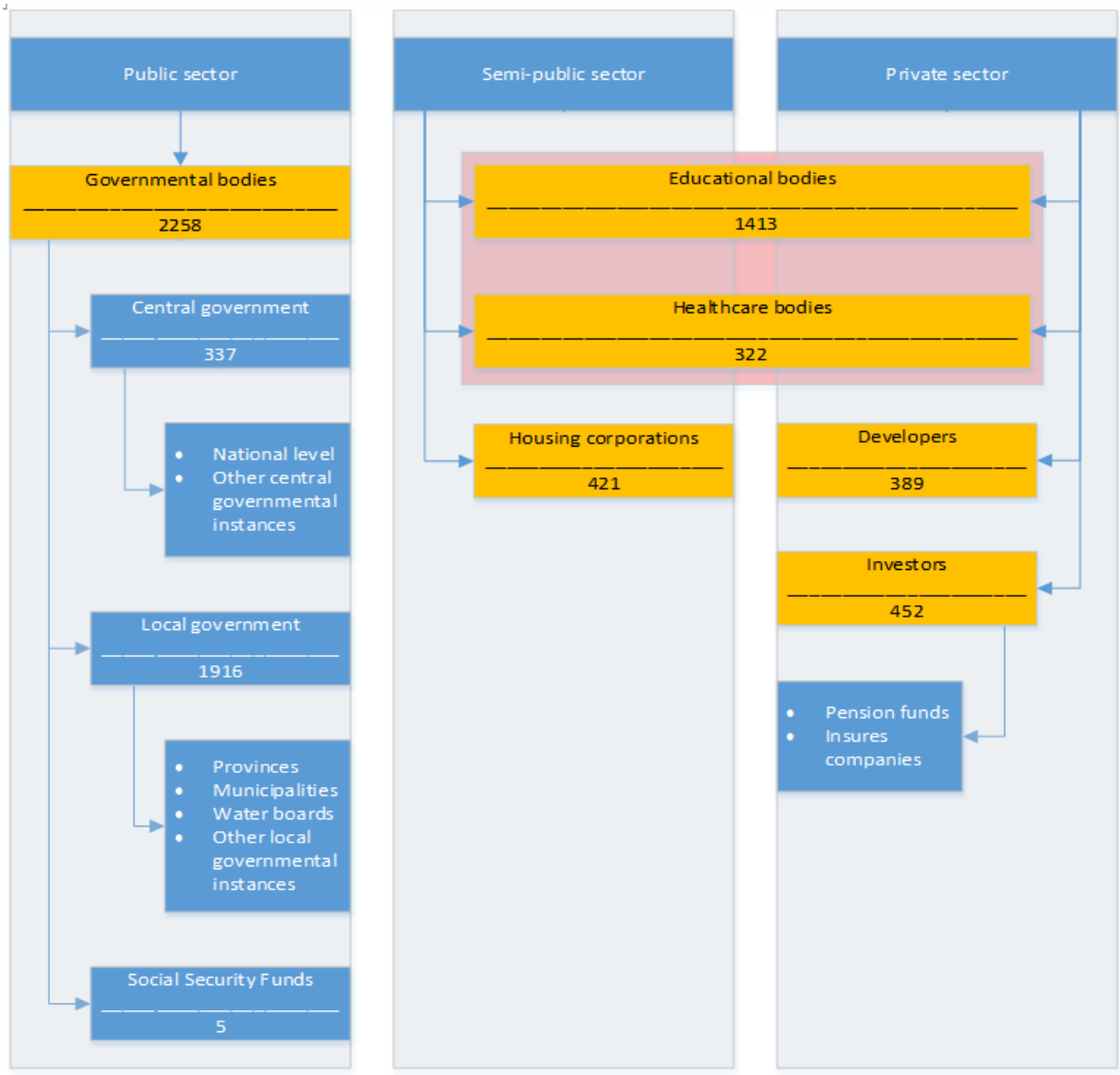


Figure 8 | Type of clients

2.8 Segmentation of building types

Earlier on in this thesis, the literature review described the different construction methods as a share of the contractor. Also an inventory of the different type of clients has been described. Since both aspects are linked to a common goal (i.e. realize a construction project) it is necessary to make an inventory of the different type of buildings. Besides, it is likely known that not all clients want to realize a same type of building with the same type of function. Figure 9 shows a list of the different building types there are in the Netherlands (Schmidt, 2013; Marsh, 2016; Integrity Data Solutions, LLC, 2017, pp. 21-36; CoStar, n.d.; Wolf, 2016; Kugler, 2019).

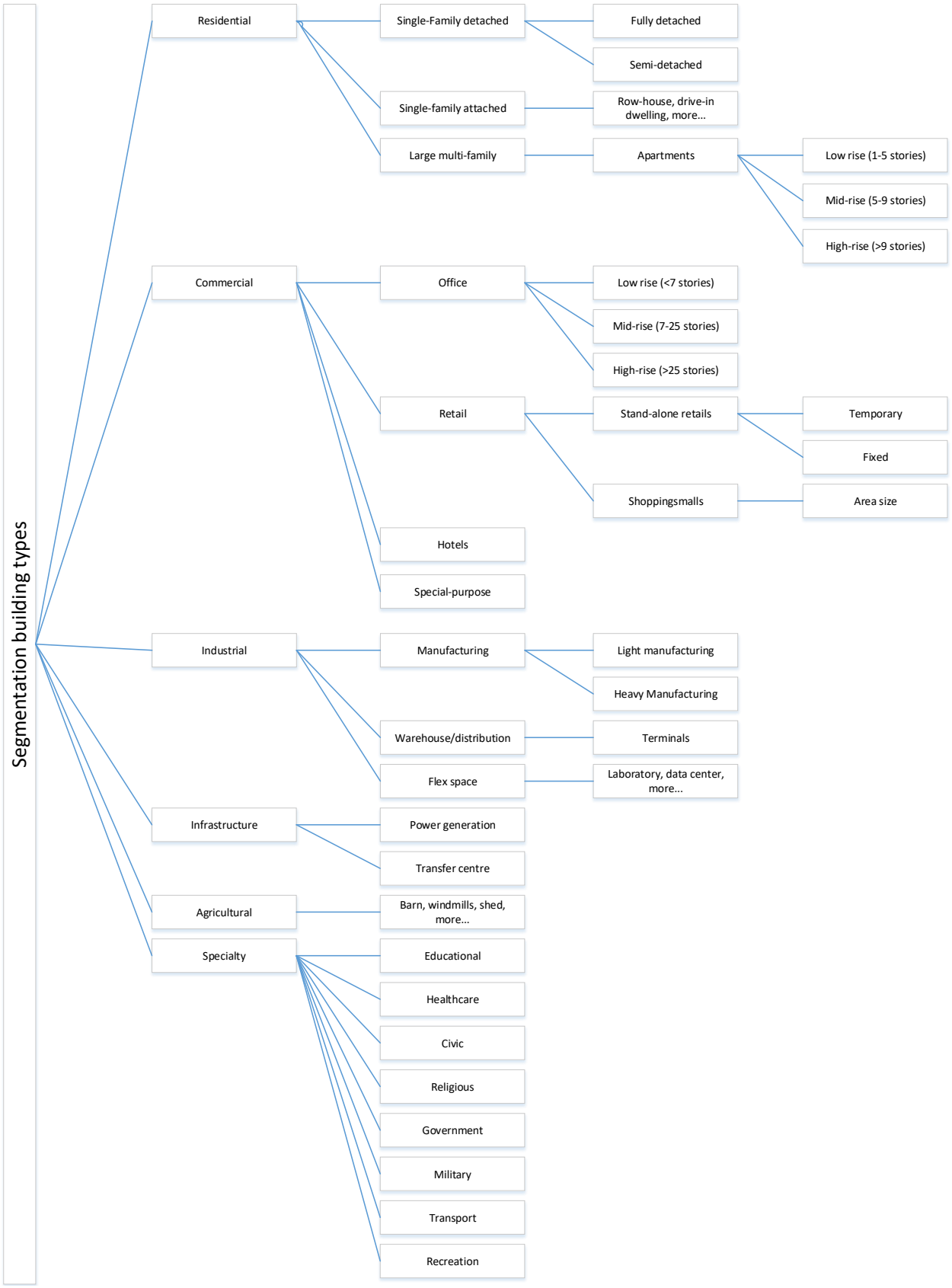


Figure 9 | Segmentation building types

2.9 Conclusion: Literature review

The focus of this literature review was to quantify the number of factors related to the construction methods. In practise the construction sector is fluctuating a lot. Since the economic and fiscal crisis a lot of small, but sometimes large construction companies, went bankrupt. Lots of employees made a shift in their career from working in the construction sector into a different sector. After the crisis the construction sector started to recover, but the number of employees stayed the same which resulted in a growing labour shortage. Many years later this development continues and the population is still growing. Not only in amount of natural births but certainly also in terms of migration. According to the CBS (2018) from 2010 onwards there is a growth of average 70.000 migrant workers and asylum seekers each year. Forasmuch, the situation concerning the construction sector in the Netherlands is poignant.

Overall it may be said that the housing market for sure needs more housing and one way to reach this is to produce more houses. The challenge inherent to production is a shortage of employees. To overcome this, innovation is required, but research conducted by (Jones, 2018; NVM, 2018) state that construction methods have been the same for years as technology or a particular mind-set holds back innovation and therefore productivity.

Construction methods are as old as there are buildings, but barely the process of the conventional construction method has been changed. However after WO II, the prefabrication construction method made its introduction. Elements are made in factories and the production time has been decreased extensively. Later on, the modular construction method made its entree and complete house units were made prefab. Hereby the execution phase turns out to be shorter than the preparation phase. Finally the conceptual construction method was developed, which is a method that uses a standardized way of constructing a building with a standardized planning. In terms of modular and conceptual, the building process turned out to be non-linear. The type of different construction methods is made visible in figure 10. Essential to this information the conclusion is formed which leads that sub-research question 1 is being answered – "What are the definitions of the four construction methods: conventional-, prefabrication, conceptual and modular way of constructing buildings?".

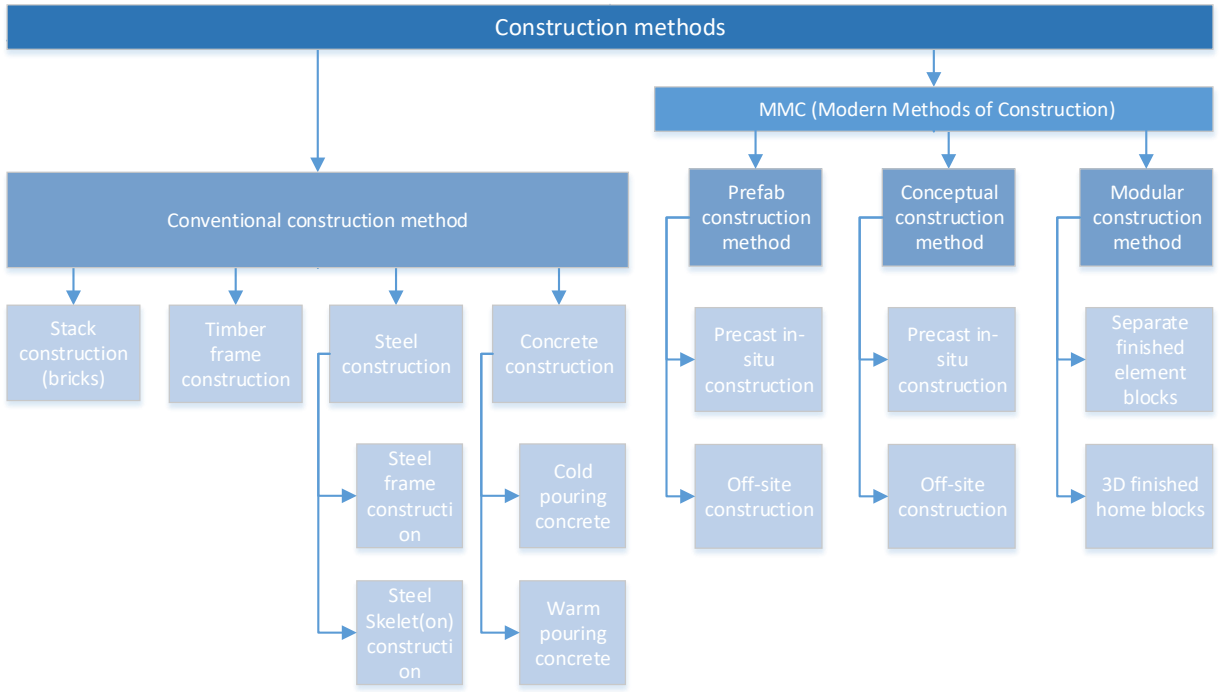


Figure 10 | Type of construction methods

Furthermore, table 6 shows a list of factors with its definitions that are explored from the literature review. This result contributes to the following research question: sub-research question 3 – "What are the (underlying) factors related to the construction methods?". With this question partially being answered, chapter 3: *client interviews*, should propose a final and complete answer on sub-research question 3.

Table 6 | List of factors from literature and their final definition

Factors from literature	
Factors	**Definition**
1. Labour intensity	Labour intensity refers to a production process whereby manual labour is a significant larger component in the final costs of a (construction) project than the capital (machines/factories).
2. Safety	Safety aims to ensure that individuals in and around a particular surrounding are not exposed to immediate danger and that the finished products of among others construction meets the required safety standards.
3. Flexibility	The ability to change or react with little effort to fulfil the maximum suitable changing needs for future use.
4. Sustainability	Meet the needs of the present without compromising the future generations while living in harmony.
5. Costs	The cash equivalent that is been charged for goods or services and is expressed in financial units.

6. Accuracy	Measurements with minimal errors that aligns with the correct value of a standard.
7. Uniqueness	Something that makes a good or service different than others.
8. Process	Sequence of stages that on its own consists of inter-dependent and linked operations but as a whole can be seen as a structure that produces an output inherent to the known goal.
9. Aesthetics (variety)	Philosophic object of art that expresses the subjective beauty and taste of its appearance.
10. Time	Dimension of the physical universe that variates between the past, present and future at a given place.
11. Production speed	Efficiency measured in terms of manual or automated pursuits that represents the amount of output per unit of input.
12. Collaboration	Two or more operating individuals (i.e. humans and/or machines) that work together towards a common goal.
13. On-site	On-site refers to the term whereby construction needs to be predominantly fabricated on the location were the final project is situated.
14. Off-site	Off-site refers to the term whereby manufacturing is done in a controlled factory other than the location were the final project is situated and only assembly needs to be done in place.
15. Innovation	Process of translating an idea into goods or services and entries the market to create and capture value.

There is a wide variety of different clients for the construction industry. This study emphasis on the client group of 337 large contractors in the Netherlands that each have more than 100 employees working for them. Research shows that the biggest group of clients can be divided into five types: governmental bodies, housing corporations, healthcare- & educational bodies, investors and developers. There are in total 2258 governmental bodies, who act as clients for the construction sector that belong to the public sector and can be divided into central government, local government and social security funds. Housing corporations belong to the semi-public sector and there are 421 corporations. Healthcare- & educational bodies belong to the semi-public sector and private sector because some of them are (fully) subsidized by the government and some of them are privately owned. There are 1413 education bodies and 322 healthcare bodies which forms a total amount of 1735. Lastly there are the developers and the investors which belong to the private sector. In total there are 389 developers and 452 investors to be found. Referring back to the research design, concluded can be that sub-research questions 2 is being answered – "What does the inventory of potential clients for the construction industry look like (i.e. top 5/10)?". From all the sectors, the private sector is fluctuating the most so therefore a remark can be made that numbers that are used today are outdated tomorrow.

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3. CLIENT INTERVIEWS

In the previous chapter the client types, building types, construction methods and their (underlying) factors are identified and have been defined for this research. Factors that were inherent to the use of construction methods were explored and listed. Table 7 shows the first composition of all reviewed factors.

Table 7 | List of factors (literature review)

Factors		
1. Labour intensity	6. Accuracy	11. Production speed
2. Safety	7. Uniqueness	12. Collaboration
3. Flexibility	8. Process	13. On-site
4. Sustainability	9. Aesthetics (variety)	14. Off-site
5. Costs	10. Time	15. Innovation

In this chapter, opinions of clients about these factors will be conveyed in so called semi-structured interviews. A query technique will be used to discover the core motives of the factors from the interviewees. Another goal of conducting interviews with clients is to find new factors. These new factors will be added to the factors derived from the literature review. This combination will form a complete list of factors that serve as input for the FDM. Consequently, this leads to answering sub-research question 3.

3.1 Theory – type of interview technique

The stated research objective, research question(s) and the knowledge acquired in the literature review on the factors that influence the choice of construction methods are the guidelines for the conducted client interviews. Just like in general research, there are two types of interview methods: the quantitative interview method and the qualitative interview method. The quantitative interview method consists of a structured way of interviewing to maximize the reliability and validity of measurement of key concepts. It is also structured, because the researcher has a clear and specified set of research questions that need to be answered. In structured interviewing, the interview is supposed to generate answers that can be coded and processed quickly. Mostly closed questions are being asked (Bryman, 2012, pp. 469-470).

According to Bryman (2012) there are two sub-types of the qualitative interview method: unstructured interview and semi-structured interview. Researchers sometimes employ the term 'qualitative interview' to encapsulate these two types of interview. In terms of a totally unstructured interview the researcher has written down a range of topics and asked the respondent only one question. The respondent will answer the question freely and the researcher will respond to that and then comes up with more questions. This will lead to a dialogue which is similar to a conversation. In terms of a semi-structured interview, Bryman (2012) state that the researcher has a list of questions or a fairly specific topic to be covered. This often is referred as an interview guide, were the interviewee has a great deal of leeway in how to reply. Not all questions are asked in the same order as they are processed on paper, however all questions do have to be asked. In addition, it is appreciated to come up with new questions during the interview (Bryman, 2012, p. 471).

As the purpose of the interview is to expose new factors of the construction method on the client's perspective and to know the underlying motives the factors, it is more likely to choose for the qualitative interview method. The qualitative interview method gives insight into what the interviewee sees as relevant and important. To give some structure to the interview, the semi-structured way of interviewing fits best in this research. All interviews will be fully transcribed to ensure that the results will be reliable.

3.2 Client interview process

3.2.1 Goal of the interview

In order to set up the interview questions, information related to the factors derived from the literature review has been used. Also the definitions of the construction methods and factors were made final so no bias would exist during the interviews. Interviewing the clients is important for this research, because this shows how the individuals think and feel about this research topic and why they hold certain opinions. For this thesis it is important to know the

clients' opinions about the factors related to the construction methods, those will be used to formulate the upcoming questionnaires. Answers on the client's profile will be used to see if they correspond with factors derived from the literature review. More importantly, the main goal of the interviews is gain information about new factors that are mentioned by clients that will be added to the already discovered factors, derived from the literature review. Together this forms the complete list of factors that serve as input for the FDM. Conducting the interviews also give a first indication of which factors, construction methods and building types the clients prefer.

3.2.2 Data collection

Before the start of the interview, an introduction will be held by the interviewer – the student. Thereafter an overview of the topics of the questions and the ground rules for processing the results of the interview will be given to the respondent. Lastly the purpose of the interview will be described. The following list in table 8 shows all the relevant client types. As could be seen, in total five out of six clients were interviewed. All clients were approached through e-mail. Interviewing the healthcare body failed, despite the researchers' efforts, by sending e-mails and using contact persons. It turned out that they did not have the time to contribute to this research. All other interviews were successful. The average time that was needed to conduct the interviews was 70 minutes per client.

Table 8 | List of respondents to interview

Client types	Organization name	Location
Governmental body	Rijksvastgoedbedrijf	Arnhem
Housing corporations	Viveste	Bunnik
Educational body	DUWO	Delft
Healthcare body	-	-
Investors	Bouwinvest	Amsterdam
Developers	Luneé	Amstelveen

3.2.3 Set-up client interviews

The first part of the interview was intended to collect demographic data from the client interviews. Demographic questions were used to collect personally bounded information and help to get the conversation started. The questions vary from organization –and building type to occupational level and working experience. In this way, it is intended to collect information about the respondents' profile. The respondents' profile determines the level of experience of the interviewed clients and gives an indication of the differences and similarities between the client types (Boeters, 2018, p. 33).

The second part of the interview will entail project based open-ended questions. To name a few questions:

- *How would you describe your project portfolio (building type, project size, target group)?*

- *Which construction methods do you think are used in the Netherlands and which ones do you prefer?*
- *Which factors are essential within your organization for the construction of a project and why?*
- (…)

Appendix C gives the complete list of interview questions. To ensure the objectivity of the answers on the questions, answers on posed questions were given without steering the interviewee. Only when the interviewees had finished listing their own factors, the researcher started asking about the remaining factors derived from the literature that were not mentioned by the interviewee before. The last questions are considered to be verifying questions to ensure that all factors and construction methods were discussed.

3.3 Results clients interviews

The interviews that were held contained sensitive information. To respect this, no names were mentioned in the transcriptions, only letter codes. Moreover, the full transcriptions are not included in this thesis, only a summary (Appendix D) is included. The demographic questions are of importance to show what the respondents working experience is, whether they have enough experience in the particular working field and whether they are capable of answering the questions relevant for this thesis. The demographic list gives an overview for the reader.
The decision was made to only interview the owners, direction or managers of the organizations. What these clients have in common is that they all have a HBO or higher level of education. Besides this, the minimum related work experience of these people is 18 years or higher. This suggests that they have sufficient knowledge and rich experience to answer the questions for this graduation research.

The literature review provided input for the interviews. The client types were explored during the literature review. The construction companies choose the construction method depending on the type of building that has to be constructed. These building types are determined by the client. Therefore, the demographic questions were asked. Consequently, this was broadened to a higher level – the organization of the client itself. Subsequently, the literature review investigated the building types and construction methods in the Netherlands. Questions on the inventory of building types have been asked. Also questions on the preferences of construction methods have been asked. Finally, questions were asked about the factors related to construction methods that have been researched in the literature review. These questions were asked with a view to broadening the explored factors in the literature review.

Table 9 represents the topics of the conducted interview with their outcomes:

Table 9 | Results of the interviews

Demographic questions	
1. Respondent:	Luneé Vastgoed is founded in the time of the crisis by –A– and –KJ– in 2007. –R– is working at Bouwinvest. –B– is working at Viveste. –J– is working at Rijksvastgoedbedrijf and –H– is working at DUWO.
2. Client type	Developer – Lunee Vastgoed Investor – Bouwinvest Housing corporation – Viveste Governmental body – Rijksvastgoedbedrijf Educational body – DUWO
3. Client	Lunee Vastgoed is focusing on the development of residential and commercial buildings in the outer ring of the city. Lunee Vastgoed is founded in 2007 and went 'live' in 2011. Bouwinvest has been investing since 1952 in real estate for the construction fund (bpfBOUW) and has multiple offices in the world: Europe, Asia-pacific and North-America. Viveste is an housing corporation situated in the semi-public sector and offers social housing to the lower segment in the Netherlands. Viveste has three offices in which are located in province of Utrecht. Rijksvastgoedbedrijf is a real estate organization from and for the central government and is part of the Ministry of Internal Affairs and Royal Relations. Rijksvastgoedbedrijf is responsible for housing of the national government agencies. DUWO is an authorized institution and is synonymic to a housing corporation, but only when it comes to students. DUWO was founded in 1945 and has 75 years later four offices spread across the Netherlands.
4. Educational journey **5. Courses, training, (…)**	The minimum level of education is HBO and almost half of the interviewed clients had a master. Real estate and property management are the key studies the had clients had done.
6. Function within the company	–A– and –KJ– are both the founders of Lunee Vastgoed. They have a lot of meetings with their clients and partners and are the spinning wheel of the organization. –R– is senior real estate developer at Bouwinvest and comes in when the acquirer finished his work. The function of –R– is comparable with a mix of project manager and an asset manager. –J– is asset manager at Rijksvastgoedbedrijf and manage the specialty assets. –B– is asset manager at Viveste and –H– is developer at DUWO and is doing acquisition of student housing.
7. Level of work experience	All the clients have a minimum related work experience of 18 years. –J– and –B– had relatively the least work experience of the interviewed client, because they were the younger than the other clients. –KJ– and –H– are having the most work experience, because they are the oldest clients of all the

	clients. They have both 45 years of experience in working in the real estate sector.
Project-based questions	
8. Average project size	Depending on the project the developer is realizing, they aim to make projects of 2-350 units. The housing corporation is having a project size between 30-92 units. This low amount in project size is due to the fact they mostly realize low-rise row houses which takes a lot of ground area. The investor is realizing projects that include 332 till 440 units (10-130 million euro). This high amount of units is due to the types of buildings the investor realizes: *Commercial* (offices) and *residential* (lot of medium-rise and high-rise) The governmental body that was interviewed has an average project size of only a few units. However, since these are *specialty* buildings and *commercial* (offices) they have a price range of 500.000 till 19 million euro. The educational body want to aim a realization up to 300 units (24-90 million euro).
9. Inventory construction methods	The housing corporation only mentioned that the conventional construction method exist. However, the interviewee also mentioned a lego-principle which is corresponding a lot with the modular construction method. The housing corporation state that stacking with universal blocks is the future (Interview #3 housing corporation, 00:13:03). All the remaining interviewees, mentioned three out of four or four out of four construction methods. The conceptual- and modular construction methods were the interchangeable ones as nobody exactly can tell the difference. For example, the developer state that a concept can be totally modular which can create overlap and therefore fuzziness (Interview #1 developer, 01:12:15).
10. Preferred construction method	All interviewees preferred the conceptual- or modular construction method. For instance, the developer state that conceptual reduces construction time, reduces failure costs and improves quality from working off-site (Interview #1 developers, 01:09:03). The investor state that their preference is working with prefab or modular construction methods because it has the benefits of a high production speed, high quality performance, off-site working where circumstance can be monitored and the error-rate of making mistakes is low (Interview #2 investor, 00:49:52).
11. Partnerships	Since the housing corporation is active in three locations only, mainly fixed partnerships are formed to realize projects. This is also the case with the developer. They have an alliance with two fixed contactors were they work with. In terms of architects and municipalities, they vary across the

	Netherlands. The investor and governmental body are large organizations and have different partnerships scattered around the Netherlands. In case of the governmental body, they also have a lot of intern partnerships which are fixed (e.g. consultancy and engineering companies which are on loan) (Interview #4 governmental body, 00:14:22). The education organization is focused mainly on the four biggest university cities in the Netherlands. In case of real estate they have fixed partnerships with municipalities and a variation of contractors.
12. Target group and building types	The developer is realizing different projects (e.g. *commercial*, *residential*) for different people (e.g. investors, government). They focus on private dwellings, social rental market, medium-rental market, higher-rental market and free sector dwellings. The target group of the housing corporation is the lower-rental market and particularly the social rental market, because they are a semi-private authority, whereas the educational organization is also focusing on the lower-rental market but particularly for students. The investor focusses more on the higher-rental market and dwellings. The governmental body is operating more on public buildings such as offices and specialties (i.e. museums, courts, prisons, etc.).
13. Project types	All interviewees described that they realize new projects and buildings. They also preform renovations and when organizations renovate, they might as well implement sustainable aspects directly. The developer, governmental body and investor performs transformation projects. Temporary accommodation is only performed by the educational body and housing corporation, because their target group is growing extensively and leads to a rapid shortage of lower-segment housing.
14. (In)dependency	In general every project is different. All organizations think that the construction methods are dependent. Also in terms of realizing a house or a utility building it demands a different approach. This is definitely the case with transforming or enlarging an existing building, thus the governmental body. According to the governmental body, construction methods depends on the type of building. "… you cannot suddenly put prefabricated materials on a half-listed building" (Interview #4 governmental body, 00:35:11).
15. Factors	The additional factors that are mentioned during the interview are listed in table 10. To avoid confusion in the definitions of factors, literature is performed to find the right definition of the factors. Also the definitions or thoughts according the clients are listed in the next table.

Table 10 | Description of factors derived from the interviews

Factors from interviews		
Factors	**Source**	**Definition**
1. Location	(Webster, 2019)	… a position or site occupied or available for occupancy or marked by some distinguishing feature.
	(Collins, 2019)	The act or process of locating or the state of being located.
	(Oxford dictionaries, 2019)	A particular place or position.
	(WordReference, 2019)	A place of settlement, activity, or residence.
2. Nuisance	(Cambridge, 2019)	Something or someone that annoys you or causes trouble for you
	(Designing Buildings Wiki, 2018)	Nuisance is unreasonable interference with another party's use of land.
	(MRSC, 2016)	A nuisance involves an unreasonable or un-lawful use of property that results in material annoyance, inconvenience, discomfort, or injury to another person or to the public.
	(Washington State Legislature, 2019)	Nuisance consists in unlawfully doing an act, or omitting to perform a duty, which act or omission either annoys, injures or endangers the comfort, repose, health or safety of others, offends decency, or unlawfully interferes with, obstructs or tends to obstruct, or render dangerous for passage, any lake or navigable river, bay, stream, canal or basin, or any public park, square, street or highway; or in any way renders other persons insecure in life, or in the use of property.
3. Quality	Peter F. Drucker	"Quality in a product or service is not what the supplier puts in. It is what the customer gets out and is willing to pay for."
	(Lifetime Reliability Solutions, 2019)	A degree of excellence, conformance to requirements, totality of characteristics which act to satisfy a need, fitness for use, fitness for purpose, freedom from defects, delighting customers
	(ISO 9000)	Quality is the degree to which a commodity meets the requirements of the customer at the start of its life.
	(STANDS4, 2019)	Quality in business, engineering and manu-facturing has a pragmatic interpretation as the non-inferiority or superiority of something

4. Circularity (economy)	(Hemmen, 2016, p. 60)	This implies infinite material productivity regarding non-regenerative materials, which intends recursive recovery of wastes and an absence of resource extraction.
	(MacMillan Dictionary, 2019)	A situation in which a series of causes and effects leads you back to the original cause, producing an argument that does not mean anything.
	(Finamore, 2017)	"The circular economy is an economic system based around the principle of exchange, espousing production methods that, at every stage of the product life cycle (goods and services), aim to increase the efficiency of resource usage and diminish environmental impact, while also improving the wellbeing of individual citizens."
	(Ellen MacArthur Foundation, 2017)	A circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system.
5. Exploitation/ operating (cost related)	(Longman Dictionary of Contemporary English, 2019)	The full and effective use of something.
	(Verbouwkosten, 2019)	…. the costs that result from owning or using real estate such as an office / company building. This includes energy costs, maintenance costs, cleaning costs, taxes, insurance and fixed costs (also known as depreciations).
	(Kenton & Murphy, Operating Cost Definition, 2019)	…. expenses associated with the maintenance and administration of a business on a day-to-day basis.
6. Compatibility	(Cambridge, 2019)	The fact of being able to exist, live, or work successfully with something or someone else.
	(Random House Unabridged Dictionary, 2019)	Something, as a machine or piece of electronic equipment, that is designed to perform the same tasks as another.
	(Business Dictionary, 2019)	Ability of two or more systems or their components to work together without user intervention or modification.
	(Hoppers, 2019)	"…. a system that works with other systems instead of a systems that works on its own".

3.4 Conclusion client interviews: exploring the critical factors

Client interviews were held among five different types of clients: developer, investor, governmental body, educational body and a housing corporation. Despite the efforts of the researcher there is no healthcare body that was willing to participate in an interview. However, the five remaining organizations had formed a total of six new factors (table 11) that can be added to the already existing list of fifteen factors derived from the literature review. The final definitions of all 21 factors are derived from the literature review and the argumentation of clients interviews.

To conclude the results of the interviews, it seems that the developer and investor together with the educational body are having the largest projects sizes. Both the developer and investor are realizing projects scattered through the Netherlands focussing on the higher-segment target group. All interviewed organizations have fixed partnerships for their projects, mostly with large contractors. This also accounts for partnerships with local municipalities, but this is depends on the developed project area. The educational body together with the housing corporation are the only interviewed organizations that are having temporary housing projects. In the interview they claimed that this is due to the growing demand of their critical target group – lower-rental segment. Important to mention is that all organizations think that the construction methods are dependent on the building types. Each project is different and is likely based on the building type that clients want. This important finding will be incorporated in the questionnaires. By asking the respondent in advance what kind of building types they have the most in their portfolio. Consequently, the questions about rating the factors will be about the chosen building types.

The factors; time, speed, location, construction costs, nuisance and collaboration were particularly mentioned by the developer. Exploitation, sustainability and circularity were multiple times mentioned by the housing corporation. Especially eco-friendly ways of constructing or renovating is what the housing corporation finds attractive, because this keeps the fixed housing costs for the residents low and affordable. Besides this, the housing corporation want to build houses for the long run, which are future orientated and therefore have high requirements concerning sustainability. The factors; quality, location, off-site, uniqueness, costs, speed, time and accuracy were particularly mentioned and can be seen as important for the investor. The buildings of the investor are for the higher-segment population and to meet the wishes of the tenants of the investor, the building must have high quality and luxury. Although quality is top priority for the investor, the costs must be well considered. While preferring a construction method the governmental body finds the factors; location, compatibility, sustainability, nuisance and safety important. With the educational body the following factors play a crucial role; safety, location and sustainability. All organizations agreed that flexibility of a building can be more easily reached by using the conventional construction method while working with modular construction method. It is better to have a rigid well thought-out floor plan than one that is more flexible, because this lowers the costs and in practise transforming floorplans is rarely done. Since both the literature

and interviews provide factors concerning the construction methods from the perspective of the client, it can be concluded that sub-research question 3 – "What are the (underlying) factors related to the construction methods?" is being fully answered.

Table 11 | List of factors from the interviews and their final definition

Factors from the interviews	
Factors	**Definition**
1. Location	A particular place of position or the state of being located.
2. Nuisance	Nuisance involves the exposure of a property or state being that results in material annoyance, inconvenience, discomfort, or injury to another person or to the public.
3. Quality	Degree to which a product or service meets the requirements that are set as a threshold and in which they fulfil the minimum standard of the customer.
4. Circularity (economy)	An economic system based around the principle of exchange, espousing production methods that, at every stage of the product life cycle (goods and services), aim to increase the efficiency of resource usage and diminish environmental impact, while also improving the wellbeing of individual citizens.
5. Exploitation/operating (cost related)	Maintenance and administrative costs that result from owning or using real estate such as an office / company building.
6. Compatibility	Unequal processes of systems that can work together with each other without user intervention or modification which makes it universal.

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4. SELECTION OF THE CRITICAL FACTORS USING THE FDM METHOD

In the previous chapter interviews were held to supplement, among other things, missing factors to the already derived factors from the literature review. Table 12 shows the second and final composition of all discovered (underlying) factors.

Table 12 | Total list of factors (literature + interviews)

Factors		
1. Labour intensity	8. Process	15. Innovation
2. Safety	9. Aesthetics (variety)	16. Location
3. Flexibility	10. Time	17. Nuisance
4. Sustainability	11. Production speed	18. Quality
5. Costs	12. Collaboration	19. Circularity (economy)
6. Accuracy	13. On-site	20. Exploitation / operating costs
7. Uniqueness	14. Off-site	21. Compatibility

Together with in-depth questioning of different type of clients it forms the input which is needed to give the questionnaire structure. In chapter 4 the methodology will be explained. Here the questionnaire is intertwined with the FDM and forms the method that is used to find out which factors are significant important for clients to choose for a particular construction method. Thereafter the set-up, data and results of questionnaire (I) and questionnaire (II) will be described.

4.1 Theory – Fuzzy Delphi Method (FDM)

In order to find the most important critical factors related to the construction methods, the Fuzzy Delphi Method (FDM) has been conducted for analysing the results of questionnaire (I) and (II). This methodology is used to calculate the clients' preferences of these factors. In the article of Hsu et al. (2010), which describes expert systems with applications, the FDM is explained (Hsu, Lee, & Kreng, 2010). According to Hsu et al. (2010) this method was proposed by Ishikawa et al. (1993), and it was derived from the traditional Delphi Method (DM) and Fuzzy set Theory (FT) (Ishikawa, et al., 1993; Glumac, Han, Smeets, & Schaefer, 2011).

The traditional DM developed by Dalkey and Helmer (1963), has been widely used to obtain a consistent flow of answers through the results of questionnaires (Hwang & Lin, 1987; Reza & Vassilis, 1988). Delphi is an expert opinion survey method consisting of three features (Hsu, Lee, & Kreng, 2010): anonymous response, iteration and controlled feedback and finally statistical group response. According to Aliev, Aliev, Ahmedov and Aliyeva (2004) the essence of the DM is as follows: a panel of experts is requested to give their opinion about a certain event. The responses of the experts to the first questionnaire are used to generate a second questionnaire. The same experts or new experts may be used to respond to the second questionnaire. Their responses are then used to generate questions for a third questionnaire, and so forth. This process could be repeated until the outcome converges to a consistency in answers (Aliev et al., 2004; Rahimianzarif & Moradi, 2017).

The FT can be considered as a functional tool which eases the decision making process. Instead of real numbers, linguistic terms are more common to use. This is inherent to large number of uncertainties, fuzziness or vagueness and therefore the FT uses fuzzy numbers which seems to be an appropriate way to make decisions. Combining the DM and the FT leads to the FDM.

The FDM is chosen to evaluate the questionnaires used in this thesis because it is an method to collect diverse panel data. The idea behind the FDM is to get consistent answers by repeating a process of questionnaires, whereby the first questionnaire serves as input for the following questionnaire and so forth. According to Habibi, Jahantighb, & Sarafrazi (2015) the FDM is based on respondents' views. In this technique, verbal expressions are used to measure views. Verbal expressions have limitations to reflect fully respondent's mental latencies. For example, the phrase "high" for A who is a stringent person is different with phrase "high" for B, this is called fuzziness. If a crisp number was used to quantify both individuals' views, the results would have been skewed. In other words, although the experts' competence and mental abilities are used for decision-making, the quantification of experts' opinions cannot completely reflect the human thinking style. Using fuzzy sets is more consistent with human linguistic and sometimes vague descriptions and it is better to make decisions in the real world by applying fuzzy numbers (Habibi, Jahantighb, & Sarafrazi, 2015, p. 133).

An alternative method to the FDM that is named in the literature is the AHP method (Kazemi, Homayouni, & Jahangiri, 2015). The AHP is used in deriving ratio scales from paired

comparisons, to see which attribute is important. However, after the researcher obtained deeper knowledge in the method by reading articles, it became clear that the disadvantages of the AHP were too many. Articles mentioned that the method had some inconsistencies, rank reversal issues, problems when having equal weight to set up a threshold value and the wrong use of eigen analysis for n>3. (Kasperczyk & Knickel, n.d.; Macharis, Springael, Bruckers & Verbeke, 2004, p. 307-317). The FDM was the right method that was applied in this thesis, because it brings geographically dispersed panel experts together (gaining input with minimal personal access). It also solves the problem of ambiguity in the consensus of clients. Besides, this methodology has proven to be success in several other articles (James, 2016, p. 75; Boeters, 2018, p. 39; Hsu, Lee, & Kreng, 2010; Fuziah Rosman Mohd Nazri Ab Rahman, Saedah Siraj 2013; Glumac et al. 2011; Ishikawa, A., Amagasa, T., Tamizawa, G., Totsuta, R. and Mieno 1993; Saedah Siraj 2012).

In the next paragraph the FDM steps that are conducted in this research will be explained and applied (Hsu, et al., 2010, p. 420):

I. Collect opinions and Set-up questionnaires → (paragraph 4.2.1);
II. Overall triangular fuzzy numbers → (paragraph 4.2.2);
III. Defuzzification → (paragraph 4.2.3);
IV. After screen evaluation indexes → (paragraph 4.2.4).

4.2 Application of the FDM

The literature review provided a list of fifteen critical factors related to the construction methods. In addition to the literature review, client interviews were not only conducted to get a first indication on the clients' preferences, but also to see what missing factors could be added to the list. The client interviews have enlarged the list of factors with six additional ones, which amount to a total of twenty-one factors (chapter 4, figure 11, p. 49). The FDM can categorize the factors and reveal the importance of them per client type (Glumac et al., 2011).

4.2.1 Collect opinions and set-up questionnaire (I) and (II)

The first step of the FDM is used to collect the opinions of experts. As has been previously mentioned: the opinions are gathered by several rounds of questionnaires. Rahimianzarif & Moradi (2017) state in their research that the steps of performing the FDM consist of a structured way of gathering opinions in two or more rounds. The success lies within the repetitive process of collecting results, analyzing, concluding and repeat until consensus has been reached (Rahimianzarif & Moradi, 2017). In this thesis, two rounds of questionnaires were conducted to reveal the preferred factors and reach consensus among the results from both questionnaires in line with the criteria of the FDM.

Both questionnaires consist of the same target group with the same number of clients: governmental bodies, housing corporations, education – and healthcare bodies, developers and investors. However, when comparing questionnaire (I) with questionnaire (II), the sample size was different. Assumed was that the second questionnaire would have less clients,

because the willingness of respondents to fill in questionnaires for two or multiples times will decline. In line with the theory described by Aliev et al., (2004) and Rahimianzarif & Moradi (2017) the results of questionaire (I) served as input for questionnaire (II).

To find the evaluation score of each alternate factor's significance, each client will rate the important factors by linguistic variables. According to SnapSurveys (2011) the most common scale to measure the 'Level of Importance' is done based on a five-point Likert scale (DeFranzo, 2011). However, the higher the variation in scale, the more detailed the results will be. Therefore there will be worked with a seven-point Likert scale with the following range of linguistic variables: "Not at all important," "Slightly Important," "Merely Important," "Important," "Fairly Important," "Very Important," and "Extreme Important" (DeFranzo, 2011). In order to reduce bias in the questionnaires, also an option called "Don't know / No opinion" is added (Dobronte, 2014).

The seven-point Likert scale used in questionnaire (I) and (II) is shown in table 13 and includes the triangular fuzzy numbers which are derivatives from figure 11 as explained in the journal article of Hsu, Lee, & Kreng (2010).

Table 13 | Seven-point Likert scale with its fuzzy numbers and explanation (Habibi, Jahantighb, & Sarafrazi, 2015, p. 136)

Linguistic expressions	**Not at all important**	**Slightly important**	**Merely important**	**Important**	**Fairly important**	**Very important**	**Extreme important**
Value	1	2	3	4	5	6	7
Fuzzy number (a_{ij}, b_{ij}, c_{ij})	$\tilde{1}$ (0, 0, 0.1)	$\tilde{2}$ (0, 0.1, 0.3)	$\tilde{3}$ (0.1, 0.3, 0.5)	$\tilde{4}$ (0.3, 0.5, 0.75)	$\tilde{5}$ (0.5, 0.75, 0.9)	$\tilde{6}$ (0.75, 0.9, 1)	$\tilde{7}$ (0.9, 1, 1)

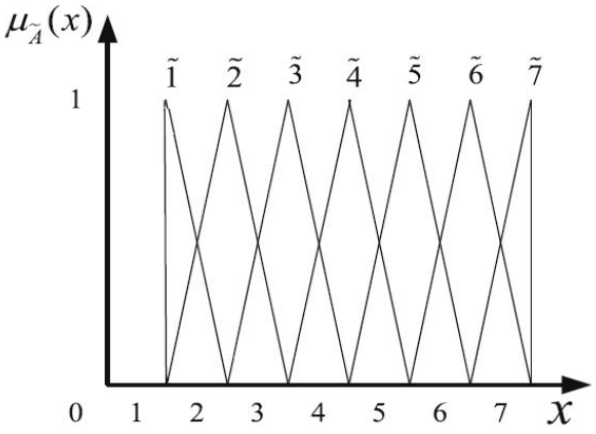

Figure 11 | Scale of fuzzy numbers (Habibi, Jahantighb, & Sarafrazi, 2015, p. 136)

4.2.2 Overall triangular fuzzy numbers

The result of questionnaire (I) and (II) will look like the following matrix (table 14) that makes clear the effect-scores of the factors that every respondent had given (Boeters, 2018, p. 41).

Table 14 | Effect-scores in matrix (Boeters, 2018, p. 41)

	R_1	R_2	....	R_n
F_1	L_{11}	L_{21}	....	L_{n1}
F_2	L_{12}	L_{22}	....	L_{n2}
....	....	....	....	....
F_m	L_{1m}	L_{2m}	....	L_{mn}

Where:
R_i = $The\ i^{th}\ respondent$, i = 1, 2, …, n
Fj = $The\ j^{th}\ factor$, j = 1, 2, …, n
$L_{i,j}$ = $The\ evaluation\ of\ the\ criterion\ j\ by\ respondent\ i$

According Hsu, Lee, & Kreng (2010) the set up for the triangular fuzzy numbers goes as followed: "Calculate the evaluation value of triangular fuzzy number of each alternate factor given by experts, find out the significance triangular fuzzy number of the alternate factor. This study used the geometric mean model of mean general model proposed by Klir and Yuan (1995) for FDM to find out the common understanding of group decision. The computing formula is illustrated as follows" (Hsu, Lee, & Kreng, 2010, p. 420):
Assuming the evaluation value of the significance of No. *j* element given by No. *i* expert of n experts is $\widetilde{W_{ij}} = (a_{ij}, b_{ij}, c_{ij}), i = 1, 2, \dots, n, j = 1, 2, \dots, m$. Then the fuzzy weighting $\widetilde{W_j}$ of No. *j* elements is $\widetilde{W_j} = (a_j, b_j, c_j), j = 1, 2, \dots, m$. Among which:

(1) $$a_j = \overset{Min}{i} \{a_{ij}\}$$

(2) $$b_j = \frac{1}{n} \sum_{i-1}^{n} b_{ij}$$

(3) $$c_j = \overset{Max}{i} \{c_{ij}\}$$

Including $a_j = \overset{Min}{i}$ and $c_j = \overset{Max}{i}$ provides a correction for data that otherwise could be skewed. Therefore it is statistically better to implement a standard deviation or variance, which is used to indicate the distribution - the degree to which the values differ - of a distribution. Taking only the average by excluding *Min* and *Max,* would lead to a point estimation without knowing the range or spread. In its turn it would result into a unknown accuracy.

4.2.3 Defuzzification

After the fuzzy aggregation of the opinions of the clients, the values should be defuzzified. This means that the linguistic values should be changed into understandable numbers. The most popular method is defuzzification done by the triangular method. Here the fuzzy weights $\widetilde{W_j}$ are defuzzified of each critical factor, by using the simple centre of gravity method used in the article of Glumac et al. (2011); Hsu et al., (2010); Boeters (p. 41, 2018) to determine the single derived numbers of S_j :

(4) If *j = 1, 2, …, m,* then $$S_j = \frac{a_j + b_j + c_j}{3}$$

4.2.4 After screen evaluation indexes

When the mean opinions of the clients are determined, the S_j results into the crisp number (or value) which will be measured against a certain threshold. If the crisp value of defuzzification of aggregated clients' opinions is larger than threshold, the criterion is confirmed. If the criterion is less than threshold, it is removed. The principle works as followed:

If $S_j \geq \alpha$ then *j* factor is not significantly important
If $S_j < \alpha$ then *j* factor is significantly important

Threshold that is commonly used is between 0.67 – 0.7. This is an arbitrary value since it depends on the amount of factors the researcher wants to filter. Confirmation of Habibi et al. (2015) state that the acceptance and rejection of criteria are subject to the threshold value that is determined by the investigator (Habibi, Jahantighb, & Sarafrazi, 2015, p. 140).

4.3 Data collection questionnaire

4.3.1 Questionnaire structure

In the literature review the type of clients for large contractors that have more than 100 employees are described. Here six type of clients are discovered: developer, investor, housing corporation, governmental body, educational body and healthcare body. Furthermore in literature the building types are researched. According to research from (Schmidt, 2013; Marsh, 2016; Integrity Data Solutions, LLC, 2017, pp. 21-36; CoStar, n.d.; Wolf, 2016; Kugler, 2019) there are six building types: *residential, commercial, industrial, infrastructural, agricultural* and *specialty*. Furthermore the literature review provided information about the construction methods. The literature review suggested four types of construction methods: conventional, prefab, conceptual and modular. Related to the construction methods, twenty-one factors were derived from the literature review and interviews with clients. An overview of these mentioned elements can be seen in figure 12.

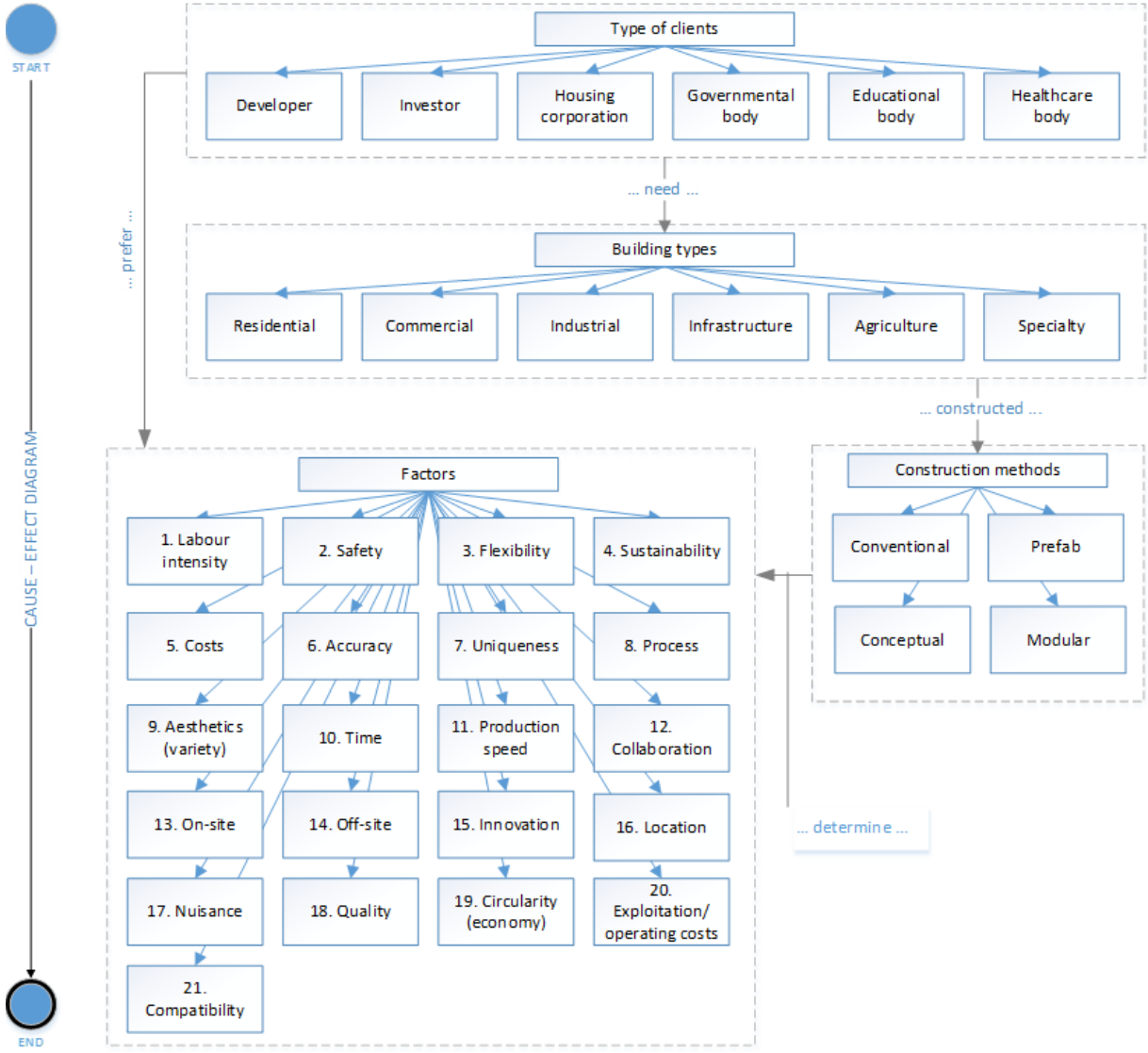

Figure 12 | Cause-effect diagram

This cause-effect diagram shows that factors are determined by the used construction methods in the Netherlands. In addition, these factors are preferred by the clients. Results of the interviews shows that the construction method are constructed by the type of buildings. Consequently, the types of buildings are needed by the different clients. Therefore the building type depends on the type of clients (Kenniscentrum Ruimte-ok, 2019). The structure in figure 12 reflects the structure that is used in questionnaire (I). Regardless of the factors that satisfy the prescribed threshold, this structure is maintained in questionnaire (II).

4.3.2 Target group

As already mentioned before in this thesis, an extended client database (Appendix B) of 5255 organizations was made. Since not all organizations included their contact data, there is chosen to only work with organizations who provided their contact data. This amount is equal to 838 organizations which are divided into the following type of clients:

- 204 housing corporations;
- 34 educational bodies;
- 124 health-care bodies
- 175 governmental bodies;
- 212 developers;
- 89 investors;

Rounds of questionnaires are being conducted to measure the clients' opinions. Consequently, the results will be analysed using the FDM. A two-step-procedure for conducting both questionnaires will take place: firstly questionnaire (I) will be online for 14 days, whereas the results will be described and discussed. Secondly, input from the results of questionnaire (I) will be lead to the formulation of questions in questionnaire (II). Also questionnaire (II) was online for 14 days.

4.4 Questionnaire (I)

4.4.1 Questionnaire design

Questionnaire (I) was designed using the free survey system of ThesisToolsPro. The questionnaire consists of three parts, starting in Part A with questions about the respondents' profile. Here the client type was recalled. At the end of Part A, respondents were asked to choose which of the six building types they mainly manage in their portfolio. In Part B, respondents were asked to give their preferences on each factor related the construction methods based on the building type the respondents have chosen in Part A. Lastly, in Part C, questions to respondents were asked about whether they could associate the four different construction methods with the six different building types. In the final question of Part C the respondents were asked whether they could rank the construction methods.

4.4.2 Data collection

From the 838 organizations, 102 organisations could not be reached, because the e-mail was labelled as undelivered. While searching their right contact information, it soon became apparent that these companies no longer existed. The cause of this was bankruptcy, merging of companies (redirected) or companies that simply do not exist anymore. From the 736 organizations that were successfully contacted, 18 organizations replied that they did not want to fill in questionnaire (I). Their reasons were: "*Being too busy*", *"Not the right target group"* or *"Not participating in (student) research activities"*.

Questionnaire (I) included 328 respondents that filled in the questionnaire. However, 147 out of 328 respondents filled in the questionnaire complete. From a total target group of 718 clients this translates itself in a response rate with useable results of 20 percent. The results of 147 respondents were placed in SPSS statistics. It was noticed that there was one "missing value" in the database. This value had been filtered out, whereas 146 results are left to analyse.

4.4.3 Results

Part A

The results of Part A of questionnaire (I), which contained questions to describe the respondents' profile, are displayed in table 15. Attributes one shows that 129 males and solely 17 females filled in the questionnaire. Attribute two shows that 5 respondents are between the age of 20-29 years. The amount of respondents increases inherently up to an age till 50-59 years. Of the respondents who are 60 years or older, 17 filled in the questionnaire. Attribute three shows that 6 respondents have a MBO level of education, 85 respondents have a HBO level of education, 51 respondents have a WO level of education and 4 respondents answered "other". Attribute four shows the work experience that respondents have. The higher the number of experience, the higher the number of respondents who filled in the questionnaire. Attribute five shows the type of organization who filled in the questionnaire. 30 respondents are working at a governmental body, 27 respondents are working at a healthcare body, 11 at an educational body, 49 at a housing corporation, 25 at a developer and 4 respondents are working at an investor. Attribute six shows that 15 respondents have a function in the management board. 64 respondents operate as managers, 31 as executive, 21 as consultant and 15 as "others". Respondents who filled in sub-attribute "other", answered with merely the same occupational level that had been given as a choice (i.e. *werkvoorbereider* is branched under planner). So although the term differentiates, the definition is the same. Attribute seven shows that respondents who filled in the questionnaire are located with their organizations in 11 out of 12 provinces in the Netherlands. Remarkable is that nobody is located in Zeeland. Attribute eight show the average project size of the respondents' organizations. Most respondents (87) filled in that their average project size is below the 10 million euro. Attribute nine show that 112 respondents mainly focus on *residential* type of buildings. 7 respondents mainly focus on *commercial* type of buildings and 27 respondents mainly focus on special type of buildings. Not a single respondent choose for the building types: *industrial*, *agricultural* and *infrastructure*.

Table 15 | Respondents' profile questionnaire (I)

Attributes	Sub-attributes	Response rate (number)	Percentage (%)
1. Gender	Male Female Gender neutral	129 17 -	88,4 11,6 -
2. Age	20-29 years 30-39 years 40-49 years 50-59 years ≥ 60 years	5 27 45 52 17	3,4 18,5 30,8 35,6 11,6
3. Education	Professional education (MBO) Higher professional education (HBO) University (WO)	6 85	4,1 58,2

	Other: - "Academy van Bouwkunst" - Secondary education (HAVO) - HBO with WO work- and level of thinking - Master (WO)	51 4	34,9 2,7
4. Work experience	< 5 years 5-9 years 10-14 years 15-19 years 20-24 years ≥ 25 years	6 7 11 23 41 58	4,1 4,8 7,5 15,8 28,1 39,7
5. Type of organization	Governmental body Healthcare body Educational body Housing corporation Developer Investor	30 27 11 49 25 4	20,5 18,5 7,5 33,6 17,1 2,7
6. Occupational level	Managing board Manager Executive Consultancy Planner Other: - (5x) Developer - (2x) Teacher - (1x) Director - (1x) Planner - (1x) Safety - (1x) Real estate advisor - (1x) Case manager Wabo - (2x) Project manager - (1x) Supervision consultant	15 64 31 21 - 15	10,3 43,8 21,2 14,4 - 10,3
7. Province	Drenthe Flevoland Friesland Gelderland Groningen Limburg Noord-Brabant Noord-Holland Overijssel Utrecht	6 7 6 26 8 4 3 19 19 26	4,1 4,8 4.1 17.8 5.5 2.7 2.1 13 13 17.8

	Zeeland Zuid-Holland	- 22	- 15.1
8. Average project size	< 10 million euro 10-19 million euro 20-39 million euro 40-59 million euro 60-79 million euro 80-99 million euro ≥ 100 million euro	87 28 10 6 2 4 9	59.6 19.2 6.8 4.1 1.4 2.7 6.2
9. Building type	Residential Commercial Industrial Infrastructure Agricultural Specialty	112 7 - - - 27	76,7 4.8 - - - 18.5

Appendix G (*Chapter 7, paragraph 7.7.1*) contains a cross-tab table which shows the relation between the type of client and the building type, average project size and province.
In perspective of the governmental body, questionnaire (I) claims that their building type differentiates with 73 percent for *residential* and 27 percent for *specialty*. Their average project size is for 67 percent below the 10 million euro. Furthermore, the largest part of the governmental bodies (37 percent) are located in the eastern part of the Netherlands.

Taken into account the perspective of the educational body, questionnaire (I) claims that their building type differentiates with 55 percent for *residential* and 45 percent for *specialty*. This is almost in equilibrium. Most of their projects (64 percent) vary between an average project size of < 10 million euro. Furthermore, the largest part of the educational bodies (55 percent) are located in the eastern part of the Netherlands.

In perspective of the healthcare body, questionnaire (I) claims that their building type differentiates with 74 percent for *residential* and 26 percent for *specialty*. The average project size is for 67 percent of the healthcare bodies less than 10 million euro. In addition 15 percent lies between 10 – 19 million euro, 11 percent lies above the 100 million euro and others lie in between. Furthermore, the largest part of the educational bodies (56 percent) are located in the western part of the Netherlands.

In perspective of the housing corporations, questionnaire (I) claims that their building type exists of 90 percent *residential*. The average project sizes vary a lot, however 55 percent of the housing corporations have an average project of less than 10 million euro. Furthermore, the largest part of the educational bodies (57 percent) are located in the western part of the Netherlands.

In perspective of the developer, questionnaire (I) claims that their building type exists of 72 percent *residential* and 20 percent *specialty*. The average project sizes vary a lot, however 56 percent of the developers have an average project of less than 10 million euro. In addition,

32 percent lies between the 10 – 19 million euro. Furthermore, most developers who filled in questionnaire (I) (68 percent) are located in the western part of the Netherlands.

In perspective of the investor, questionnaire (I) claims that their building type exists of 50 percent *residential* and 50 percent *commercial*. 50 percent of the developers claim to have an average project size of over 100 million euro. In addition 25 percent lies below the 10 million euro and 25 percent lies between the 40 – 59 million euro. Furthermore, most investors (75 percent) are located in the western part of the Netherlands.

Part B

In Part B of questionnaire (I) the FDM was used to calculate the factors that were rated on a seven-point Likert scale to determine the importance level. In order to reduce the twenty-one factors related to the construction methods based on the client's preferences, a threshold of $\alpha = 0.7$ was used. As already is mentioned in *chapter 4, paragraph 4.1.1* this threshold depends on the amount of factors that will be accepted. The threshold of 0.7 is supported by various literature (Habibi, Jahantighb, & Sarafrazi, 2015; Hair et al., 2006; Kamarulzaman et al., 2015). Figure 13 shows a diagram with all factors and their scores. The orange bars shows the factors that are accepted and the blue bars shows the factors that are rejected. Table 16 shows all the factors that are accepted and ranked based on the scores given by the respondents.

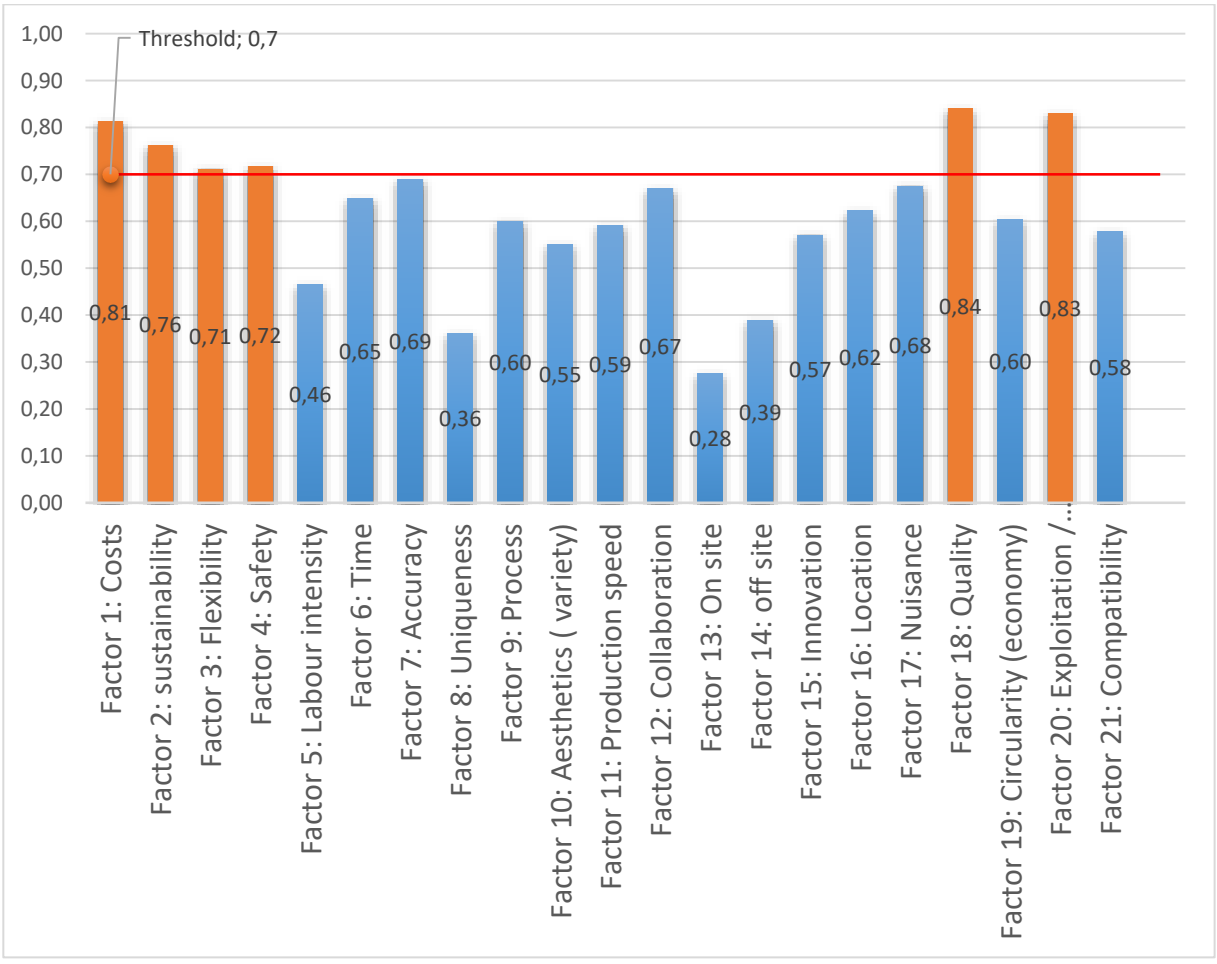

Figure 13 | Ranking the important levels for the factors

Table 16 | Rank accepted factors (single derived number α ≥ 0.70)

No.	Factors	S_j = Crisp value	Accepted / Rejected
1	Quality	0.84	Accepted
2	Exploitation / operating costs	0.83	Accepted
3	Costs	0.81	Accepted
4	Sustainability	0.76	Accepted
5	Safety	0.72	Accepted
6	Flexibility	0.71	Accepted

Part C

In Part C of questionnaire (I) the respondents were asked to select one or multiple building type(s) conform the type of construction method what they think is best suitable for constructing a building. Table 17 shows that 81.5 percent of the respondents, in terms of building type; *residential*, tend to choose working with prefab. Thereafter respondents often tend to choose for the modular construction method, next the conceptual construction method and lastly for the conventional construction method. According to the respondents, building type; *commercial* is mostly build using the prefab construction method. Building type; *specialty* is mostly build using the conventional construction method. Building type; industrial is mostly build using the prefab construction method and the modular construction method. According to the respondents, building type; *agricultural* is mostly build using the modular construction method. According to the respondents, building type; *infrastructure* can be build using every construction method. I seems that the percentages are low and similar to each other as the percentages varies between 17.8 and 19.9 percent.

Table 17 | Cross-tab of building types with construction methods

Attribute	Construction method							
	Conventional construction method (number)	Average (%)	Prefab construction method (number)	Average (%)	Conceptual construction method (number)	Average (%)	Modular construction method (number)	Average (%)
Building type								
Residential	66	45.2	119	81.5	92	63.0	94	64.4
Commercial	15	10.3	53	36.3	33	22.6	43	29.5
Specialty	77	52.7	17	11.6	38	26.0	22	15.1
Industrial	14	9.6	45	30.8	31	21.2	45	30.8
Agricultural	22	15.1	36	24.7	20	13.7	37	25.3
Infrastructure	28	19.2	26	17.8	29	19.9	27	18.5

Furthermore respondents were asked to rank the construction methods based on the building type the respondents have chosen in Part A, from position 1 of being most desired to position 4 of being least desired. Since all respondents in Part A have chosen that they mainly have three out of six building types in their portfolio; only *residential*, *commercial* and *specialty* has been ranked per construction method (figure 14a, 14b and 14c). In terms of the three building types, the rank order for the construction methods from 1 to 4 is as follows:

- Residential
  1. Prefab
  2. Conceptual
  3. Conventional
  4. Modular
- Commercial
  1. Prefab
  2. Modular
  3. Conventional
  4. Conceptual
- Specialty
  1. Conventional
  2. Prefab
  3. Conceptual
  4. Modular

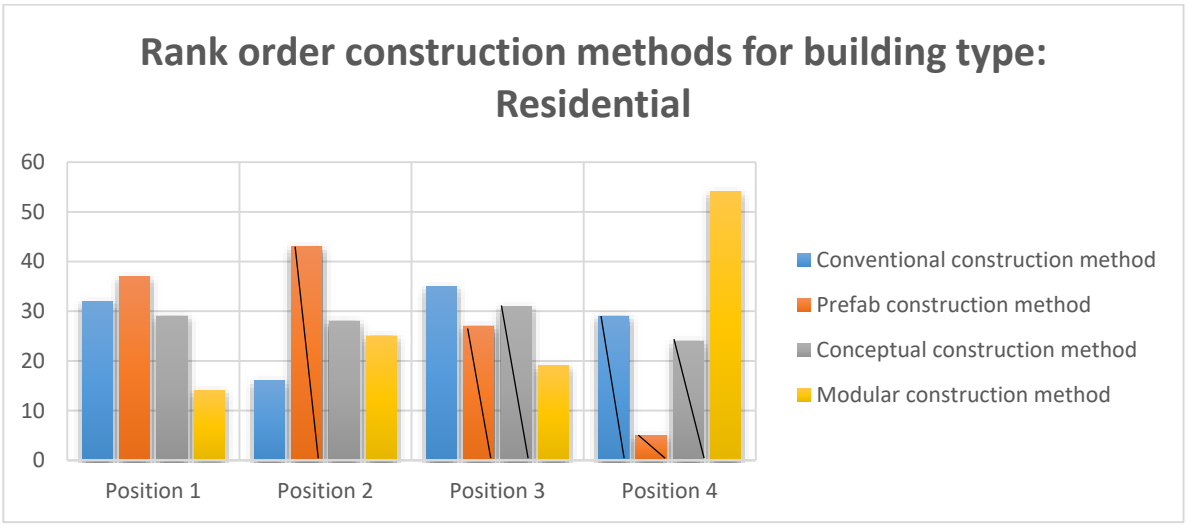

Figure 14a | Rank order for building types per construction method

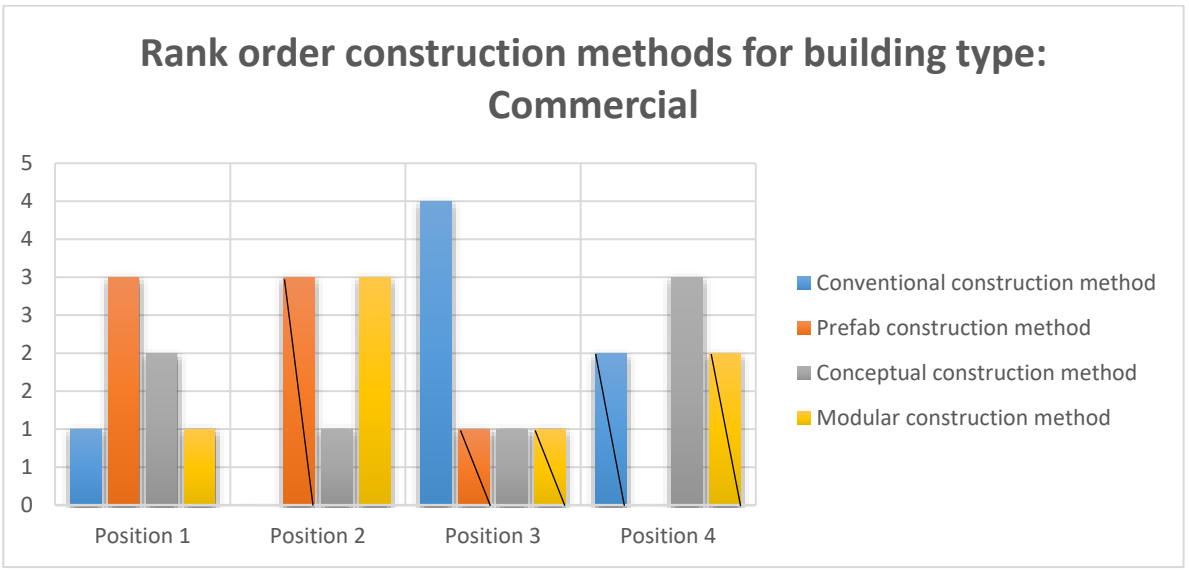

Figure 14b | Rank order for building types per construction method

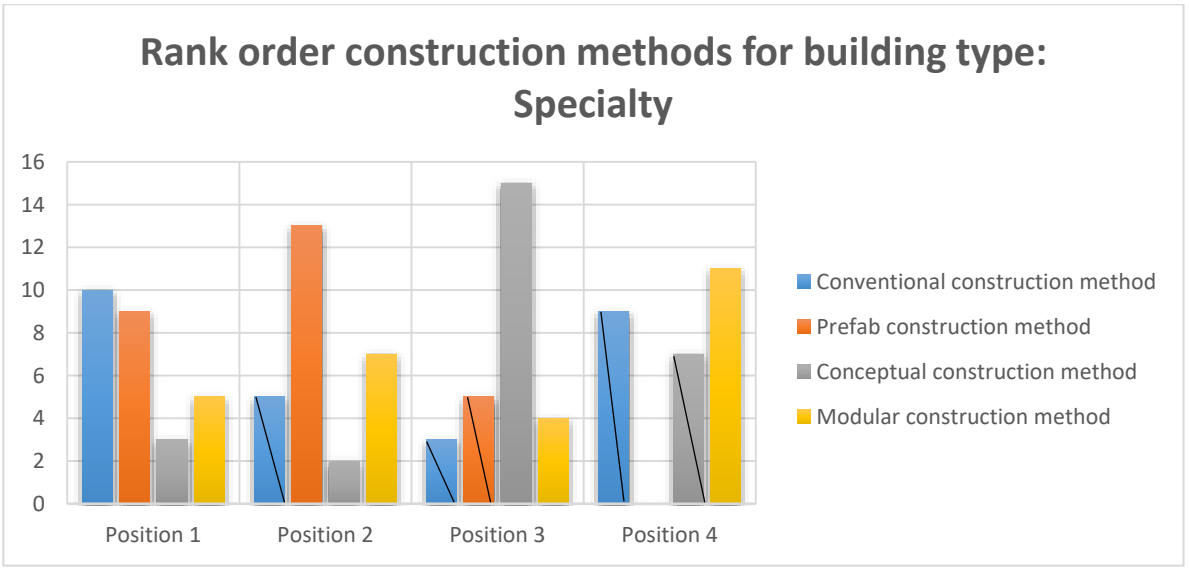

Figure 14c | Rank order for building types per construction method

4.5 Conclusion: questionnaire (I)

Questionnaire (I) focused on selecting the most important critical factors related to the used construction methods in the Netherlands. This has been done from the clients' perspective in which respondents were categorized into different types of organizations. From the literature review performed in this thesis fifteen factors (*costs, sustainability, flexibility, safety, labour intensity, time, accuracy, uniqueness, process, aesthetics, production speed, collaboration, on-site, off-site, innovation*) were discovered. In the next phase of this graduation research six additional factors (*location, nuisance quality, circularity, exploitation / operating, compatibility*) were discovered while interviews were held with five different clients (*governmental body, educational body, healthcare body, housing corporation, developer, investor*). The FDM was applied to analyse the results of Part B of questionnaire (I). The purpose of the FDM was to answer sub-question 4 – "In terms of the different construction methods, which factors do clients find important in realizing a project?".

Questionnaire (I) had been online for 14 days which led to a response of 146 respondents to analyse. The questionnaire was divided into three parts, where Part A contains profile information of the respondents. More than 80 percent of the respondents who filled in the questionnaire is male and a majority of the respondents has an age between the 40 – 59 years. Obviously true and verified, in the results; the older the respondent, the more experienced. The governmental body, healthcare body, housing corporations and developers mainly include *residential* in their portfolio. The educational body variates strongly between *residential* and *specialty*, whereas the investor strongly variants between *residential* and *commercial*. The average project size between < 10 – 19 million euro is for all client types, except the investor, 75 percent or higher. Most respondents that were active as investors have an average project size of above the 100 million euro. Most respondents working within the governmental body and educational body are located in the eastern part of the Netherlands. The other remaining respondents of the four client types are largely located in the western part of the Netherlands.

Part B of questionnaire (I) was made to indicate which of the twenty-one factors are important enough to overcome the threshold of $\alpha = 0.7$. Since the questions about factors are based on the building type each respondent has chosen in Part A, framing of the questions gave the respondents context. Results using the FDM has led to six important factors that were accepted by the threshold:

Factors	**Crisp value (S_j)**
1. Quality	(0.84)
2. Exploitation / operating costs	(0.83)
3. Costs	(0.81)
4. Sustainability	(0.76)
5. Safety	(0.72)
6. Flexibility	(0.71)

Part C of questionnaire (I) was created to indicate the relation between the construction methods, building types and type of clients. Results of Part C pointed out that the majority of respondents thinks that the conventional construction method (52.7 percent) is best suited to realize *specialty* buildings. In terms of the prefab construction method (81.5 percent), conceptual construction method (63.0 percent) and modular construction method (64.4 percent) a majority of respondents think that these methods are best suited for realize *residential* buildings with it.

Furthermore respondents were asked to rank the construction methods based on the building type the respondents have chosen in Part A, from position 1 of being most desired to position 4 of being least desired. Since the respondents mainly had *residential*, *commercial* and *specialty* in their portfolio, these were the attributes in which the construction methods are ranked in. Results on this question shows that the prefab construction method to realize the building types; *residential* and *commercial,* is the most desired one. According to the respondents the conventional construction method is the most desired method to realize the building type; *specialty*. Since the results of the questionnaire in Part C are the same, it can be confirmed the prefab construction method is the most desired method to work with. When realizing a *specialty* building, desired is to work with the conventional construction method.

After answering sub-question 4, by providing six important critical factors and the relation between the building types and construction methods, questionnaire (II) can be designed in the next paragraph of this thesis. So in paragraph 4.6 the results from Part B (six important critical factors) of questionnaire (I) will be used as input for questionnaire (II) where the FDM ensures consensus and full disclosure of answering sub-question 4. This also applies for the relation between the building types and construction methods.

4.6 Questionnaire (II)

4.6.1 Questionnaire design

Questionnaire (II) was also designed using the free survey system of ThesisToolsPro. The questionnaire consists of three parts, starting in Part A with questions about the respondents' profile. Here the client type will be recalled. At the end of Part A respondents were asked to choose which of the six building types they mainly manage in their portfolio. In Part B, questions about the six factors related the construction methods derived from questionnaire (I) will be assessed. This will also be done using the FDM. A seven-point Likert scale is used to help the respondents determining the important level of the six factors per construction method. Lastly, in Part C, questions to respondents are asked whether they could rank the construction methods. In addition the association with the building type and the different construction methods will be asked to the respondents.

4.6.2 Data collection

The data collection was conducted similar to questionnaire (I). Only now 134 out of the 838 organizations could not be reached. From the 704 organizations that were successfully contacted, 12 organizations replied that they did not want to fill in questionnaire (II). Their

reasons were: "*On business meeting*", "*Being too busy*", *"Not the right target group"* or *"not participating in (student) research activities"*.

Questionnaire (II) included 176 respondents that filled in the questionnaire. However, 72 out of 176 respondents filled in the complete questionnaire. From a total target group of 692 clients, this translates itself in a response rate with useable results of 10 percent. The data was transferred from excel to SPSS. While viewing all the results of the respondents in SPSS, it was noticed that no "missing values" were found.

4.6.3 Results

Part A

Part A of questionnaire (II) was implemented to described the respondents' profile. Table 19 shows the results. Attributes one shows that 68 males and 4 females filled in de questionnaire. Attributes two shows that the age of the respondents who filled in questionnaire (II). Only respondents of 30 years and older filled in the questionnaire. The most respondents were between the age of 40 and 59 years old. The next attributes claims that a minority of 5 respondents have a MBO level of education. The largest group of respondents (44) have a HBO level of education and in-between, with 23 respondents, are the respondents with a university degree. Attribute four shows the work experience that respondents have. The higher the number of experience, the higher the number of respondents who filled in the questionnaire. Attribute five shows the type of organization who filled in questionnaire (II). 17 respondents are working at a governmental body, 12 respondents are working at a healthcare body, only 1 at an educational body, 26 at a housing corporation, 11 at a developer and 5 respondents are working at an investor. Attribute six describes the occupational level of respondents. The majority of the respondents is working in a managing position. Then there are 16 executives, zero planners and 6 other occupational levels. These 6 other occupational levels are having 4 different occupational functions: initiator, project leader, technical assessor and real estate developer. Attribute seven shows that respondents who filled in the questionnaire are located with their organizations in 10 out of 12 provinces in the Netherlands. Remarkable is that nobody is located in Zeeland nor Friesland. Attribute eight show the average project size of the respondents' organizations. Most respondents (41) filled in that their average project size is below the 10 million euro. Attribute nine show that 51 respondents mainly focus on *residential* type of buildings. 4 respondents mainly focus on *commercial* type of buildings and *infrastructure* and 13 respondents mainly focus on special type of buildings. Not a single respondent choose for the building types: *industrial* and *agricultural*.

Table 18 | Respondents' profile questionnaire (II)

Attributes	Sub-attributes	Response rate (number)	Percentage (%)
1. Gender	Male Female Gender neutral	68 4 -	94.4 5.6 -

2. Age	20-29 years 30-39 years 40-49 years 50-59 years ≥ 60 years	- 9 23 24 16	- 12.5 31.9 33.3 22.2
3. Education	Professional education (MBO) Higher professional education (HBO) University (WO) Other	5 44 23 -	6.9 61.1 31.9 -
4. Work experience	< 5 years 5-9 years 10-14 years 15-19 years 20-24 years ≥ 25 years	1 2 3 8 18 40	1.4 2.8 4.2 11.1 25 55.6
5. Type of organization	Governmental body Healthcare body Educational body Housing corporation Developer Investor	17 12 1 26 11 5	23.6 16.7 1.4 36.1 15.3 6.9
6. Occupational level	Managing board Manager Executive Consultancy Planner Other: - (1x) Initiator - (3x) Project leader - (1x) Technical assessor - (1x) Real estate developer	9 32 16 9 - 6	12.5 44.4 22.2 12.5 - 8.3
7. Province	Drenthe Flevoland Friesland Gelderland Groningen Limburg Noord-Brabant Noord-Holland Overijssel Utrecht Zeeland Zuid-Holland	3 3 - 12 5 3 2 11 12 12 - 9	4.2 4.2 - 16.7 6.9 4.2 2.8 15.3 16.7 16.7 - 12.5

8. Average project size	< 10 million euro	41	56.9
	10-19 million euro	10	13.9
	20-39 million euro	11	15.3
	40-59 million euro	1	1.4
	60-79 million euro	3	4.2
	80-99 million euro	1	1.4
	≥ 100 million euro	5	6.9
9. Building type	Residential	51	70.8
	Commercial	4	5.6
	Industrial	-	-
	Infrastructure	4	5.6
	Agricultural	-	-
	Specialty	13	18.1

Appendix G (*Chapter 7, paragraph 7.7.2*) contains a cross-tab table which shows the relation between the type of client and the building type, average project size and province.
In perspective of the governmental body, questionnaire (II) claims that their building type differentiates with 67 percent for *residential* and 33 percent for *specialty*. Their average project size is for 59 percent below the 10 million euro. Furthermore, the largest part of the governmental bodies (37 percent) are located in the eastern part of the Netherlands.

Only one respondent who is working for at an educational body filled questionnaire (II). Since the sample size is not large enough, this is considered not representative for this research. However this one respondent said they mainly focus on *commercial*, have an average project size below the 10 million euro and is located in *Overijssel*, which is in the eastern part of the Netherlands.

In perspective of the healthcare body, questionnaire (II) claims that their building type differentiates with 58 percent for *specialty* and 33 percent for *residential*. 67 percent of the healthcare bodies have an average project size of less than 10 million euro. In addition 17 percent lies between 10 – 19 million euro, 8 percent lies above the 100 million euro and others lie in between. Furthermore, the largest part of the educational bodies (67 percent) are located in the eastern part of the Netherlands.

In perspective of the housing corporations, all respondents (100 percent) mainly focus on having *residential* in their portfolio. The average project sizes vary a lot, however 54 percent of the housing corporations have an average project of less than 10 million euro. Furthermore, the largest part of the educational bodies (57 percent) are located in the western part of the Netherlands.

In perspective of the developer, questionnaire (II) claims that their building type exists of 64 percent *residential* and 27 percent *commercial*. The average project sizes vary a lot, however 56 percent of the developers have an average project of less than 10 million euro. In addition, 32 percent lies between the 10 – 19 million euro. Furthermore, the most developers (82 percent) are located in the western part of the Netherlands.

In perspective of the investor, questionnaire (II) claims that their building type exists of 80 percent *residential* and 20 percent is *specialty*. 60 percent of the developers claim to have an

average project size between 20 – 39 million euro. 20 percent of their average project size lies below the 10 million euro and 20 percent lies above the 100 million euro. Furthermore, the most investors (80 percent) are located in the western part of the Netherlands.

4.6.4 Chi-square goodness of fit test on the respondents' profile

Questionnaire (I) and (II) were held among the same target group and in both questionnaires Part A consists of the same demographic questions. Since the sample size differs and the respondents were all anonymous, it is interesting to see if there are differences in the results. In statistics it is common known that a confidence level is measured that performs a comparison at once over multiple data files with an overall measure of confidence. This makes the research scientific substantiated.

To perform a test like this, the chi-square goodness of fit test is used. The term goodness of fit is used to compare the observed sample distribution with the expected probability distribution. The difference is called *residual.* When the p-value (*A symp. Sig*) is below 5 percent, the null-hypothesis is rejected and the alternative-hypothesis is accepted. If the value is above 5 percent, the null-hypothesis is accepted. Here, the null-hypothesis means that there is no difference among the results. If the alternative-hypothesis will be accepted, it can be concluded that there is a difference in the results (Statistic solutions, 2019; Moore, Notz, & M.A. Fligner, 2012).

Results

As earlier mentioned, the chi-square goodness of fit test is used to compare the results on the respondents' profiles. In order to execute this test, the results of questionnaire (I): Part A, is used as a base for comparing the results with questionnaire (II): Part A. The results of the executed chi-square goodness of fit tests are listed in *Appendix G, section 7.7.3.* The p-values < 0.05 are coloured red. Table 18 shows the results on the chi-square goodness of fit test. The attributes in the first column are the attributes where no significant difference are measured in the results. This means that these attributes accept the null-hypothesis because the p-value is not statistically significant. The second column of the table shows the attributes where a significant difference has been found. This means that the alternative hypothesis is accepted and the p-value is statistically significant. The height of the difference is indicated by the *residual* number. These numbers can be found in the results listed in *Appendix G, section 7.7.3.*

Table 19 | Results chi-square goodness of fit test

Attributes		**Sub-attribute**
Null hypothesis accepted	**Alternative hypothesis accepted**	
Gender	Age	→ 30-39 years; ≥ 60 years
Level of education	Average project size	→ 20-39 million euro
Related work experience	Building type	→ Infrastructure
Type of organisation		
Occupational level		
Province		

Part B

In Part B of questionnaire (II) the six (underlying) factors (*costs, sustainability, flexibility, safety, quality, exploitation / operating (cost related)*) were rated on a seven-point Likert scale to determine the important level and see which of the critical factors are most important. Respondents had to rate the factors per construction method. Just like in questionnaire (I), a threshold of $\alpha = 0.7$ had been used. Figure 15abcd shows a diagram of the six factors rated per construction method. The orange bars shows the factors that are accepted and the blue bars shows the factors that are rejected. An overview of the total scores per construction method is included in Appendix G (*Chapter 7, paragraph 7.7.2*).

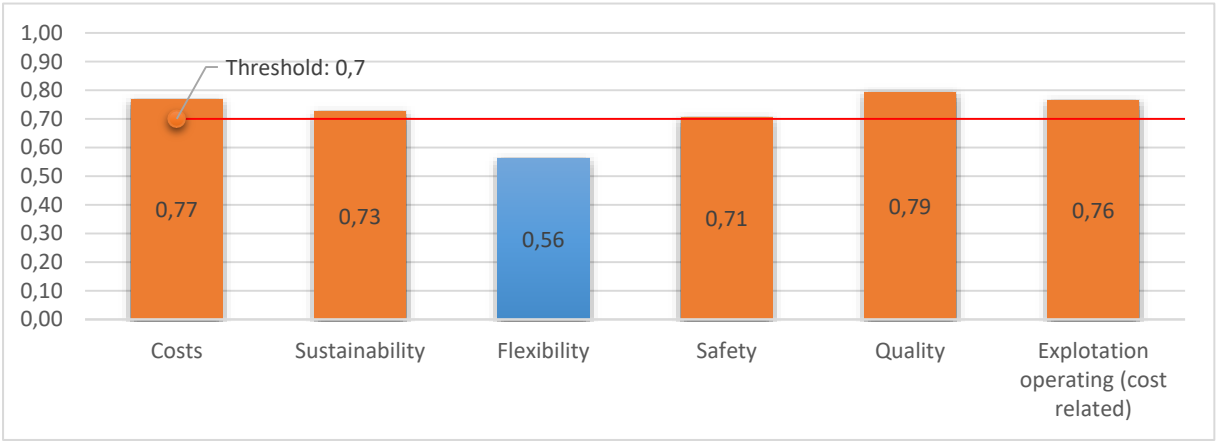

Figure 15a | Conventional construction method: Ranking the important levels for the factors

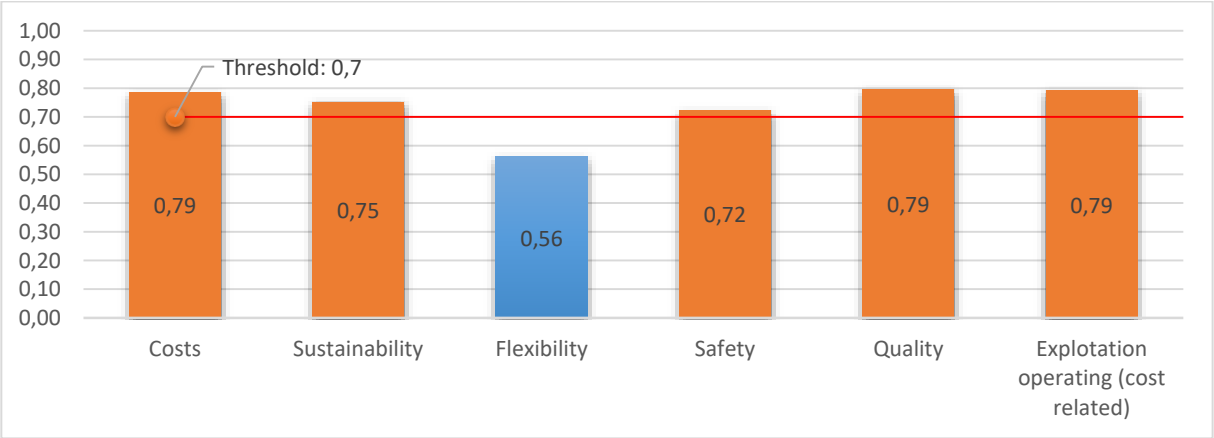

Figure 15b | Prefab construction method: Ranking the important levels for the factors

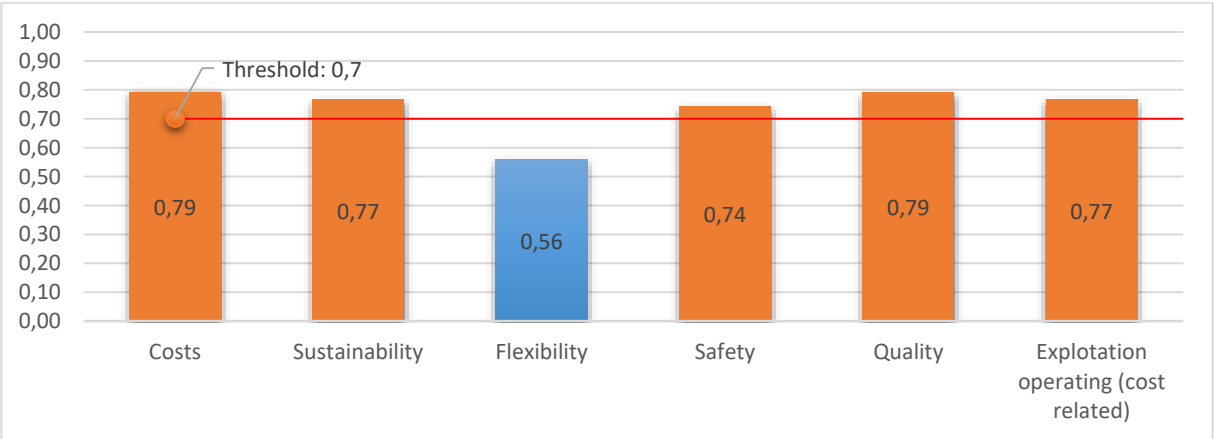

Figure 15c | Conceptual construction method: Ranking the important levels for the factors

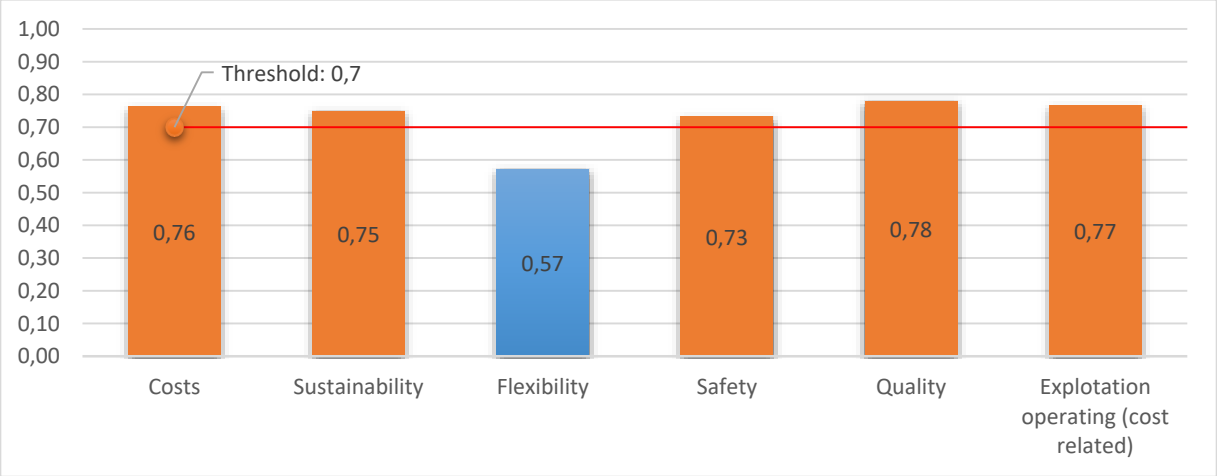

Figure 15d | Modular construction method: Ranking the important levels for the factors

Table 20 shows the accepted factors and their rank order. The values represent the average scores of the factors, regardless of the choice for the type of construction method. No.1 is seen as most important, whereby No. 5 is seen as least important. In other words; quality is seen as the most important critical factor and safety as the least important critical factor.

Table 20 | Rank accepted factors (single derived number α ≥ 0.70)

No.	**Factors**	**S_j = Crisp value**	Accepted / Rejected
1	Quality	0.79	Accepted
2	Costs	0.78	Accepted
3	Exploitation / operating (cost related)	0.77	Accepted
4	Sustainability	0.75	Accepted
5	Safety	0.73	Accepted

The next figure represents the scores of the factors in more detail. Here is shown that the preferred construction methods, based on the five remaining factors, are the prefab construction method and conceptual construction method. Thereafter the modular construction method is being preferred, whereas the conventional construction method is the least preferred construction method. In terms of the factors, the rank order stays the same except for the modular construction method. Here the factor *exploitation / operational (cost related)* is ranked second whereafter *costs* is ranked third.

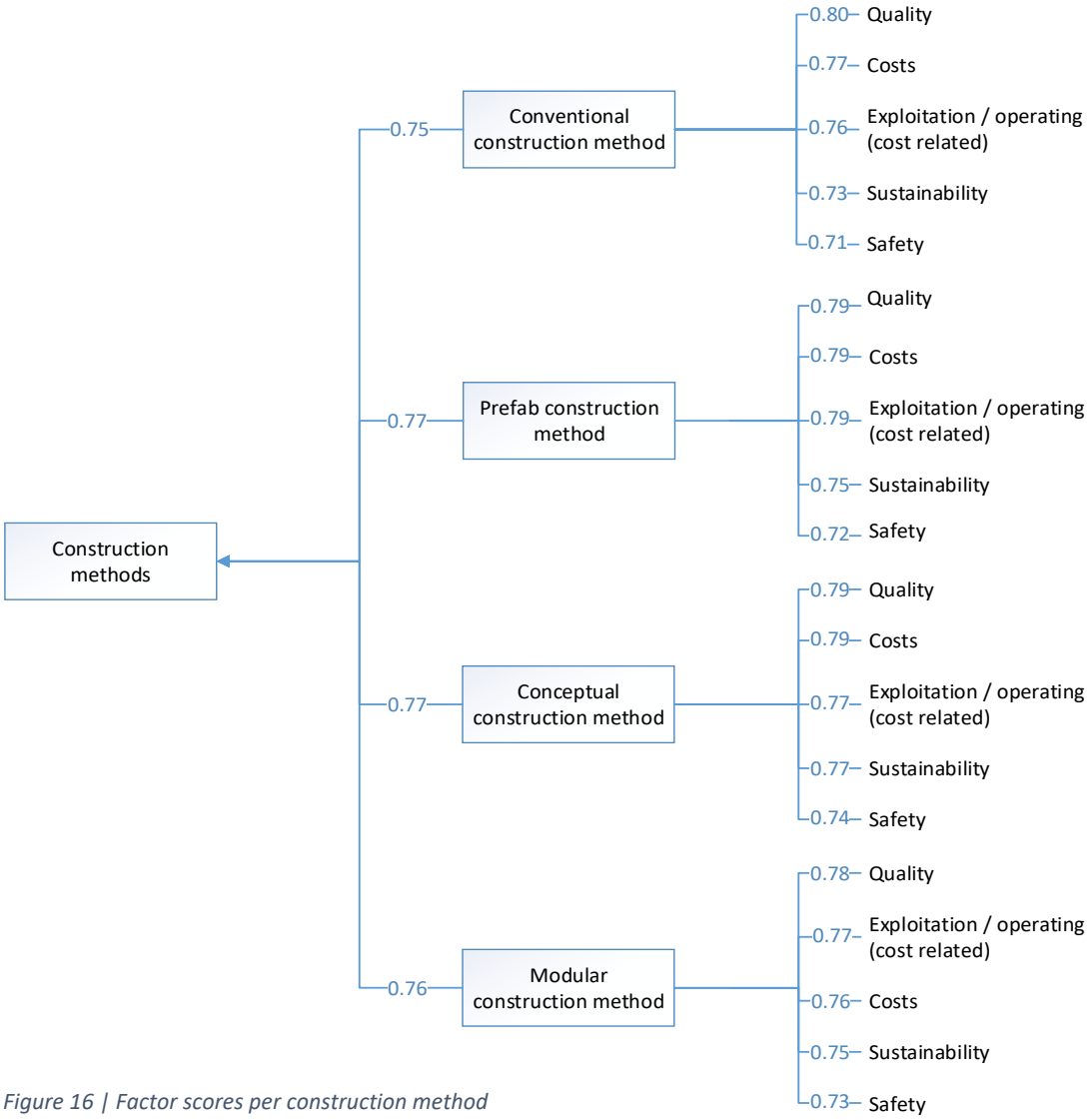

Figure 16 | Factor scores per construction method

Part C

In Part C of questionnaire (II) first the respondents were asked to rank the construction methods based on the building type the respondents have chosen in Part A, from position 1 of being most desired to position 4 of being least desired. Based on the four selected building types, figure 17abcd shows the rank order the respondents had made:

- Residential
  1. Conventional
  2. Prefab
  3. Conceptual
  4. Modular
- Specialty
  1. Conventional
  2. Prefab
  3. Modular
  4. Conceptual
- Commercial
  1. Conventional
  2. Prefab
  2. Conceptual
  4. Modular
- Infrastructure
  1. Conventional
  2. Prefab
  3. Conceptual
  3. Modular

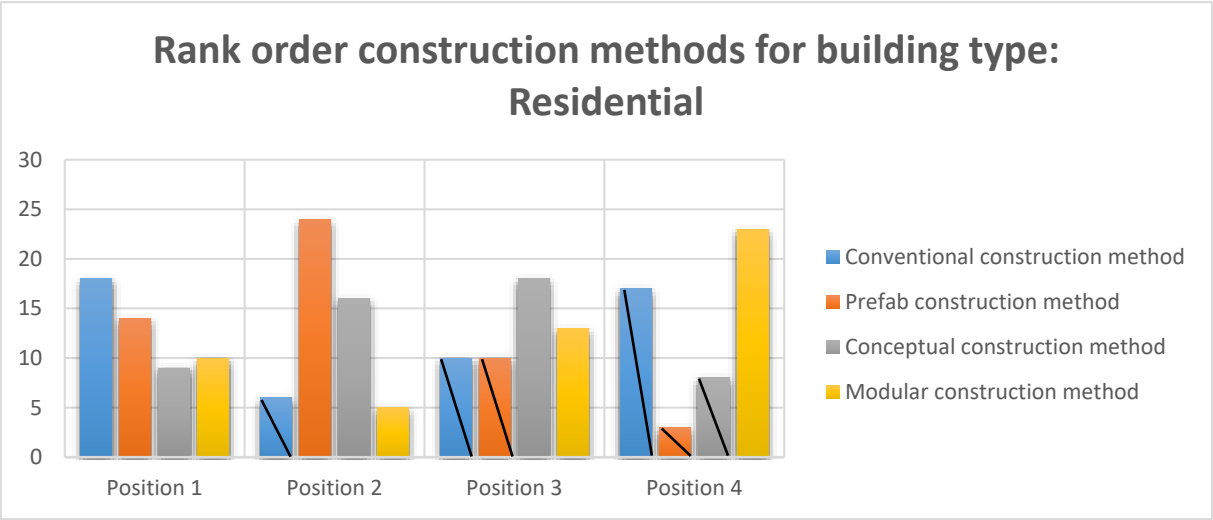

Figure 17a | Rank order for building types per construction method

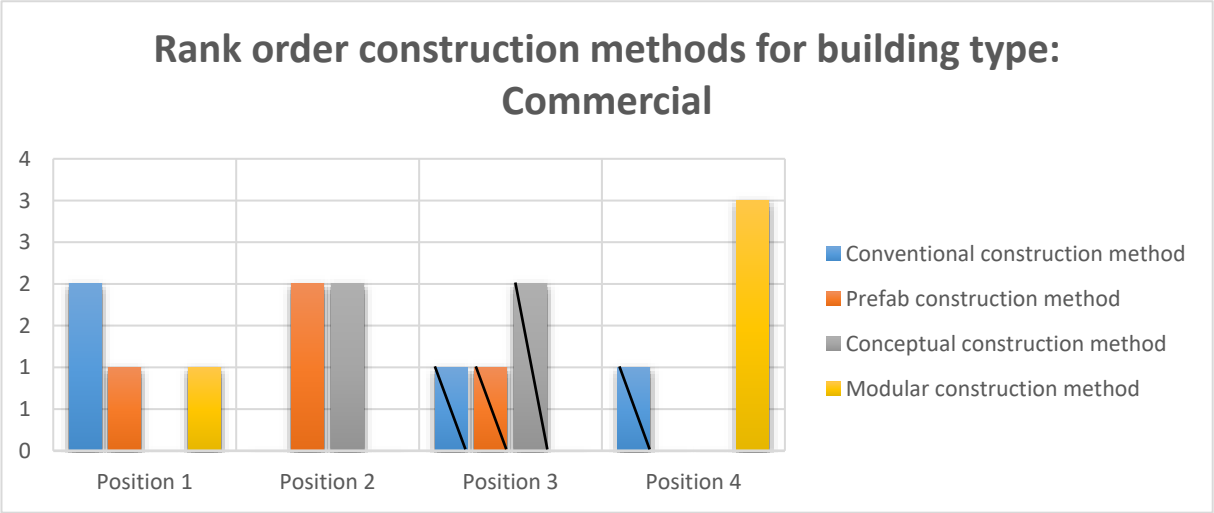

Figure 17b | Rank order for building types per construction method

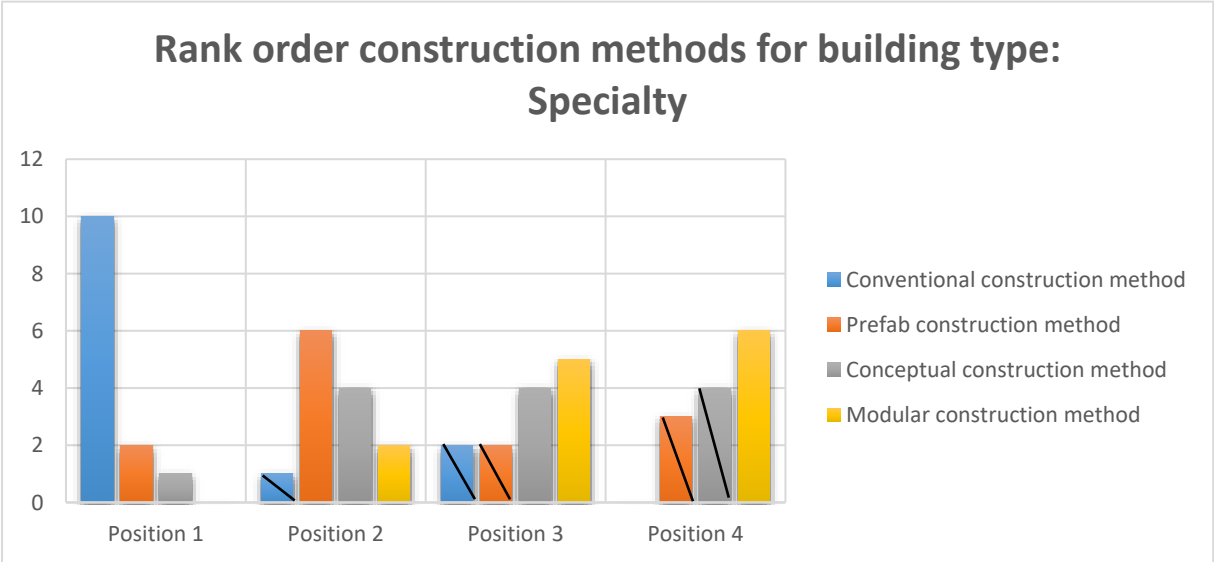

Figure 17c | Rank order for building types per construction method

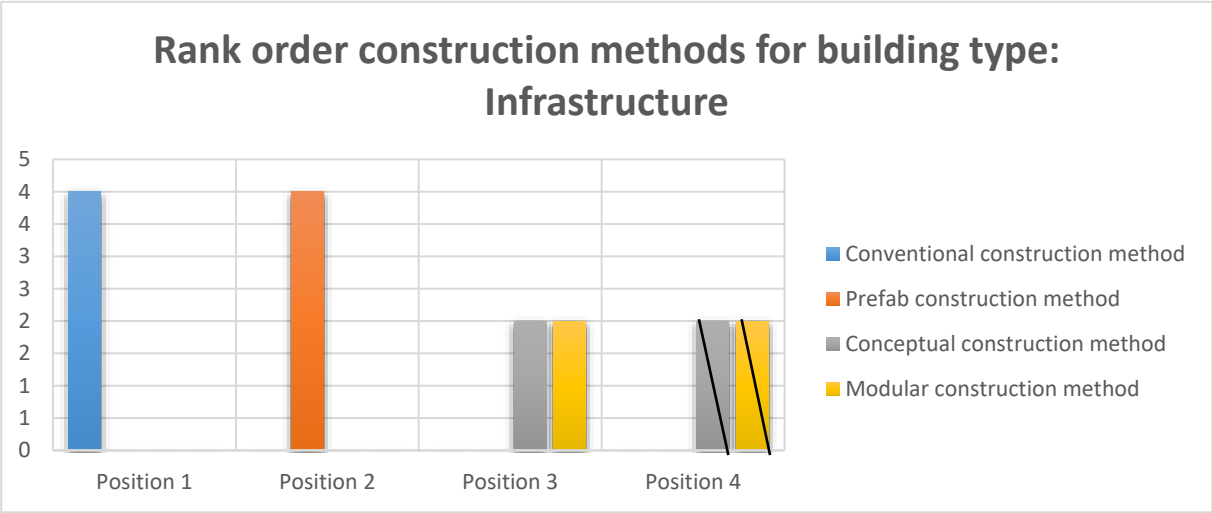

Figure 17d | Rank order for building types per construction method

Besides the question about ranking the construction methods per building type, also a question is phrased about which building type(s) fits best to the investigated construction methods. Table 21 shows that respondents who tend to choose for building type; *residential* with 65.3 percent, think that working with the prefab construction method fits best. In terms of developing a *commercial* building type, most respondents tend to work with modular closely followed by prefab. Respondents who want to work develop the building type; *specialty*, choose for working with conventional. According to respondents who are developing *industrial* buildings, often desire to work with the prefab construction method, closely followed by the modular construction method. Respondents think that building type; *agricultural* fits best with the prefab construction method. Lastly, respondents think that building type; *infrastructure* fits best with the conventional construction method. However the percentages for all construction method are low similar to each other, which indicates that *infrastructure* can be build using every construction method.

Table 21 | Cross-tab of building types with construction methods

Attribute	Construction method							
	Conventional construction method (number)	Average (%)	Prefab construction method (number)	Average (%)	Conceptual construction method (number)	Average (%)	Modular construction method (number)	Average (%)
Building type								
Residential	39	54,2	47	65,3	42	58,3	38	52,8
Commercial	18	25,0	27	37,5	23	31,9	28	38,9
Specialty	39	54,2	15	20,8	21	29,2	11	15,3
Industrial	11	15,3	28	38,9	19	26,4	27	37,5
Agricultural	7	9,7	24	33,3	9	12,5	19	26,4
Infrastructure	15	20,8	14	19,4	9	12,5	11	15,3

In as much as the connections between the clients, buildings, construction methods and factors are discussed in Part A and B of this chapter, a tree-diagram is made (figure 18). Results from questionnaire (I) and (II) shows the differentiation of response per client type: 21.6 percent of the respondents is a governmental body; 17.9 percent is a healthcare body; 5.5 percent is an educational body; 34.4 percent is a housing corporation; 16.5 percent is a developer; and 4.1 percent is an investor. Since figure 18 is barley readable, it only shows the

tree structure. For a detailed version of the tree structure it is recommend to see Appendix G (*Chapter 7, section 7.7.2)*. The branches from type of clients are divided in percentages, whereas the other branches represents the crisp values (S_j) calculated by the FDM.

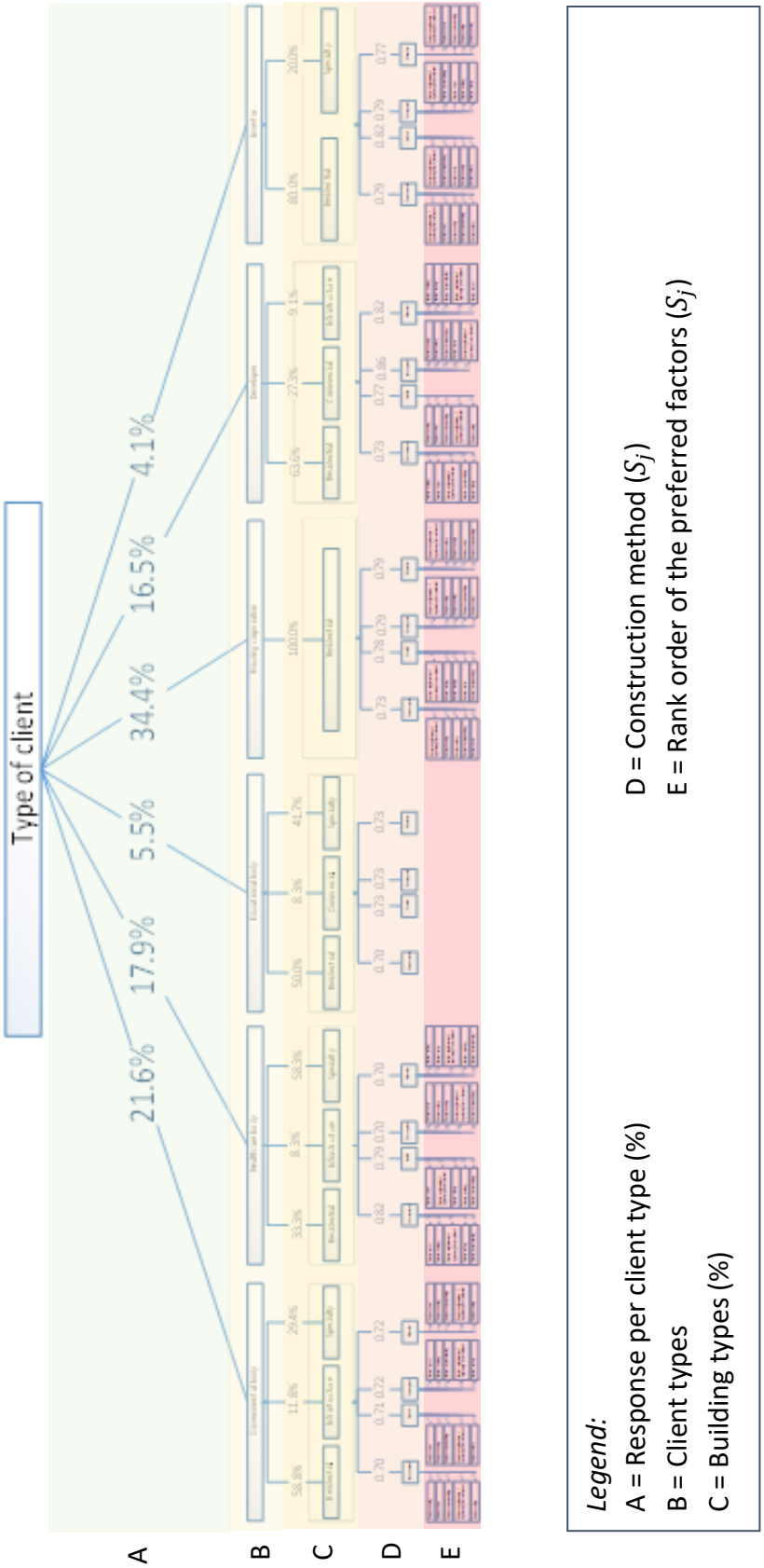

Figure 18 | Explanation of the tree diagram, choice based

The results of the tree-diagram shows that the governmental body mostly prefers *residential* building type. Thereafter this is *specialty* followed by *infrastructure* building types. The preferred construction methods for the governmental body are evenly distributed, with a slightly preference towards the conceptual and modular construction methods. For the conventional construction method *quality* is the most important critical factor and *safety* is the least important critical factor. For the conventional-, prefab- and modular construction method *costs* is the most important critical factor and *safety* is the least important critical factor.

The healthcare body prefers mostly *specialty* building types. Thereafter this is *residential* followed by *infrastructure* building types. The conventional construction method is the most preferred construction method and *costs* seems to be the most important critical factor. The least important critical factor seems to be *sustainability*.

The educational body prefers the *residential*- and *specialty* building types the most. The modular construction method seems to be the most preferred construction method. Since there was only one respondent that filled in questionnaire (II), it was not representative to show the preferred factors per construction method.

For the housing corporation it is clear that they prefer mostly *residential* building types. In particular they prefer to work with conceptual- and the modular construction methods. According to the housing corporation the least preferred construction method is the conventional construction method. The most important critical factor for the conceptual construction method seems to be *exploitation/operating (cost related)* and the least important critical factor seems to be the factor *costs*. The most important critical factor for the modular construction method seems to be *exploitation/operating (cost related)* and the least important critical factor seems to be the factor *sustainability*.

The developer mostly prefers the *residential* building type, followed by the *commercial* and *infrastructure* building types. The preferred construction method for the developer is the conceptual construction method. Here is *quality* the most important critical factor and *exploitation/operating (cost related)* the least important critical factor.

Lastly, the most preferred building type for the investor is the *residential* building type, followed by the *specialty* building type. The preferred construction method for the investor is the prefab construction method. Here *exploitation/operating (cost related)* is considered to be the most important critical factor and *safety* the least important critical factor.

4.7 Conclusion: questionnaire (II)

Questionnaire (II) was made to reveal the final preferred factors and reach consensus among the results from both questionnaires. Questionnaire (II) was conducted among the same target group, but had different sample size. The results from questionnaire (I) for revealing the preferred factors were used as input for questionnaire (II). So, results from questionnaire (I) showed that six factors (*quality, exploitation / operating (cost related), costs, sustainability, safety, flexibility*) claimed to be important since respondents gave the highest scores to these factors. The FDM was applied to analyse the results on the preferred factors of questionnaire

(II). With questionnaire (II) being applied, a final answer can be given to sub-question 4 – "In terms of the different construction methods, which factors do clients find important in realizing a project?".

Similar to questionnaire (I), questionnaire (II) was online for 14 days. This led to a response rate of 10 percent, translated to 72 respondents. The questionnaire was divided into three parts were in Part A the respondents' profile was framed. 94.4 percent of the respondents who filled in the questionnaire recalled themselves as male. The majority of the respondents were between the age of 40 and 59 years old. A lot of respondents are above the age of 40 and a majority of respondents have a work experience of 20 years or more. The governmental body, housing corporations, investors and developers mainly have *residential* building types in their portfolio. The healthcare body mainly has *specialty* building types in their portfolio. General 65 percent of the average project size of all the clients lay between < 10 – 19 million euro, except for they investor. They claim to have a higher average project size. Mostly this is between the 20 – 39 million euro and above the 100 million euro. Half of all clients (governmental body, educational body, healthcare body) are located in the eastern part of the Netherlands. The other half of the clients (housing corporations, developer, investor) are located in the western part of the Netherlands.

The results of the respondents' profiles in questionnaire (II) in comparison to questionnaire (I), were scientifically tested by the chi-square goodness of fit test. No significant differences were measured in the attributes; gender, level of education, related work experience, type of organisation, occupational level and province. However, in the attributes: *age*, *average project size* and *building type* there were some differences measured in the results. In the attribute *age*, significant differences are measured in the sub-attributes: *30-39 years* and *≥ 60 years*. For the attribute *average project size*, significant differences were measured in the sub-attribute *20-39 million euro*. Finally, for the attribute *building type*, significant differences were measured in the sub-attribute *infrastructure.* This is because infrastructure was mentioned in questionnaire (II), but not in questionnaire (I).

Part B of questionnaire (II) was made to indicate which of the six factors are important enough so that they can meet the threshold of α = 0.7. With the results of the second questionnaire, also a final rank towards the most important factors can be composed. Results using the FDM has led to five important critical factors that were accepted by the threshold:

Factors	**Crisp value (S_j)**
1. Quality	(0.79)
2. Costs	(0.78)
3. Exploitation / operating (cost related)	(0.77)
4. Sustainability	(0.75)
5. Safety	(0.73)

Flexibility had scored below the threshold of α = 0.7, which suggest that this factor is not important enough. The five remaining factors are subdivided per construction method and consists of different values. In terms of the conventional-, prefab- and conceptual construction

methods the factors are ranked as followed from 1 to 5: *quality, costs, exploitation / operating (cost related), sustainability, safety*. In terms of the modular construction method, the factors have a different rank order: *quality, exploitation / operating (cost related), costs, sustainability, safety.* Since the values of the factors are different per construction method, a rank order also exists in terms of preferred construction method. As the prefab- and the conceptual construction method scored the same, these are considered to be the most preferred construction methods to work with. Thereafter the modular construction method is the most preferred one, which is followed by the conventional construction method.

Part C of questionnaire (II) was created to indicate the relation between the construction methods, building types and type of clients. Results of Part C pointed out that the majority of respondents use the conventional construction method (54.2 percent) to realize a *specialty* and *residential* type of building. In case of using the prefab construction method (65.3 percent), conceptual construction method (58.3 percent) and modular construction method (52.8 percent) a majority of the respondents prefers to realize residential buildings with it.

After all the results of questionnaire (II) were analysed, a tree-diagram was made which shows the relation and preferred attributes among the client types, building types, construction methods and factors. Results of tree-diagram shows that the preferred construction methods of the governmental body are evenly distributed. The factors *costs* are considered to be highly important. The healthcare body prefers to work with the conventional construction method. Here also the factor *costs* is considered to be highly important. The educational body prefers to work with the prefab-, conceptual- and modular construction methods. The housing corporation prefers to work with the prefab-, conceptual- and modular construction methods. All three construction methods shows that the factor *exploitation / operating (cost related)* is the most important critical factor. For the developer the most preferred construction method is the conceptual construction method, followed by the modular construction method. Here the factor *quality* is the most important critical factor. In terms of the investor, prefab is the most preferred construction method. Here the factor *exploitation / operating (cost related)* is considered to be the most important critical factor.

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5. CONCLUSION

In the final chapter, the overall research findings of this thesis will be elaborated which leads to answering the main research question of this thesis. Next, the limitations about this thesis will be discussed. Thereafter, in paragraph 5.3, the scientific and practical relevance will be discussed. Lastly, in paragraph 5.4, the recommendations of this thesis for future research will be described.

5.1 Research findings

This thesis consists of qualitative research as well as quantitative research: valuable knowledge has been gathered by conducting an extended literature review, by client interviews and questionnaire rounds while making use of the FDM. The purpose of this thesis was to investigate and uncover all reviewed factors related to the construction methods that are applied in the Netherlands from the perspective of the client. In order to fulfil this purpose, it is important to know the clients' preferences of the factors that are related to the construction methods. This could help construction companies in their choice of using a particular construction method to realize a construction project. Working with the FDM discovered what the most important critical factors are.

In order to successfully complete the thesis, the following main research question must be answered:

Which (underlying) factors related to conventional-, prefabrication-, conceptual- or modular construction methods in the Netherlands, are of importance for construction companies when choosing a construction method in light of the clients' preferences?

The main research question consists of four sub-research questions, which were mentioned in paragraph 1.3, p. 5 and had been answered in every sub-conclusion of this thesis.

In the preparation phase on this research, a literature review was performed to get a clear sense of the knowledge gap in the literature. This has led to the research subject. Thereafter the definitions of the used construction methods in the Netherlands and factors derived from the use of the different construction methods were researched. This resulted in the following researched construction methods: The conventional construction method refers to a construction method that has a linear process of building and is labour intensive from the early design phase on the building site. The prefab construction method is the practise of creating building elements in a factory and assemble them on-site. The conceptual construction method is a method that uses a standardized way of construction a building by means of a standardized process. It is characterized by its dry-stacking principle and its parallel way of construction. In terms of the modular construction method, module sections are constructed at an off-site factory where only assembly will be done on-site. When the modules exit the factory, they are fully furnished and made install ready. The client types that were researched in the literature review of this thesis are as follows:

- Governmental body;
- Healthcare body;
- Educational body;
- Housing corporation;
- Developer;
- Investor.

After the literature review on the relevant factors was conducted, client interviews were conducted. These interviews were conducted to give a first indication of which factors, construction methods and building types the clients prefer; correspond with factors derived

from the literature review; why clients hold certain opinions about this research topic; and more importantly to gain information about new factors that are mentioned by clients that will be added to the already discovered factors, derived from the literature review. In total twenty-one factors related to the four construction methods were found.

The literature review and clients interviews served as input for the questionnaires. Both questionnaires consists of three parts: Part A was about the respondents' profile, Part B was about rating factors related to the construction methods according to the clients' preferences and Part C was about the relation of the building types and construction methods.

Results on both questionnaires about the respondents' profile were measured to ensure the confidence level of the asked attributes. This makes the research scientific substantiated. This was done with the chi-square goodness of fit test. This tests showed that in six out of nine attributes no differences in the results were measured. Three out of nine attributes were considered to be statistically significant, as there was a difference measured: Differences were measured in the attributes: *age, average project size* and *building types.*

Results on both questionnaires about rating the factors related to construction methods based upon the clients' preferences, were calculated using the FDM. In this research, results from questionnaire (I) were calculated by the FDM and used as input for the set-up of questionnaire (II). On its turn, the results from questionnaire (II) are also calculated by the FDM. The repeating process ensures consistency in answers and leads to consensus of the results. The remained factors from questionnaire (II) were calculated per construction method for each of the six clients. Together with the managed building types of the clients and their response rate on the questionnaires, a tree diagram has been formed (figure 19). For a detailed version of the tree structure it is recommend to see Appendix G (*Chapter 7, section 7.7.2)*.

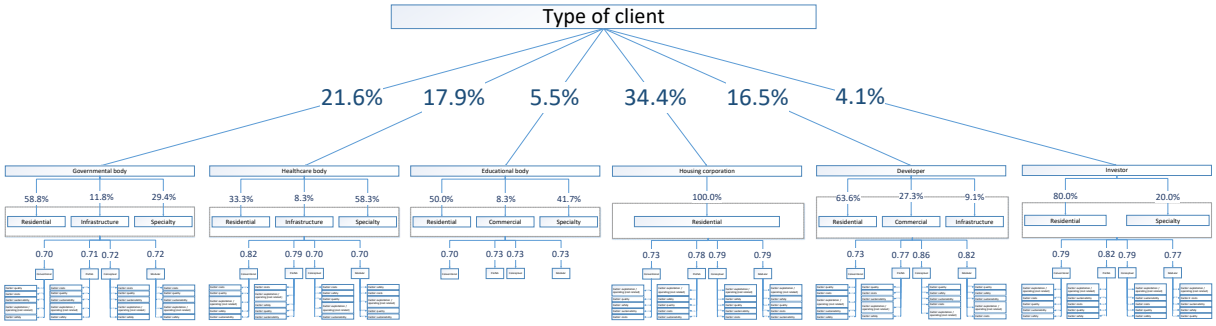

Figure 19 | Tree diagram, choice based

According to the tree diagram, most respondents who filled in both questionnaires came from the housing corporations. All respondents included the building type: *residential* in their portfolio. Besides the *residential* building type, the building types *commercial, specialty* and *infrastructure* were managed by the six client types. The clients who managed the *residential* building types the most, are the housing corporations. The prefab construction method and the conceptual construction method are both the most preferred construction methods. Thereafter this is the modular construction method, followed by the conventional construction method.

For the conventional-, prefab- and conceptual construction methods, the following important critical factors are ranked in sequential order: *1# quality, 2# costs, 3# exploitation / operating (cost related), 4# sustainability, 5# safety.* For the modular construction method counts that the same order will be applied, except that the factor *costs* is now ranked third and *exploitation / operating (cost related)* is ranked second. Figure 20 shows the process that had been gone through of Filtering the amount of factors. When all the crisp values of factors from questionnaire (II) – derived from the FDM calculation – are combined together, it gives the following ranked green list of most important critical factors. As should be noted: this is an overall view, the rank order differs per client type. Figure 20 gives an overall view.

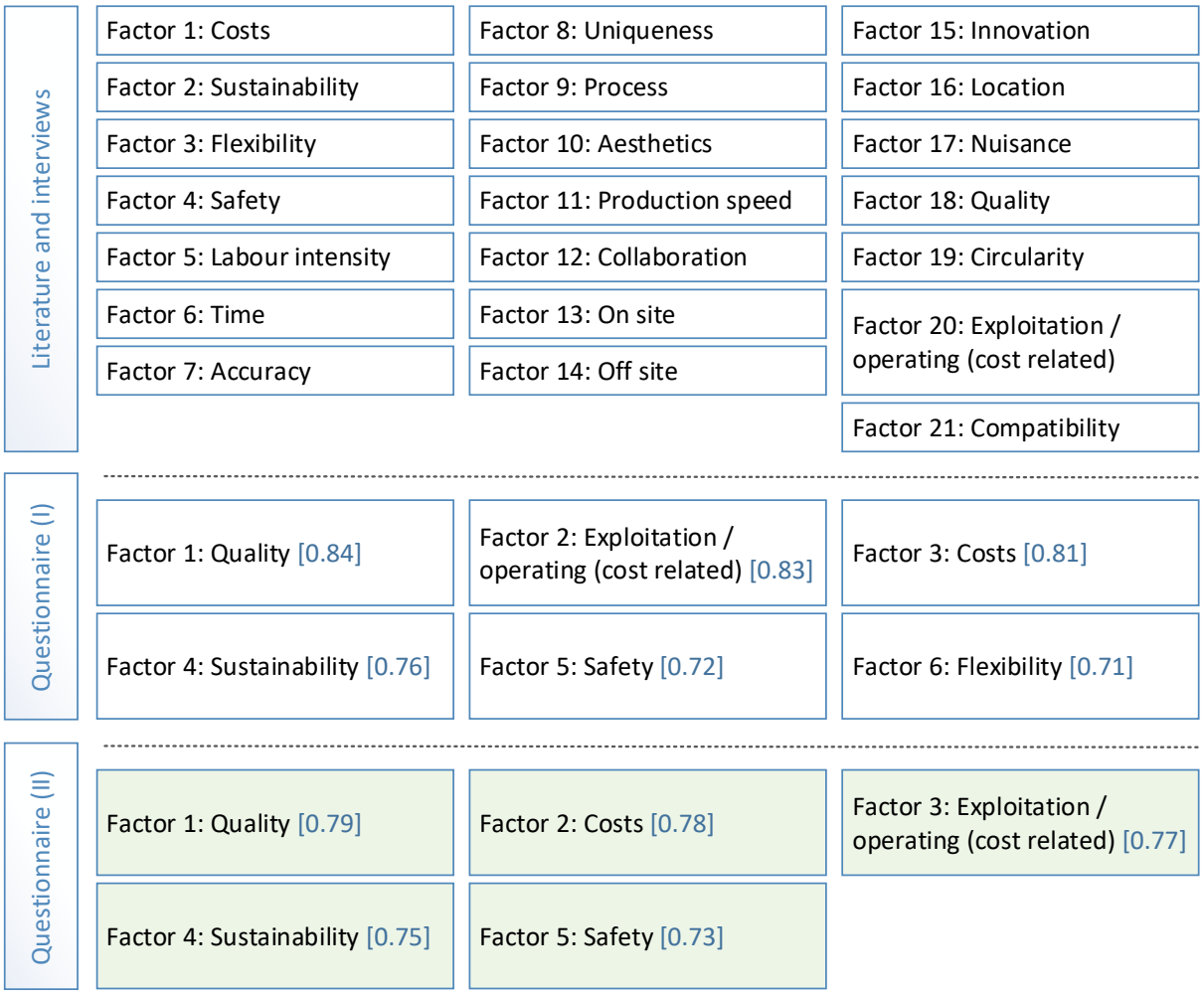

Figure 20 | Overview of the filtered factors

5.2 Research limitations

The first limitation of this graduation research lies in the difficulty of explaining the difference between the construction methods. The conceptual construction method can often be seen as a hybrid construction method and therefore it is hard to imagine for respondents and

interviewees which characteristics are included or excluded. To overcome and to ensure that there is no confusion, everything is defined as clearly as possible.
Feedback received from both the respondents that filled in the questionnaires and the interviewees, stated that they sometimes have little influence in choosing construction methods. During the interview it became clear that for instance the investor stood too far away from the process to exert influence on the construction method or some of its factors. This is also reflected in the low response rate by the group of investors that have completed the questionnaires. Consequently, this can be seen as the second limitation.

The research subject of this thesis has not been studied thoroughly in the Netherlands. Therefore, it is important to collect the right information about the factors that are linked to the construction methods. A literature review has been executed to emphasize the research problem, forming an inventory of the target groups, methodology and to find the various factors based on the various construction methods related to the clients' perspective. In addition to this, client interviews and questionnaires have been conducted in a (semi-) structured way on the basis of a general set of questions to identify the most important factors. To ensure the results are reliable and valid, it is important that the sample size is large enough to represent the population. A low response rate of the investors in both questionnaires and the educational body in questionnaire (II) led to a sample size that is not representative of how the opinions of those client types are formed. This could be due to the size of these two contacted target groups: they are considered to be the smallest target groups in this research (34 educational bodies, 89 investors) compared to the other target groups of clients (204 housing corporations, 124 healthcare bodies, 175 governmental bodies, 212 developers). Thus, the last limitation, a more common limitation in research, is that the sample size is not large enough to represent the population.

5.3 Relevance

5.3.1 Scientific relevance

In other literature the emphasis is on one or two construction methods at a time. An example of this is the thesis from J.T. Overbeeke (2013). Here the student compares opportunities for the realization of hospital real estate between working with the conventional construction method and the modular construction method (Overbeeke, 2013). Another example is the research of Kamali & Hewage (2017) which shows a comparison in the development of performance criteria for sustainability of conventional versus modular construction method (Kamali & Hewage, 2017). Besides comparison studies, a lot of articles are available in which the authors describe the advantages and disadvantages of one or more construction methods. For this reason, this thesis about studying the factors related to all used construction methods in perspective of the client within the Netherlands is relevant for the extension of the scientific knowledge.

Many international articles have identified various factors that were related to construction methods. However, neither international nor Dutch research exists as far as the

researcher knows on the topic of linking (underlying) factors from the perspective of the client with all four construction methods. This also accounts for the link towards the clients' perspective, because they are eventually the experts who grade the factors.

5.3.2 Societal relevance

This thesis specifically contributes to the insights of construction companies. The tree diagram in chapter 5 could serve as a tool that construction companies could use to identify the preferences of clients concerning the factors. Moreover, they could then decide which factors they should prioritise depending on the client. When they start working with new clients, the tree diagram gives an overview of which building type is preferred by a particular type of client. Depending on the factors and type of clients with their building type, the construction company has knowledge about the most preferred construction method. The service that the construction companies provide could therefore be more efficient and fit the clients' needs better. Thus, the insights of this research also benefit the clients.

In addition to this another contribution of this thesis concerns the government. *Quality, costs* and *exploitation / operating (costs related)* seem to be the most important critical factors that resulted out of both questionnaires. According to both questionnaires *sustainability* and *safety* also seems to be important, however less. Knowing the valuation of the preferred factors by the interviewees, could also serves as a valuable insight for the government. If they want to achieve the environmental targets, such as 49 percent fewer greenhouse gas emissions in 2030 compared to 1990 – they should put sustainability higher on the agenda of both the clients and construction companies.

5.4 Recommendations

According to Toshkov (2016), this thesis can be seen as an exploratory research, because no similar research is conducted before. Questionnaires are also commonly used in exploratory research. Research in this thesis has been conducted concerning the (underlying) factors related to the conventional-, prefab-, conceptual- and modular construction methods that are used in the Netherlands from the clients' perspective. Since the factors only are focused on the clients' perspective, further research can be done about other stakeholders in the building industry. It could be interesting to know how the composition of factors looks like for other stakeholders and which factors are important for them (Toshkov, 2016).

Another valuable perspective could be to broaden the horizon of the research by taking a more international approach. In addition to this, new construction methods could be interesting to explore. For instance, printing technologies as a construction method are becoming increasingly popular and it is very interesting to see what the possibilities compared to the existing construction methods are.

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7. APPENDIXES BOOK

The appendixes show information that is not essential for explaining the findings of this thesis, but supports the analysis in extended matters. Each Appendix is lettered separately from A, B, C, … onwards (Uni Learning, 2000).

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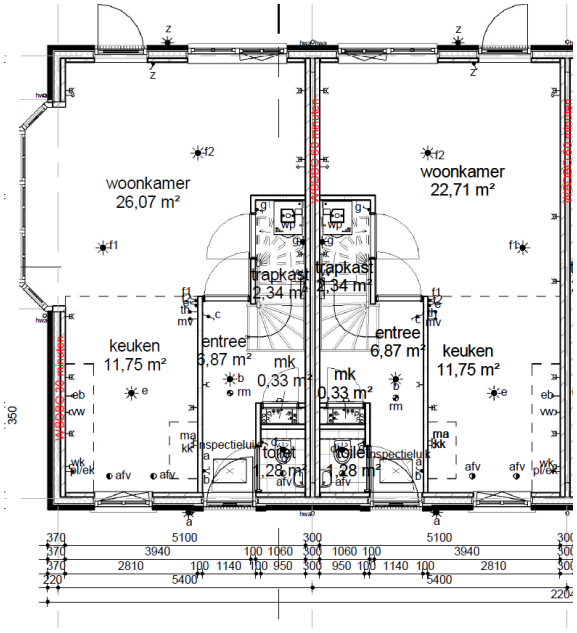
7.1 APPENDIX A: Conceptual construction method

7.1.1 Huisvanu Woningbouw (House of today – housing) structure

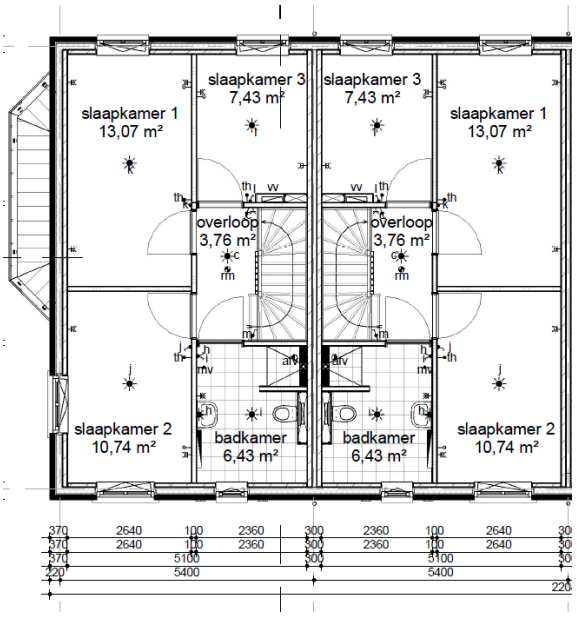
This method is widely used for the housing and utility construction. In term of *housing* the same structure is applicable every time: The foundation is laid precast and with pen and hole solutions junctures are connected together. Any deep junctures, fits and damages are poured in-situ. On top of the foundation a rib cassette floor will be placed which is prefabricated. The bearing walls are placed on the end-sides. Bathroom units are placed inside the building and the goal is to always give them same shape in the project. The finishing layers can be personalized (i.e. tiles). This unit also includes the installation cabinet. The non-bearing walls on the first and second floor are Ytong walls (= cellular concrete) of 1.2x2.6m and are glued together on site. Electrical points are made up-front in the Ytong walls. The end-walls of each house are made out of precast concrete and are called partition walls and form the span direction of the prefab hollow-core slab floors for the storey floors. The floors have standard sizes and the thickness of the floor is the same for every project. Houses within the conceptual construction method can have a flat roof or can have a pointed roof (i.e. saddle roof, shield roof, pent roof). No curved or extravagant roofs are used in the concept of Plegt-Vos. The roofs are also made prefab and have integrated skylights and can include holes for prefab dormers. Again the dormers are made prefab and are assembled on-site. Based on the standard reference house and apartment can within 16 weeks after the laying of the ground floor the work be completed.

7.1.2 Floorplans

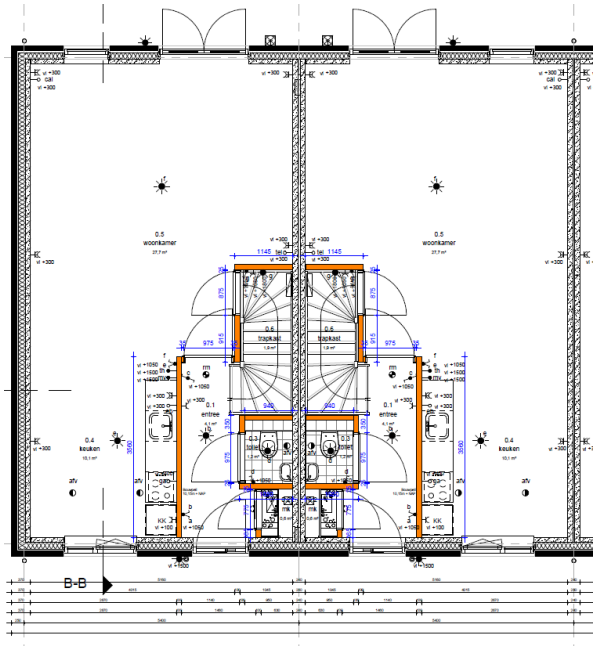
Here a number concept floor plans of getting access to the building and apartment floor plans are shown which represents the conceptual construction method.



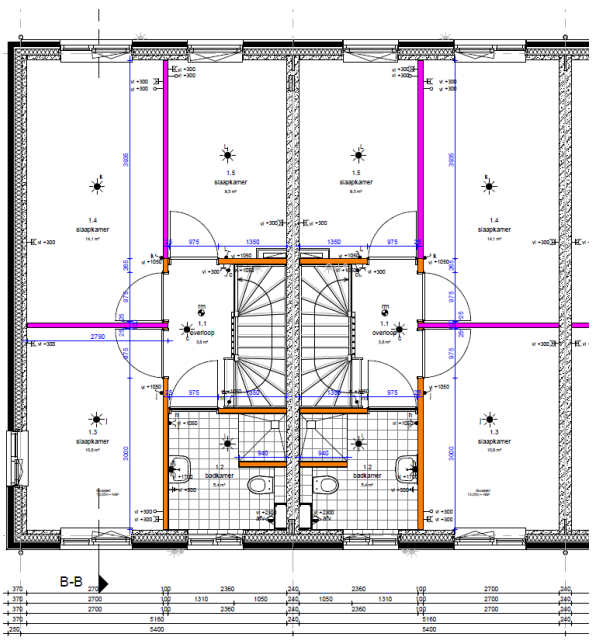
Ground floor (Project "Haarzicht")



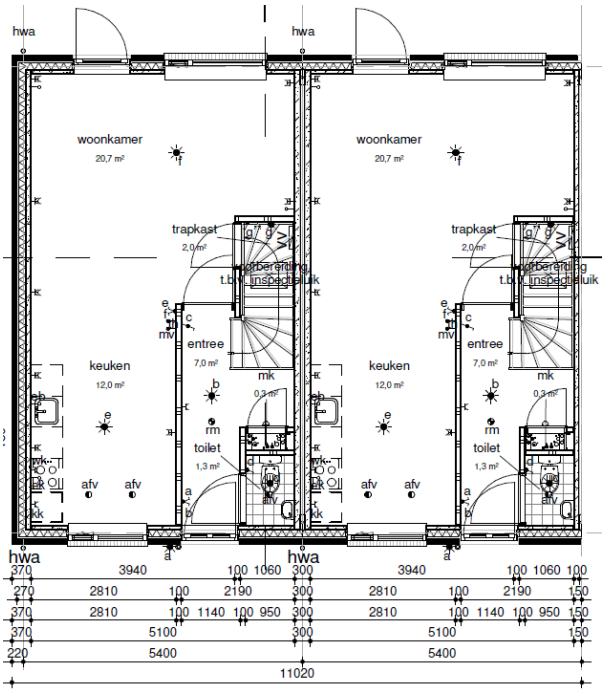
Second floor



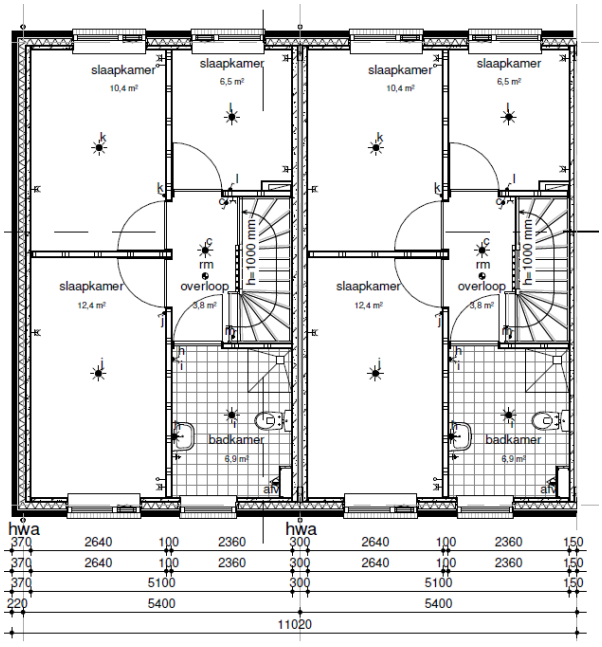
Ground floor (Project "Arnhem")



Second floor



Ground floor (Project "Oldenzaal")



Second floor

7.1.3 Huisvanu Appartementen (House of today – apartments) structure

Based on the concept of *Huisvanu Woningbouw* is the apartment version created. If necessary large foundation columns are hammered into the ground and the prefab foundation is made with pen and hole connection together. On the outer walls the foundation has a width of 500mm with a support width of 100mm. The foundation under the separation walls has a width of 400mm. After that the isolated hollow core slab is been made which always has a thickness of 380mm on the ground floor (120mm insulation + 260mm concrete). The isolated hollow core slab has a standard width of 1200mm and a maximum span of 9500mm. There where the installation and pipes are made in the floor, the floor will exist of a special floor called tap floor. This is a special hollow core slab floor but here the bottom plate is thicker and the channels are less big and more concentrated so that the floor still remains structurally strong. On top of floors a special insulated finishing floor will be poured to reduce nuisance. The end walls exist out of precast concrete with a thickness of 200mm and the partitioning walls exist out of 250mm concrete walls. The bathroom is a prefab unit and is hoisted in the right place of the apartment. It has its own floor and roof and is disconnected from the structure. The installation only needs to be connected. The base point is that the whole building has the same configuration of bathroom. The technical room is integrated in this unit. The height of the apartments is based on the first tolerance (draagweg). This means that working with the standard floor and wall dimensions of the concept can be done safely up to four elevations in the whole of The Netherlands. If the apartments needs to be higher a second tolerance (draagweg) needs to be added. However, this rule depends per municipality. Sometimes an apartment with one tolerance (draagweg) can have maximum of six elevations, but to make it generic for every municipality the maximum number of elevations has been set to four. The storey floor are made out of precast hollow slab floor AL320mm. Also here an insulated finishing floor is made on top of the structural floor. The façades are made in the factory and are wooden elements filled with insulation and a finishing layer depending on the choice of the customer. The base point for the construction to draw in Revit is 420mm because if you assume a thicker construction, it is much easier to make it slimmer not vice versa. The basepoint for the balcony is that there are four type of balconies that can offer any desired

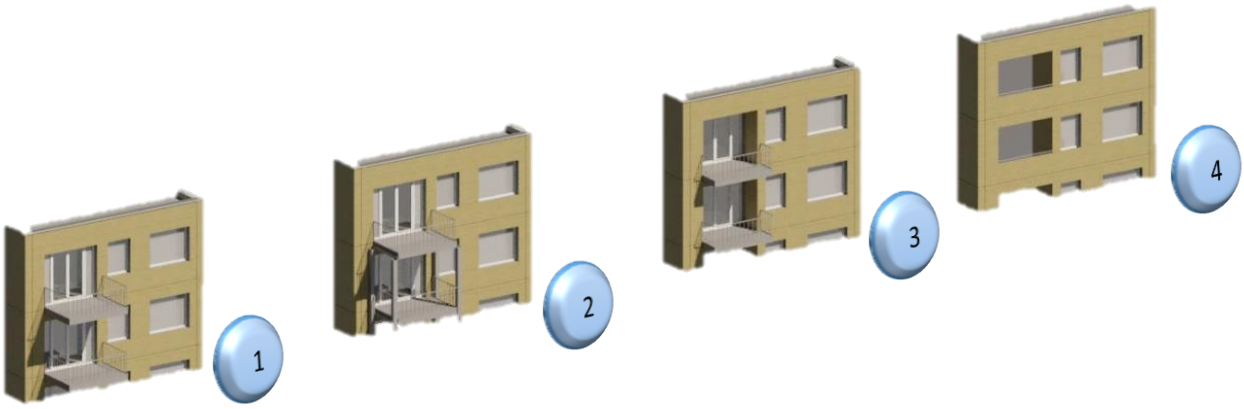


image.

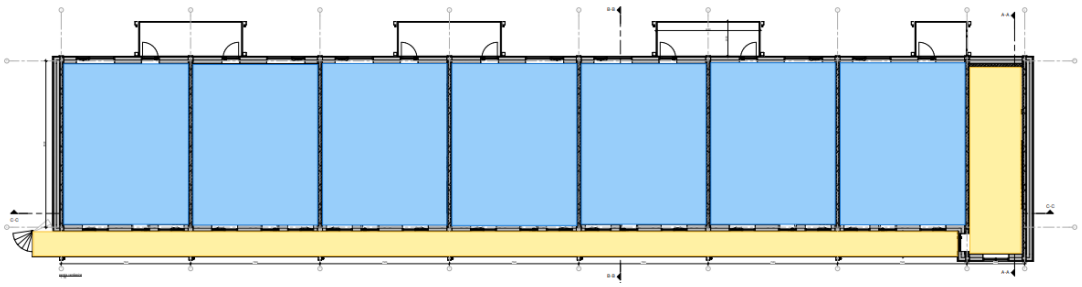
The first variant is a balcony which is self-supported and the second variant is a balcony with steel columns. The third variant is a balcony that is semi-immersed and the fourth balcony

variant has a loggia which is fully-immersed. The first variant must have a lightweight railing (i.e. glass, aluminium, etc.) and the rest can have any desired railing or coverage that is possible.

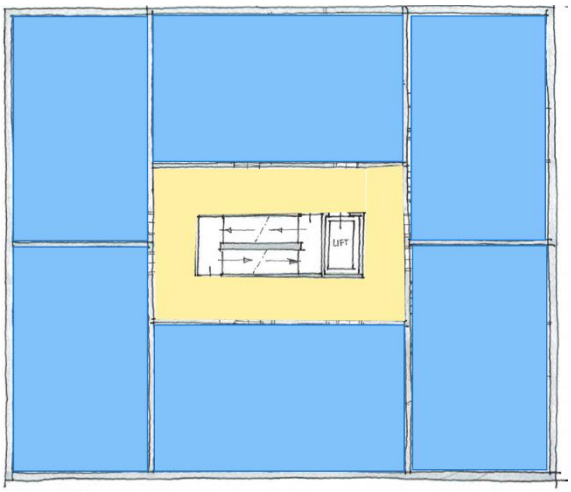
Installations within the apartment concept are considered flexible as there are various options to choose from to suit different wishes and sustainability ambitions. All installations within the concept are gasless. The basic configuration is based on individual air heat pumps with an outdoor unit on the roof. However, there are also possibilities for district heating, collective systems or for soil heat. The basic principle of the concept is that the large installation components are disconnected from the construction. This has the advantage that in the future the installation will remain flexible and adaptable if users' want to implement building changes.

7.1.4 Floorplans

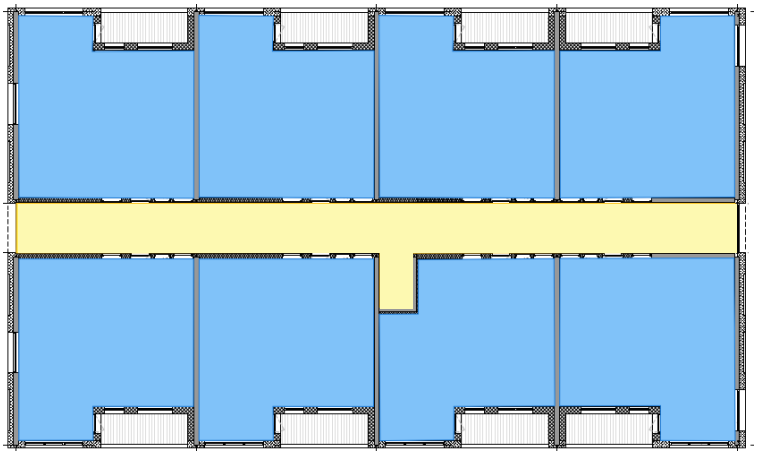
Here a number concept floor plans of getting access to the building and apartment floor plans are shown which represents the conceptual construction method.



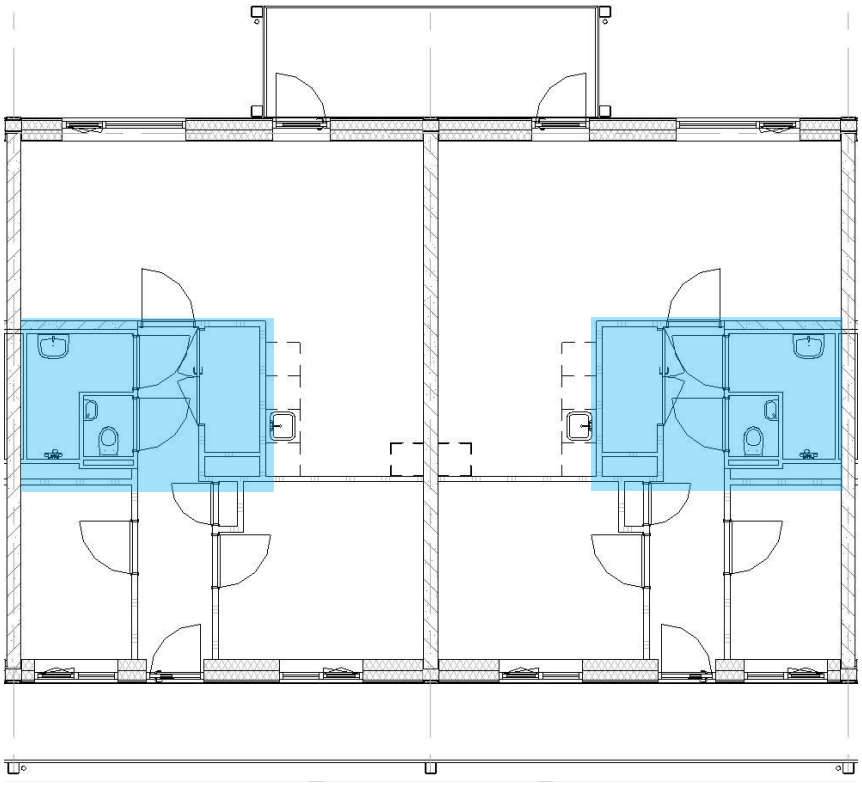
Concept gallery-access



Concept central-access

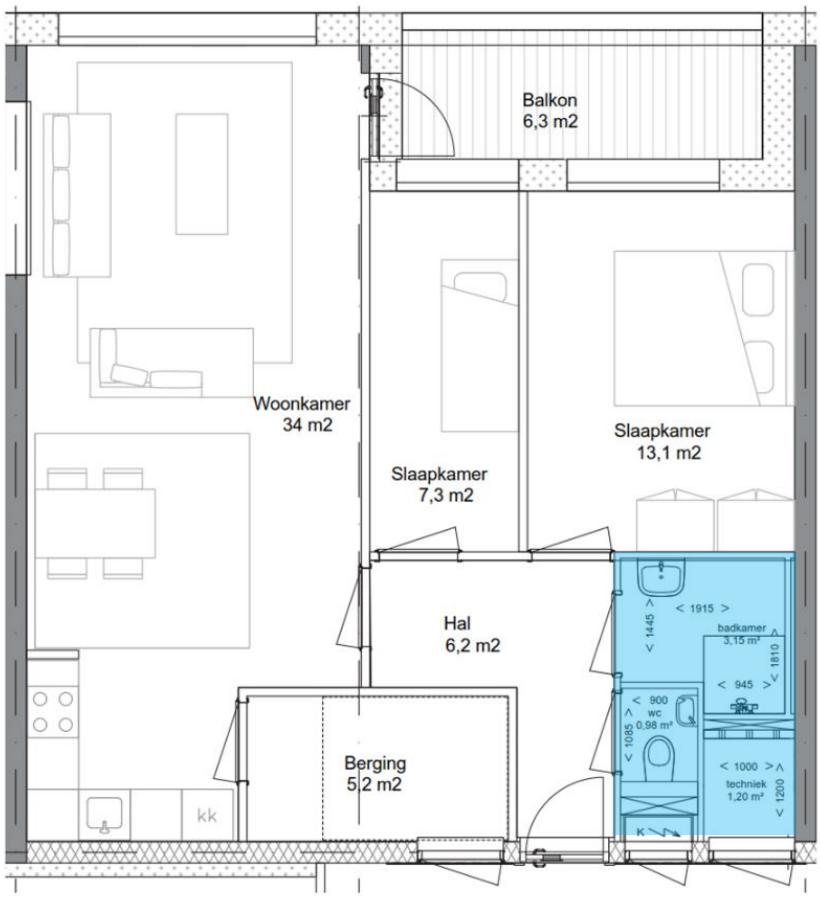


Concept corridor-access



Floorplan gallery-access (example 66m^2)

Floorplan portico/central-access (example 69m²)



Floorplan corridor-access (example 72m²)

7.2 APPENDIX B: Client longlist

Toelichting

Dit bestand bevat lijsten met instellingen die meegerekend zijn in de statistieken van de overheidsfinanciën voor verslagjaren 2016, 2017. Daarnaast is de klantenlijst van Plegt-Vos van anno 2019 hierin verwerkt.
Deze statistieken zijn op 22 juni 2018 op www.cbs.nl gepubliceerd.
De instellingen die op deze lijst staan zijn minimaal voor één kwartaal meegerekend in de statistieken van het verslagjaar.
Tabbladen 2016 en 2017 hebben identieke kolommen.
Jaarlijks wordt dit bestand geactualiseerd.

Datum deze publicatie

31 juli 2017

Contact

Indien u vragen heeft over deze lijst, dan kan dit via het volgende e-mailadres:
overheidsregister@cbs.nl

Disclaimer

Deze lijst is bedoeld voor statistische doeleinden, en heeft geen bestuurlijke of juridische consequenties voor de instellingen die op deze lijst staan.

Hieronder volgt een beschrijving van de kolommen.

Naam

Dit is de naam van de instelling.

Sector

Dit is de code van de subsector van de sector overheid waar de betreffende eenheid is ingedeeld volgens de richtlijnen van Het Europees systeem van nationale en regionale rekeningen 2010 (ESR2010).

Type of clients		Number
	Public Sector	**2258**
S.1311	Central government	337
S.1313	Local government	1916
S.1314	Social Security Funds	5
	Semi-public Sector	**2029**
S.1411	Educational bodies	1413
S.1412	Healthcare bodies	195
S.1413	Housing corporations	421
	Private Sector	**968**
S.1511	Educational bodies	n.b.
S.1512	Healthcare bodies	127
S.1513	Developers	389
S.1514	Investors	452

Total number of clients = 5255

SBI sectie

Dit is de Standaard Bedrijfsindeling 2008 (SBI 2008) 1 digit.
Meer informatie over de SBI 2008 is te vinden op de pagina:
SBI 2008.

SBI sectie omschrijving

Dit is een omschrijving van de SBI 1 digit.

SBI afdeling

Dit is de SBI 2 digits.

Input

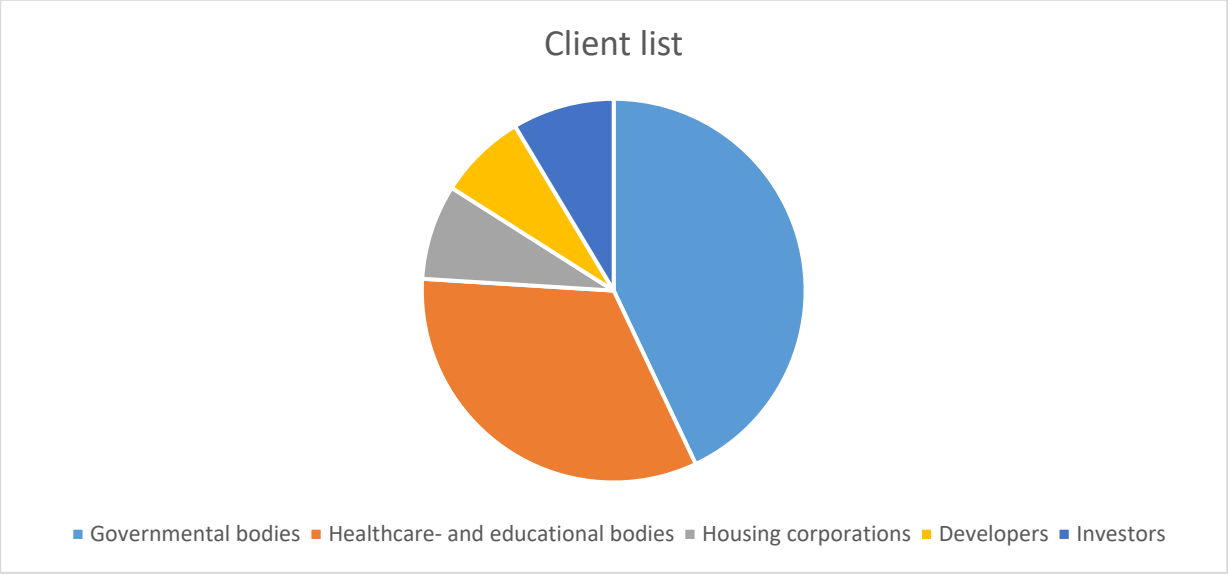
Een omschrijvingen van of deze opdrachtgever extern is of in het klantenbestand van Plegt-Vos staat.

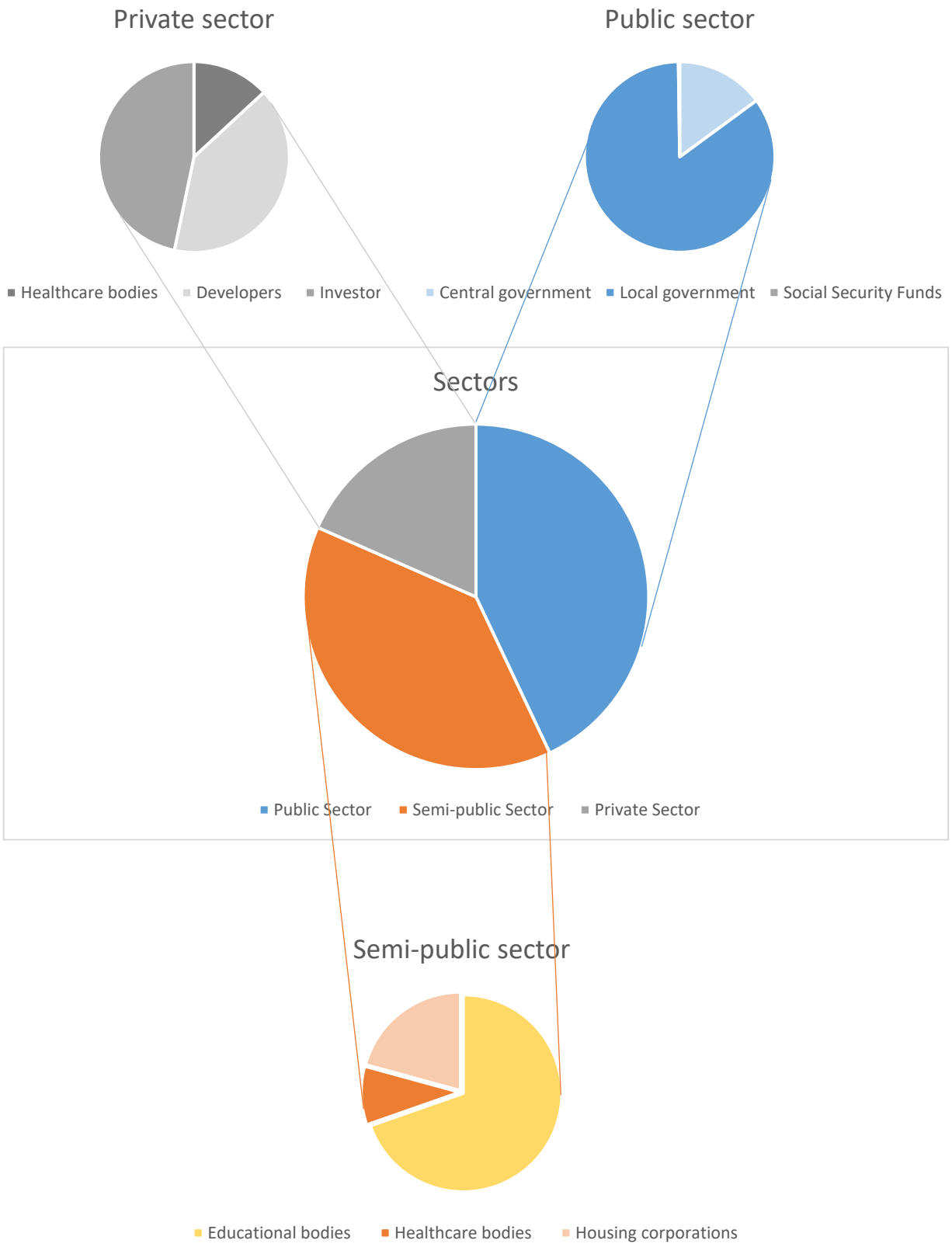
Sub input

Onderverdeling van de sectoren

Top 5 totaal aantal opdrachtgevers

Governmental bodies	2258
Healthcare- and educational bodies	1735
Housing corporations	421
Developers	389
Investors	452




Private sector
Public sector
Healthcare bodies
Developers
Investor
Central government
Local government
Social Security Funds
Sectors
Public Sector
Semi-public Sector
Private Sector
Semi-public sector
Educational bodies
Healthcare bodies
Housing corporations

Naam	Sector	SBI sectie omschrijving	SBI afdeling	Input	Sub-input
APPLIED NANOSYSTEMS B.V.	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
STICHTING AANPAK FINANCIEEL-ECONOMISCHE CRIMINALITEIT IN NEDERLAND (SAFECIN)	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
STICHTING ADVISERING BESTUURSRECHTSPRAAK VOOR MILIEU EN RUIMTELIJKE ORDENING	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
STICHTING ENTERPRISES ACCOUNTING	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
STICHTING FONDSBEHEER DGGF LOKAAL MKB	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
STICHTING HET JURIDISCH LOKET	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
STICHTING SKAL	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
TRAJECTUM PHARMA B.V.	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	69	Extern	Publieke sector
ACTA HOLDING B.V.	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	70	Extern	Publieke sector
B.V. TOPSELECT	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	70	Extern	Publieke sector
CELLAGENICS B.V.	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	70	Extern	Publieke sector
DUTCH RESEARCH INSTITUTE FOR TRANSITIONS B.V.	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	70	Extern	Publieke sector
ERASMUS CENTRE FOR ENTREPRENEURSHIP B.V.	S.1311	ADVISERING, ONDERZOEK EN OverheidSPECIALISTISCHE ZAKELIJKE DIENSTVERLENING	70	Extern	Publieke sector
↓	↓	↓	↓	↓	↓
GEM PRESIDENT C.V.	S.1313	BOUWNIJVERHEID	41	Extern	Publieke sector
GEM RIJNHOEK B.V.	S.1313	BOUWNIJVERHEID	41	Extern	Publieke sector
GEM WESTERAAM ELST C.V.	S.1313	BOUWNIJVERHEID	41	Extern	Publieke sector
GR BLEIZO	S.1313	BOUWNIJVERHEID	41	Extern	Publieke sector
IBA PARKSTAD B.V.	S.1313	BOUWNIJVERHEID	41	Extern	Publieke sector
ONTWIKKELINGSMAATSCHAPPIJ HATTEMERBROEK B.V.	S.1313	BOUWNIJVERHEID	41	Extern	Publieke sector
Stichting Universitaire Woonwijk Boerhaave	S.1411	Onderwijs	97	Plegt-Vos	Semi-publieke sector
Twents Carmel College	S.1411	Onderwijs	97	Plegt-Vos	Semi-publieke sector
Universiteit Twente	S.1411	Onderwijs	97	Plegt-Vos	Semi-publieke sector
Vastgoedbedrijf Universiteit Leiden	S.1411	Onderwijs	97	Plegt-Vos	Semi-publieke sector
Wageningen University & Research	S.1411	Onderwijs	97	Plegt-Vos	Semi-publieke sector
Wageningen UR	S.1411	Onderwijs	97	Plegt-Vos	Semi-publieke sector
Wittenborg	S.1411	Onderwijs	97	Plegt-Vos	Semi-publieke sector
ACIS STICHTING VOOR OPENBAAR PRIMAIR ONDERWIJS HOEKSCHE WAARD	S.1411	Onderwijs	97	Extern	Semi-publieke sector
AERES B.V.	S.1411	Onderwijs	97	Extern	Semi-publieke sector
AGORA, STICHTING VOOR BIJZONDER PRIMAIR ONDERWIJS IN DE ZAANSTREEK	S.1411	Onderwijs	97	Extern	Semi-publieke sector
AIRCRAFT MAINTENANCE & TRAINING SCHOOL B.V.	S.1411	Onderwijs	97	Extern	Semi-publieke sector
ALLURE, STICHTING VOOR OPENBAAR PRIMAIR ONDERWIJS	S.1411	Onderwijs	97	Extern	Semi-publieke sector
ALMEERSE SCHOLEN GROEP (ASG) STICHTING VOOR OPENBAAR PRIMAIR ONDERWIJS, NIEUWE WIJKEN	S.1411	Onderwijs	97	Extern	Semi-publieke sector
↓	↓	↓	↓	↓	↓

STICHTING REGIOPLUS ARBEIDSMARKT ZORG EN WELZIJN	S.1412	Zorg	98	Extern	Semi-publieke sector
STICHTING SBOH	S.1412	Zorg	98	Extern	Semi-publieke sector
STICHTING TRIMBOS-INSTITUUT, NETHERLANDS INSTITUTE OF MENTAL HEALTH AND ADDICTION	S.1412	Zorg	98	Extern	Semi-publieke sector
STICHTING VO SAMENWERKINGSVERBAND AMSTELLAND EN DE MEERLANDEN	S.1412	Zorg	98	Extern	Semi-publieke sector
Stichting Warande	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
THE MAASTRICHT FORENSIC INSTITUTE B.V.	S.1412	Zorg	98	Extern	Semi-publieke sector
UVA B.V.	S.1412	Zorg	98	Extern	Semi-publieke sector
WERKIDEE B.V.	S.1412	Zorg	98	Extern	Semi-publieke sector
WERKSTROOM B.V.	S.1412	Zorg	98	Extern	Semi-publieke sector
WILLIAM SCHRIKKER STICHTING ZORG & WONEN	S.1412	Zorg	98	Extern	Semi-publieke sector
Abrona	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Accare	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Aedis Actiz	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Agis Zorgkantoren	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Alliade Zorggroep	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Ambiq	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Ariens Zorgpalet	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Attent Wonen Welzijn Zorg	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Aveleijn SDT	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
AxionContinu	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Baalderborggroep	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Bart Haarman	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
Bartholomeus Gasthuis	S.1412	Zorg	98	Plegt-Vos	Semi-publieke sector
WoonWijkVereniging De Volharding	S.1413	Corporaties	99	Extern	Semi-publieke sector
Woonwijze	S.1413	Corporaties	99	Extern	Semi-publieke sector
Woonzorg Nederland	S.1413	Corporaties	99	Plegt-Vos	Semi-publieke sector
Wormerwonen	S.1413	Corporaties	99	Extern	Semi-publieke sector
WSG	S.1413	Corporaties	99	Extern	Semi-publieke sector
Zaam Wonen	S.1413	Corporaties	99	Extern	Semi-publieke sector
Zayaz	S.1413	Corporaties	99	Extern	Semi-publieke sector
Zeeuwland	S.1413	Corporaties	99	Extern	Semi-publieke sector
Zorggroep Meander	S.1413	Corporaties	99	Extern	Semi-publieke sector
Zowonen	S.1413	Corporaties	99	Extern	Semi-publieke sector
Aantal onbekend	S.1511	Onderwijs	100	Extern	Private sector
Accolade Zorg	S.1512	Zorg	101	Plegt-Vos	Private sector
Aliantus Oud Seyst	S.1512	Zorg	101	Extern	Private sector
Altenastaete Nieuwendijk	S.1512	Zorg	101	Extern	Private sector
Balanszorg	S.1512	Zorg	101	Extern	Private sector
Ben Oude NijHuis	S.1512	Zorg	101	Extern	Private sector
Berghse Haven	S.1512	Zorg	101	Extern	Private sector
Beweging 3.0, Zorgerf Buiten-verblijf	S.1512	Zorg	101	Extern	Private sector
Boeijend Huys	S.1512	Zorg	101	Extern	Private sector
Bos-enmeerzicht	S.1512	Zorg	101	Extern	Private sector
Buyten Haven	S.1512	Zorg	101	Extern	Private sector
Care Residence Zonnestraal	S.1512	Zorg	101	Extern	Private sector
Claris Zorgvilla Wassenaar	S.1512	Zorg	101	Extern	Private sector
Compartijn - [6]	S.1512	Zorg	101	Extern	Private sector
Crataegus Woonzorg	S.1512	Zorg	101	Extern	Private sector
Dagelijks Leven - [34]	S.1512	Zorg	101	Extern	Private sector
De Eemhorst, Particulier verpleeg- en verzorgingshuis voor de	S.1512	Zorg	101	Extern	Private sector
De Gouden Leeuw Groep 2	S.1512	Zorg	101	Extern	Private sector
De Leeuwenhof Zorg	S.1512	Zorg	101	Extern	Private sector
↓	↓	↓	↓	↓	↓
3W real estate	S.1513	Ontwikkelaars	102	Extern	Private sector
Aalberts Ontwikkeling BV	S.1513	Ontwikkelaars	102	Extern	Private sector
ABB Ontwikkeling B.V.	S.1513	Ontwikkelaars	102	Extern	Private sector
ABN AMRO Bank N.V	S.1513	Ontwikkelaars	102	Extern	Private sector
Ahold Europe Real Estate & Construction B.V	S.1513	Ontwikkelaars	102	Extern	Private sector
Altera Vastgoed NV	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
AM	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
Amvest Management BV	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
ARCUS COLLEGE HOLDING B.V.	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
ASR Vastgoed Projecten B.V.	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
Ballast-Nedam, Stg. Pensioenfonds	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
Bemog Projektontwikkeling B.V.	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
Blauwhoed	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
Boelens de Gruyter	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
Borghese Real Estate B.V.	S.1513	Ontwikkelaars	102	Plegt-Vos	Private sector
Bouwbedrijf M.J. de Nijs en Zn B.V.	S.1513	Ontwikkelaars	102	Extern	Private sector
Bouwinvest Real Estate Investors	S.1513	Ontwikkelaars	102	Extern	Private sector
↓	↓	↓	↓	↓	↓

Hooghenraed Levensverzekeringen N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
DELA Natura- en levensverzekeringen N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
Nationale-Nederlanden Levensverzekering Maatschappij N.V	S.1514	INVESTORS	103	Extern	Levens verzekering
Allianz Nederland Levensverzekering N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
Klaverblad Levensverzekering N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
BNP Paribas Cardif Levensverzekeringen N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
Delta Lloyd Levensverzekering N.V.	S.1514	INVESTORS	103	Plegt-Vos	Levens verzekering
ASR Levensverzekering N.V.	S.1514	INVESTORS	103	Plegt-Vos	Levens verzekering
Goudse Levensverzekeringen N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
AEGON Levensverzekering N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
Achmea Pensioen- en Levensverzekeringen N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
Brand New Day Levensverzekeringen N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
Generali levensverzekering maatschappij N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
ABN AMRO Levensverzekering N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
SRLEV N.V.	S.1514	INVESTORS	103	Extern	Levens verzekering
↓	↓	↓	↓	↓	↓
Abbott Nederland, Stg. Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
ABN AMRO BankN.V.	S.1514	Investeerders	103	Extern	Private sector
ABP	S.1514	Investeerders	103	Extern	Private sector
AC Nielsen, Stg. Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
Ace Holland Management	S.1514	Investeerders	103	Plegt-Vos	Private sector
Achmea, Stg. Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
Actua Schadeverzekering N.V.	S.1514	Investeerders	103	Extern	Private sector
AEGON Levensverzekering N.V.	S.1514	Investeerders	103	Extern	Private sector
Ahold, Stg. Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
AKZO Nobel Assurantie N.V.	S.1514	Investeerders	103	Extern	Private sector
Aldi (Vastgoed) Zoetermeer BV	S.1514	Investeerders	103	Plegt-Vos	Private sector
Algemene Friese Onderlinge Schadeverzekeringsmaatschapp	S.1514	Investeerders	103	Extern	Private sector
Alliance, Stg. Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
Allianz Nederland, Stg. Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
↓	↓	↓	↓	↓	↓
Corio Vastgoed Ontwikkeling B.V.	S.1514	Investeerders	103	Plegt-Vos	Private sector
Croda, Stg. Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
Crosslane Dutch Developments B.V.	S.1514	Investeerders	103	Plegt-Vos	Private sector
Curaçao, Algemeen Pensioenfonds van	S.1514	Investeerders	103	Extern	Private sector
Curlew Alternative Asset Management	S.1514	Investeerders	103	Plegt-Vos	Private sector
Cushman & Wakefield	S.1514	Investeerders	103	Plegt-Vos	Private sector
CZ Groep Aanvullende Verzekering Zorgverzekeraar	S.1514	Investeerders	103	Extern	Private sector
dak woningbeleggingen	S.1514	Investeerders	103	Plegt-Vos	Private sector
DAS Nederlandse Rechtsbijstand Verzekeringmaatschappij N.	S.1514	Investeerders	103	Extern	Private sector
DBV BV	S.1514	Investeerders	103	Plegt-Vos	Private sector
De Elf Provincien	S.1514	Investeerders	103	Plegt-Vos	Private sector
↓	↓	↓	↓	↓	↓
Zilveren Kruis Zorgverzekeringen N.V.	S.1514	Investeerders	103	Extern	Private sector
Zoetwarenindustrie, Bpf. voor de	S.1514	Investeerders	103	Extern	Private sector
Zorg en Welzijn, Pensioenfonds	S.1514	Investeerders	103	Extern	Private sector
Zuivel en Aanverwante Industrie, Stg. Bpf. voor de	S.1514	Investeerders	103	Extern	Private sector

7.3 APPENDIX C: Semi-structured interview

Introductie van het kwalitatieve interview:	
Tijdsduur van het interview:	Ca. 60 minuten
Introductie onderzoeker:	Mijn naam is Brian van Hamond en ik ben een student aan de Technische Universiteit Eindhoven. Ik studeer daar *Construction Management and Engineering* en zit momenteel in de afstudeerfase van mijn studie. De titel van mijn onderzoek luidt: "*Construction method selection on the clients' needs*" en ik ga onderzoeken welke factoren van belang zijn, sterker nog doorslaggevend zijn bij het kiezen van een bouwmethoden.
Participatie en verwerking:	Het interview wordt opgenomen en achteraf tekstueel verwerkt. Door aan het interview deel te nemen wordt aangenomen dat het is toegestaan om de resultaten te verwerken in het afstudeeronderzoek. Echter dient vooraf ter validatie de uitwerking retour gestuurd te worden naar de respondent en alleen wanneer deze is goedgekeurd mogen de resultaten gebruikt worden. Na goedkeuring worden opnames verwijderd en ten alle tijden blijft de respondent anoniem.
Doel van het interview:	• Het peilen van factoren die een rol spelen bij de voorkeur van een bouwmethode; • De onderliggende motieven achterhalen van factoren; • Naast het literatuuronderzoek, nieuwe factoren ophalen om een zo compleet mogelijk beeld te vormen.
Overzicht:	Om u beroepsmatig beter te leren kennen zal het eerste deel van het interview uit demografische vragen bestaan. Het volgende deel zal gaan over projectmatige vragen.

Demografische vragen:	
1. Respondent:	
2. Type organisatie:	
3. Naam van de organisatie:	
4. Opleidingsniveau	☐ Middelbaar beroepsonderwijs (MBO) ☐ Hoger beroepsonderwijs (HBO) ☐ Wetenschappelijk onderwijs (WO) ☐ Anders
5. Cursussen	
6. Functie van de respondent: (Kunt u iets over uzelf vertellen, wat doet u binnen deze organisatie?)	
7. Werkervaring	☐ < 5 jaar ☐ 6 – 10 jaar ☐ 11 – 15 jaar ☐ 16 – 20 jaar ☐ 21 – 25 jaar ☐ > 25 jaar

Projectcase vragen:	
8. Gemiddelde projectgrootte:	☐ < 499.000 euro ☐ 500.000 – 1mjn euro ☐ 1mjn – 2mjn euro ☐ 3mjn – 5mjn euro ☐ 6mjn – 10mjn euro ☐ 11mjn – 20mjn euro ☐ 21mjn – 30mjn euro ☐ 31mjn – 40mjn euro ☐ > 41mjn euro
9. Gericht op Nederland worden projecten gerealiseerd door het gebruik van verschillende bouwmethodes. Welke denkt u dat er allemaal zijn? Zo ja wat houdt dit in voor u?	
Onderstaande vragen worden gespecificeerd per genoemde bouwmethoden	
10. Welke bouwmethode prefereert u en Waarom?	
11. In aanloop van een bouwproject, hoe ziet de samenstelling eruit van partners waarmee u samenwerkt?	
12. Hoe zou u uw project portefeuille willen omschrijven? (Type woningen, omvang project, specifieke doelgroepen)	
13. In wat voor type bouw wordt er onderscheid gemaakt binnen uw organisatie? (nieuwbouw, renovatie, restauratie, transformatie, tijdelijk)	
14. Zijn volgens u bouwmethoden project afhankelijk of niet? Waarom?	

15. Welke factoren zijn binnen uw organisatie volgens u van wezenlijk belang bij de bouw van een project en waarom?	
16. Als het niks zou uitmaken welke bouwmethoden er wordt gekozen, welke factoren spelen er dan nog een belangrijke rol?	
17. Welke factoren acht u wenselijk op de bouw?	
18. Noem de aantal gemiste factoren vanuit literatuur en kijk hoe daarop wordt gereageerd: • Ten aanzien van [tijd], in hoeverre bepaald dat de bouwmethoden? • Ten aanzien van [….], in hoeverre bepaald …. • ….	
Noem de gemiste bouwmethode en stel bovenstaande vragen nog een keer	

Afsluiting:	
Heeft u nog vragen en of opmerkingen?	
Dan wil ik u graag bedanken voor de tijd. Ik zou graag later deze maand een digitale vragenlijst naar u toe willen sturen die mij verder helpt met het onderzoek. Hierbij is het van belang om aan te geven welke factoren het belangrijkst wegen.	
(Contact gegevens uitwisselen)	

7.4 APPENDIX D: Interview elaboration

Interview #1: Luneé

Interview details	
Organization	Developer
Interviewees	--KJ--and --A--
Date	22-03-2019
Time	14:30-15:48
Interview language	Dutch

Summary interview:

Luneé Vastgoed is founded in the time of the crisis by --A-- and --KJ-- in 2007. Since that time they explored the Dutch market for years and in 2011 projects started to get loose. Years of networking started to pay off and expanded the company with an additional of 4 more employees and a lot of ongoing projects. Luneé is a small developer who claims to work on a transparent manner together with their different clients. The main clients of Luneé are investors, municipalities and housing corporations. Together with their fixed contractors, they prefer to be involved early in the process to ensure that everybody is working seamless in a team. To emphasize collaboration, Luneé argued that lot of contractors are dispersed which leads to a lot of partnerships. Nobody can do it on their own so here applies that unity is strength.

Luneé went across the European boundaries to start up projects in the Asian and Latin American continent to complement them with affordable housing and employment opportunities. However, due to political issues and lack of working together with a NGO made it impossible to launch the new developments.

Luneé thinks that there are three types of construction methods to differentiate: Traditional, Conceptual and Modular. Despite they know the variety of construction methods, little they know about the difference between Conceptual and Modular. Luneé is focusing on developing areas for new houses and redevelopment projects and especially in urban areas for clients like investors. Here they prefer to work with the conceptual construction method to reduce as much nuisance in the neighborhood as possible. In terms of price they noticed that there is not much of a difference between traditional and conceptual in realizing a building. However, the speed in which the project can be finalized in using the conceptual construction method is two times faster compared with the traditional way of building. In the end this indirectly generates more revenue for Luneé. In terms of aesthetics it can concluded that the core inside is pretty fixed with enough flexibility to make it personal. Regardless of the different construction methods, there is enough variation in the facade possible, because the architects still have enough freedom of movement to make it unique.

Interview #2: Bouwinvest

Interview details	
Organization	Investor
Interviewees	--R--
Date	02-04-2019
Time	15:30-16:43
Interview language	Dutch

Summary interview:

Bouwinvest claims to be a true investor who invest for pension funds. The construction industry is considered to be their largest shareholder (90%). This pension funds is good for approximately 8 billion euros. The remaining 10% consist of 9 other pension funds that are good for 300-600 million euros. Bouwinvest is divided into three mandates: Europe, Asia-pacific and North-America. In the Asia-pacific mandate and North-America mandate Bouwinvest invest indirectly in bricks, thus in people. In the Europe mandate Bouwinvest invest directly in bricks. Here their construction shareholder consists of 5 types of Dutch funds: housing, office, healthcare, hotel and retail. Here the housing portfolio is the largest one, but what also is been noticed is that there is a growing demand for healthcare. In terms of housing Bouwinvest divided the portfolio in 40% dwellings and 60% apartments. The target group consists of mainly renters for the higher segment and sometimes social rent. However this is only when a municipal obligates Bouwinvest to develop a building were x % needs to be social.

To make a lot of return, Bouwinvest uses turnkey collaboration. They will work with a contractor who is also a developer. Bouwinvest prefers to be involved early in the process to maximize their influence in the design and wishes. When the project is finished, they keep the building for a cycle of 15years in their own portfolio. After every cycle Bouwinvest will rebound or renovate the building. This depends on the value of the building and the return what they get back it. Location here is an important factor because experience learns that dense urban areas, like Amsterdam, are more favorable than a row house in Assen which is more the outskirt. To make it more retainable, Bouwinvest claims to function in six core areas to invest:

- region of Amsterdam (Haarlem, hoofddorp, Zaandam);
- region of The Hague / Rotterdam;
- region of Brabant;
- region of Maastricht;
- region of Arnhem (Nijmegen, Zwolle) and;
- the region of Utrecht.

Bouwinvest thinks that there are three types of construction methods to differentiate: Conventional construction method, prefab construction method and modular construction method. According to Bouwinvest, modular has a great advantage when there is a lot of repetition going on. As well by prefab and modular there is work to be done in a factory and Bouwinvest says that this is a win-win situation. Perfect circumstances for workers that create rapid and accurate production. Furthermore the quality of work is considered to be an important factor. Even more important than speed or costs. Sustainability also plays a role in

Bouwinvest as they are performing a higher standard than the minimum requirements of the Dutch Building Degree. However in terms of renovation work this sometimes leads to the discussion of raising the rent. Sustainability goes hand in hand with costs and Bouwinvest state that The Netherlands often asks too much of this.

Interview #3: Viveste

Interview details	
Organization	Housing corporation
Interviewees	--B--
Date	08-04-2019
Time	14:30-15:24
Interview language	Dutch

Summary interview:
Viveste is an housing corporation situated in the semi-public sector and offers social housing to the lower segment in the Netherlands. Viveste has 7000 dwellings that are dispersed over the area of *Houten* and *Wijk bij Duurstede*. Besides these areas they manage also some dwellings of another corporation in *Bunnik*. Logically, Viveste has offices in these three locations: one back office in *Bunnik* and two front offices in *Houten* and *Wijk bij Duurstede.* The average project size of Viveste is about 10 million euro per project and some 95% of the portfolio of Viveste contains housing.

Looking to the different construction methods Viveste thinks that traditional is outdated and legalization will be the future. Innovation seems to be an important drive, Viveste cites: "*we moeten niet komen met een plan van eisen, maar komen met een plan van wensen*". This reflects the degree of creativity. Favorable should be to create a building which is better and aesthetically nicer for the same amount of money, because Viveste does not want to ask more rent from their tenants. Just like legolization, the modular construction method seems to be appealing for Viveste. According to Viveste they find sustainability important but circularity even more important. By doing work as much as possible off-site in factories, it is not only more ethically friendly, but also more environmentally friendly. Flexibility in terms of layout is not merely important. Viveste is better satisfied with a well-considered fixed layout. On the other hand, flexibility in terms of materials is important. At forehand this should be arranged circular. Costs are also an important issue for Viveste. As they want to keep the rent low, the costs also should be kept low. So costs are important, but exploitation is much more important. Viveste state: "*…. dit is zowel de betaalbaarheid voor onze bewoners en de betaalbaarheid voor ons*".

Interview #4: Rijksvastgoedbedrijf

Interview details	
Organization	Governmental body
Interviewees	--J--
Date	10-04-2019
Time	10:00-11:09
Interview language	Dutch

Summary interview:
Rijksvastgoedbedrijf is a real estate organization from and for the central government and is part of the Ministry of Internal Affairs and Royal Relations. Rijksvastgoedbedrijf is responsible for housing of the national government agencies. This goes from tax offices to Justitie, courts, museums and the house of the Royal family. As Rijksvastgoedbedrijf describes: "*We own the governmental portfolio and we use it for governmental services*". Rijksvastgoedbedrijf has different portfolios. The first division that can be made is the division in the housing system. In some cases housing systems are owned by Rijksvastgoedbedrijf and in that case they pay everything. However in other cases housing systems are also owned by Rijksvastgoedbedrijf, but here the client pays for everything. And with some housing systems, only real estate is managed. The latter does Rijksvastgoedbedrijf for the defense portfolio. The second division is made in the different portfolios of the housing system. According to Rijksvastgoedbedrijf approximately 40% of their real estate are offices and 60% are specialties (museums, courts, etc.).

Rijksvastgoedbedrijf thinks that there are three types of construction methods to differentiate: conventional construction method, prefab construction method and the modular construction method. Despite the modular construction method is named by Rijksvastgoedbedrijf, they claim to have not much experience with this type of construction method. Rijksvastgoedbedrijf particular hears this term a lot with developers. Based on own experience Rijksvastgoedbedrijf prefers to build with prefab because they endorse the speed and accuracy that comes along with it. As the off-site construction methods are made in factories, more development knowledge can be reached in terms of automation. This also has to do with process work. If a process is arranged, this also can influence the safety on the building site. But not only here, also in the neighborhood. A short time on-site can minimize dangerous situations and therefore this is considered to be important. Furthermore Rijksvastgoedbedrijf thinks that traditional construction methods are more flexible than prefab and prefab more than modular because working with restrictions limits your freedom of movement. One factor that seems to be important for Rijksvastgoedbedrijf is acquisition. According to Rijksvastgoedbedrijf this translates itself in the accessibility of a product or construction method. So it is better to create a system that works with other systems instead of a systems that works on its own. In other words this is the compatibility that is related to the construction method.

Interview #5: Duwo

Interview details	
Organization	Educational body
Interviewees	--H--
Date	25-04-2019
Time	11:00-12:13
Interview language	Dutch

Summary interview:
Duwo is an authorized institution and is synonymic to a housing corporation. For example; a housing corporation rents out social rental homes and Duwo also, but primarily for students. The locations were Duwo is responsible for student housing are The Hague, Delft, Leiden and Amsterdam. These regions are also the locations were all the offices of Duwo are located. The main office of Duwo is located in Delft because this is the location where it all begun. Back after the war in 1945 students wanted to resume or start their studies and it became clear that there was a shortage of living space. More than 75 years later Duwo has about 170 employees and over 33.000 living spaces for students. About 75% of the living spaces (units) is divided in ownership and 25% of the living spaces is divided into property management. Duwo preferably wants to invest in large projects with a lot of units for students. The project sizes of Duwo vary between 24 up to 90 million euro. Duwo is characterized by the fact that they provide affordable housing to students. Example of affordable housing: 80% of all independent units amounts to a monthly rent of 400 euro.

As an educational body Duwo has a lot of fixed partnerships with educational institutions and local municipalities. Besides this, Duwo also has a lot of contact with corporations and developers. Especially corporations play an interesting role in the renovations of student houses because former social (row) houses can be transformed easily. When this or existing student houses/complexes are renovated, new sustainable features are added to upgrade the building. Duwo said that construction methods are project dependent and location based. Why location based? To avoid nuisance it is smarter to build modular or conceptual in a dense urban city and better to build conventional in a more rural location. According to Duwo safety is also an important matter. Not only for the end-users but also for the way a project will be constructed can safety be seen as an important issue.

7.5 APPENDIX E: Questionnaire (I)

Voorpagina

Pagina 1

Measuring the importance of factors regarding to the construction methods in the Netherlands on the Clients' needs

Thank you in advance for taking the time and effort to fill in the questionnaire. As the title already suggests, the critical factors based on the revealed construction methods in The Netherlands will be investigated. The factors that will be mentioned in this questionnaire are reviewed in literature and derived from client interviews. To determine which of these factors are relevant and important (critical), you are asked to indicate the importance of the different factors that will be named.

The questionnaire consists of 3 parts which takes in total 15 minutes:
Part A: General questions (3 minutes)
Part B: Assessment of factors in general (7 minutes)
Part C: Assessment of factors per construction method (5 minutes)

Go to next page (1 out of 7)

Pagina 2

17%

Part A takes about 3 minutes of your time and consists of 9 general questions. They are listed as follows:

Go to next page

Pagina 3

29%

1. What is your gender?

- A Male
- B Female
- C Gender neutral

2. What is your age?

- A 20-29 years
- B 30-39 years
- C 40-49 years
- D 50-59 years
- E ≥ 60 years

3. What is your level of education?

- A Professional education (MBO)
- B Higher professional education (HBO)
- C University (WO)
- D Other, namely:

- A < 5 years
- B 5-9 years
- C 10-14 years
- D 15-19 years
- E 20-24 years
- F ≥ 25 years

5. Which type of organization are you?

- [A] Governmental body
- [B] Healthcare body
- [C] Educational body
- [D] Housing corporation
- [E] Developer
- [F] Investor

6. What is your occupational level?

- [A] Managing board
- [B] Manager
- [C] Excecutive
- [D] Consultancy
- [E] Planner
- [F] Others, namely:

7. In which province is the organization located in which you are (mainly) active?

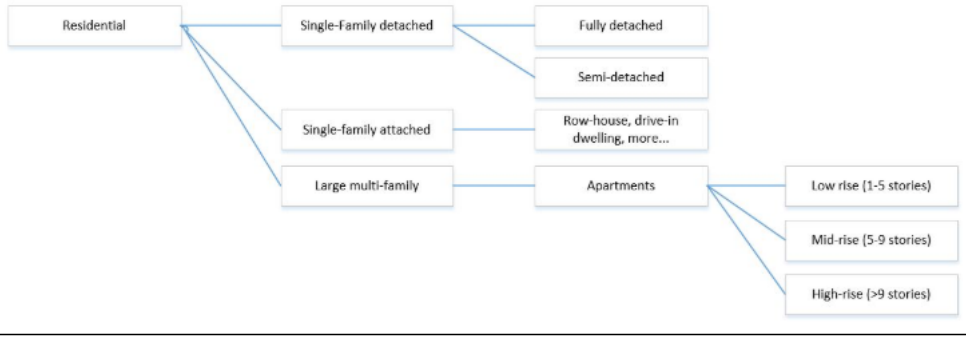
- [A] Drenthe
- [B] Flevoland
- [C] Friesland
- [D] Gelderland
- [E] Groningen
- [F] Limburg
- [G] Noord-Brabant
- [H] Noord-Holland
- [I] Overijssel
- [J] Utrecht
- [K] Zeeland
- [L] Zuid-Holland

8. What is the average project size of the organization?

- [A] <10 million euro
- [B] 10-19 million euro
- [C] 20-39 million euro
- [D] 40-59 million euro
- [E] 60-79 million euro
- [F] 80-99 million euro
- [G] ≥ 100 million euro

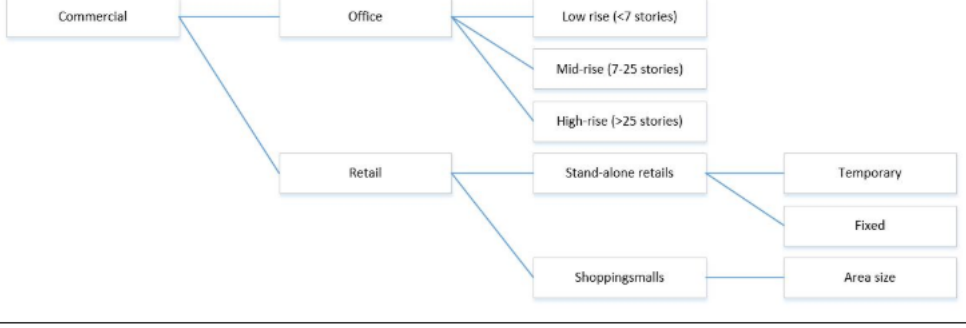
9. Please choose the building type that is mainly used in your organizations' portfolio

[A]

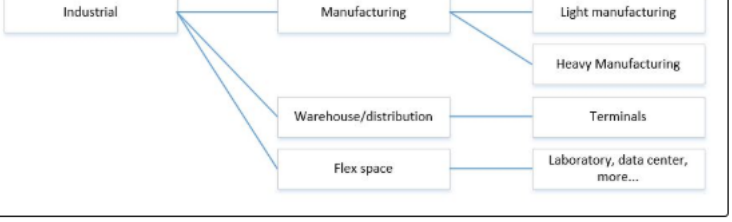


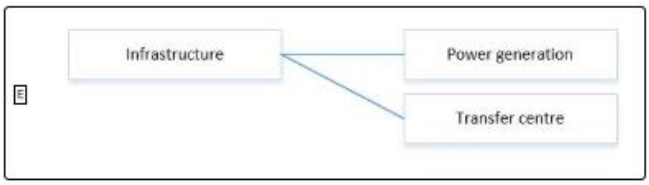
[B]

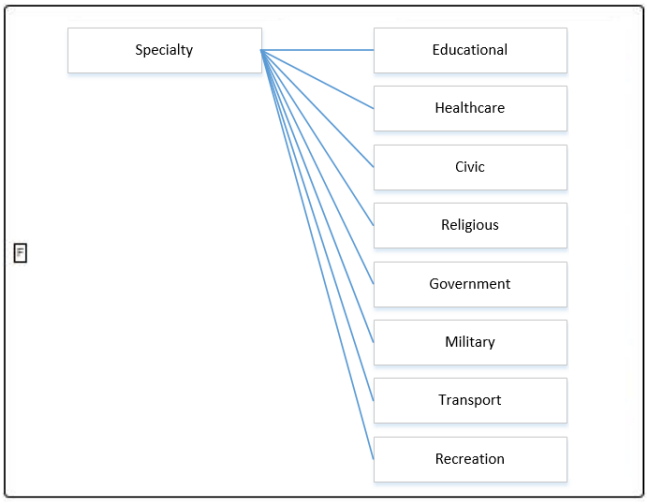
[C]



[D]







Pagina 4

43%

In part B of the survey you are asked to rate the importance of the factors that resulted from the literature research and client interviews.
This takes about 7 minutes of your time.

Go to next page (4 out of 7)

Pagina 5

57%

10. Based on the building type you have chosen before, how important do you think that the following factor for your organization is while choosing for a particular construction method? This is based on a seven-point Likert scale in which you can select your opinion.
Costs - The cash equivalent that is been charged for goods or services and is expressed in financial units.

	1 Not at all important	2 Slightly important	3 Merely important	4 Important	5 Fairly important	6 Very important	7 Extreme important	No opinion
Costs	○	○	○	○	○	○	○	○

+20

Pagina 5

67%

In the last part of the survey, part C, you are going to be asked which construction method you prefer. At forehand a description of the different construction methods are shown. Please read this carefully.

Conventional (= traditional): The term conventional is often used to describe the types of linear construction, where each individual step is not only constructed entirely (or largely) on site, but also needs to be completed before the project can move on to the next phase.

Prefab: Prefabrication is a mix of factory made elements and labour work on-site to construct a building. Usually prefab elements are made off-site in the factory.

Conceptual: This is a method that uses a standardized way of constructing a building (standard measurements) with a standardized planning. This method can be characterized by the following terms: non-linear building process, different concepts to choose from, short building time (e.g. 16 weeks to realize a 4-storey apartment).

Modular: Modular is the far opposite of conventional were there will be worked in a predetermined way with predefined measurements. Here designing offers a high degree of limitations. Modular is made entirely off-site in a factory which leads to a high preparation/production time. On the other hand, the on-site time will be minimized as only assembly will be done at the site location.

Go to next page

Pagina 6

83%

31. Based on your thoughts, please choose the type of building that best fit the construction method

	Residential	Agricultural	Commercial	Industrial	Infrastructure	Specialty
Conventional construction method						
Prefab construction method						
Conceptual construction method						
Modular construction method						

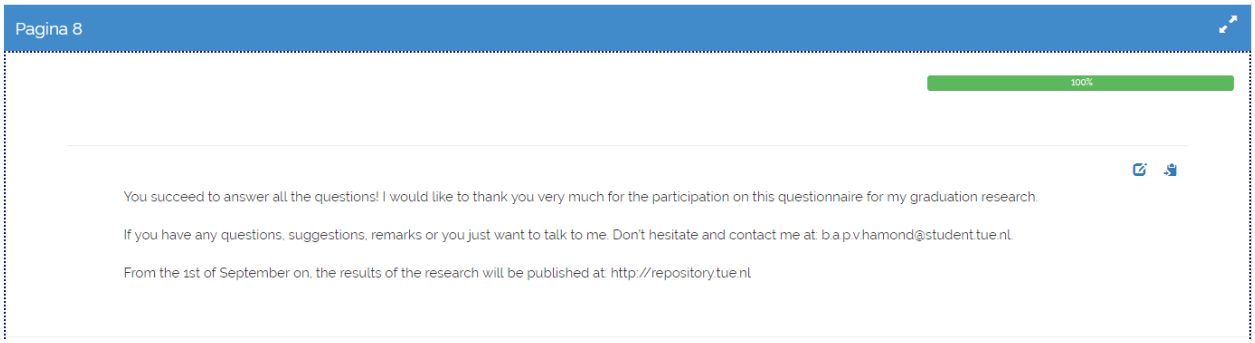
32. Based on the building type you have chosen in Part A, drag the construction methods in the desired order. Hereby is the one on top is most desired and the bottom one being least desired.
This takes about 2 minutes of your time.

Conventional construction method

Prefab construction method

Conceptual construction method

Modular construction method


Pagina 8
100%
You succeed to answer all the questions! I would like to thank you very much for the participation on this questionnaire for my graduation research.
If you have any questions, suggestions, remarks or you just want to talk to me. Don't hesitate and contact me at: b.a.p.v.hamond@student.tue.nl.
From the 1st of September on, the results of the research will be published at: http://repository.tue.nl

7.6 APPENDIX F: Questionnaire (II)

Voorpagina

Pagina 1

Measuring the importance of factors regarding to the construction methods in the Netherlands on the Clients' needs

Thank you in advance for taking the time and effort to fill in the second part of the questionnaire. Based on results from part 1, the amount of factors are filtered from 21 to 6. These 6 factors are now being further investigated by conducting this questionnaire.

As the title already suggests, the critical factors based on the revealed construction methods in The Netherlands will be investigated. The factors that will be mentioned in this questionnaire are reviewed in literature and derived from client interviews. To determine which of these factors are relevant and important (critical), you are asked to indicate the importance of the different factors that will be named.

The questionnaire consists of 3 parts which takes in total 10 minutes:
Part A: General questions (3 minutes)
Part B: Assessment of factors per construction method (5 minutes)
Part C: Preference of building type construction method and building type (2 minutes)

Go to next page

Pagina 2

14%

Part A takes about 3 minutes of your time and consists of 9 general questions. They are listed as follows:

Go to next page

Pagina 3

29%

1. What is your gender?

- [A] Male
- [B] Female
- [C] Gender neutral

2. What is your age?

- [A] 20-29 years
- [B] 30-39 years
- [C] 40-49 years
- [D] 50-59 years
- [E] ≥ 60 years

3. What is your level of education?

- [A] Professional education (MBO)
- [B] Higher professional education (HBO)
- [C] University (WO)
- [D] Other, namely:

4. How many years of work related experience do you have?

- [A] < 5 years
- [B] 5-9 years
- [C] 10-14 years
- [D] 15-19 years
- [E] 20-24 years
- [F] ≥ 25 years

5. Which type of organization are you?

- [A] Governmental body
- [B] Healthcare body
- [C] Educational body
- [D] Housing corporation
- [E] Developer
- [F] Investor

6. What is your occupational level?

- [A] Managing board
- [B] Manager
- [C] Excecutive
- [D] Consultancy
- [E] Planner
- [F] Others, namely:

7. In which province is the organization located in which you are (mainly) active?

- A Drenthe
- B Flevoland
- C Friesland
- D Gelderland
- E Groningen
- F Limburg
- G Noord-Brabant
- H Noord-Holland
- I Overijssel
- J Utrecht
- K Zeeland
- L Zuid-Holland

8. What is the average project size of the organization?

- A <10 million euro
- B 10-19 million euro
- C 20-39 million euro
- D 40-59 million euro
- E 60-79 million euro
- F 80-99 million euro
- G ≥ 100 million euro

9. Please choose the building type that is mainly used in your organizations' portfolio

- A Commercial
- B Residential
- C Specialty
- D Industrial
- E infrastructure
- F Agricultural

Go to next page

Pagina 4

43%

In Part B, you are going to be asked to rate the factors you think are important based on the four construction methods. This is based on a seven-point Likert scale in which you can select your opinion. In case you really have no preference or just don't know, you can select "No opinion".

At forehand a description of the different construction methods is shown. Please read this carefully.
Answering these questions should take about 5 minutes of your time.

Conventional (= traditional): The term conventional is often used to describe the types of linear construction, where each individual step is not only constructed entirely (or largely) on site, but also needs to be completed before the project can move on to the next phase.

Prefab: Prefabrication is a mix of factory made elements and labour work on-site to construct a building. Usually prefab elements are made off-site in the factory.

Conceptual: This is a method that uses a standardized way of constructing a building (standard measurements) with a standardized planning. This method can be characterized by the following terms: non-linear building process, different concepts to choose from, short building time (e.g. 16 weeks to realize a 4-storey apartment).

Modular: Modular is the far opposite of conventional were there will be worked in a predetermined way with predefined measurements. Here designing offers a high degree of limitations. Modular is made entirely off-site in a factory which leads to a high preparation/production time. On the other hand, the on-site time will be minimized as only assembly will be done at the site location.

Go to next page

Pagina 5

57%

10. **Based on the building type you have chosen in Part A, how important do you think that the factor "Costs" is for your organization?**
Factor "Costs" = The cash equivalent that is been charged for goods or services and is expressed in financial units.

	1 Not at all important	2 Slightly important	3 Merely important	4 Important	5 Fairly important	6 Very important	7 Extreme important	No opinion
Conventional construction method								
Prefab construction method								
Conceptual construction method								
Modular construction method								

11. **Based on the building type you have chosen in Part A, how important do you think that the factor "Sustainability" is for your organization?**
Factor "Sustainability" = Meet the needs of the present without compromising the future generations while living in harmony.

	1 Not at all important	2 Slightly important	3 Merely important	4 Important	5 Fairly important	6 Very important	7 Extreme important	No opinion
Conventional construction method								
Prefab construction method								
Conceptual construction method								
Modular construction method								

12. **Based on the building type you have chosen in Part A, how important do you think that the factor "Flexibility" is for your organization?**
Factor "Flexibility" = The ability to change or react with little effort to fulfil the maximum suitable changing needs for future use.

	1 Not at all important	2 Slightly important	3 Merely important	4 Important	5 Fairly important	6 Very important	7 Extreme important	No opinion
Conventional construction method								
Prefab construction method								
Conceptual construction method								
Modulair construction method								

13. **Based on the building type you have chosen in Part A, how important do you think that the factor "Safety" is for your organization?**
Factor "Safety" = Safety aims to ensure that individuals in and around a particular surrounding are not exposed to immediate danger and that the finished products of among others construction meets the required safety standards.

	1 Not at all important	2 Slightly important	3 Merely important	4 Important	5 Fairly important	6 Very important	7 Extreme important	No opinion
Conventional construction method								
Prefab construction method								
Conceptual construction method								
Modular construction method								

14. **Based on the building type you have chosen in Part A, how important do you think that the factor "Quality" is for your organization?**
Factor "Quality" = degree to which a product or service meets the requirements that are set as a threshold and in which they fulfil the minimum standard of the customer.

	1 Not at all important	2 Slightly important	3 Merely important	4 Important	5 Fairly important	6 Very important	7 Extreme important	No opinion
Conventional construction method								
Prefab construction method								
Conceptual construction method								
Modular construction method								

15. **Based on the building type you have chosen in Part A, how important do you think that the factor "Exploitation/operating (cost related)" is for your organization?**
Exploitation/operating (cost related) = maintenance and administrative costs that result from owning or using real estate such as an office / company building.

	1 Not at all important	2 Slightly important	3 Merely important	4 Important	5 Fairly important	6 Very important	7 Extreme important	No opinion
Conventional construction method								
Prefab construction method								
Conceptual construction method								
Modular construction method								

Go to next page

Pagina 6

71%

In the last of the questionnaire, Part C, you are asked to share your thoughts about the different construction methods.
This takes about 2 minutes of your time.

Go to next page

Pagina 7

86%

16. Based on the building type you have chosen in Part A, drag the construction methods in the desired order. Hereby is the one on top is most desired and the bottom one being least desired.

- Conventional construction method
- Prefab construction method
- Conceptual construction method
- Modular construction method

17. Based the conventional construction method, please choose the type(s) of building that best fit this method.

A Commercial | B Industrial | C Infrastructure | D Specialty | E Residential | F Agricultural

18. Based the prefab construction method, please choose the type(s) of building that best fit this method.

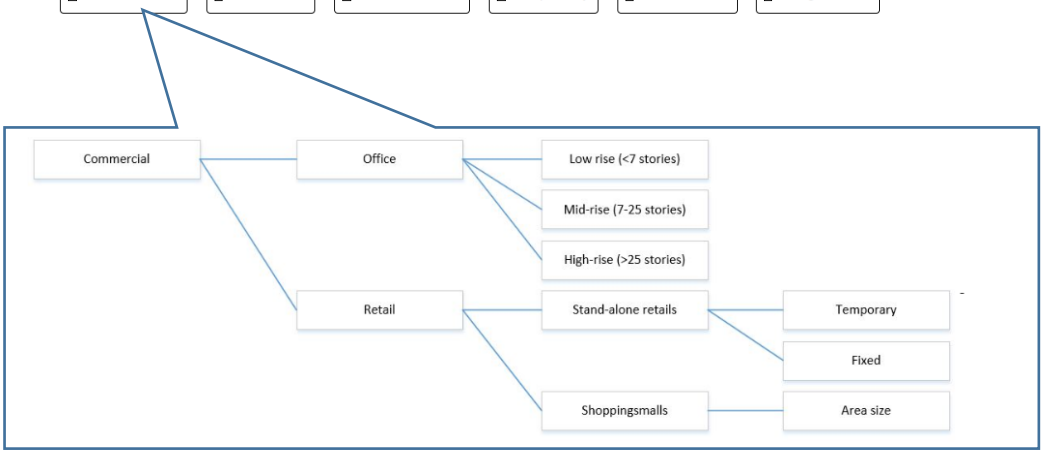
A Commercial | B Industrial | C Infrastructure | D Specialty | E Residential | F Agricultural

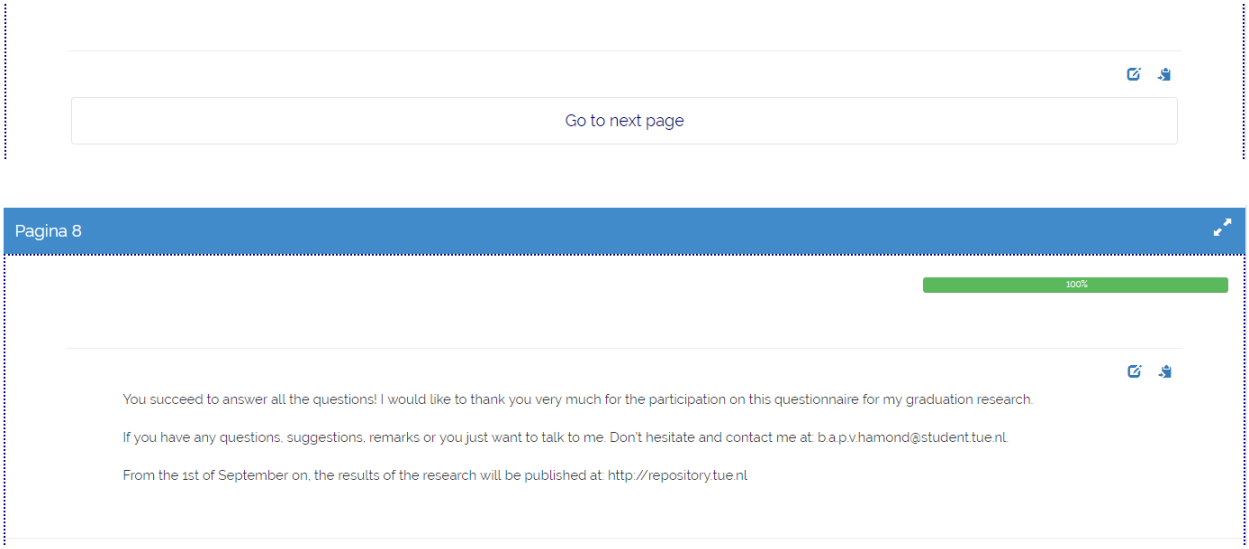
19. Based the conceptual construction method, please choose the type(s) of building that best fit this method.

A Commercial | B Industrial | C Infrastructure | D Specialty | E Residential | F Agricultural

20. Based the modular construction method, please choose the type(s) of building that best fit this method.

A Commercial | B Industrial | C Infrastructure | D Specialty | E Residential | F Agricultural




Go to next page
Pagina 8
100%
You succeed to answer all the questions! I would like to thank you very much for the participation on this questionnaire for my graduation research.
If you have any questions, suggestions, remarks or you just want to talk to me. Don't hesitate and contact me at: b.a.p.v.hamond@student.tue.nl.
From the 1st of September on, the results of the research will be published at: http://repository.tue.nl

7.7 APPENDIX G: Results – FDM, Crosstabs, Chi square goodness of fit, tree-diagram

7.7.1 Questionnaire (I)

Factors	S_j Crisp value
Factor 1: Costs	0,81
Factor 2: sustainability	0,76
Factor 3: Flexibility	0,71
Factor 4: Safety	0,72
Factor 5: Labour intensity	0,46
Factor 6: Time	0,65
Factor 7: Accuracy	0,69
Factor 8: Uniqueness	0,36
Factor 9: Process	0,60
Factor 10: Aesthetics (variety)	0,55
Factor 11: Production speed	0,59
Factor 12: Collaboration	0,67
Factor 13: On site	0,28
Factor 14: off site	0,39
Factor 15: Innovation	0,57
Factor 16: Location	0,62
Factor 17: Nuisance	0,68
Factor 18: Quality	0,84
Factor 19: Circularity (economy)	0,60
Factor 20: Exploitation / operating (cost related)	0,83
Factor 21: Compatibility	0,58

Threshold	0,7

Attributes	Type of client											
	Governmental body (number)	Average (%)	Educational body (number)	Average (%)	Healthcare body (number)	Average (%)	Housing corporation (number)	Average (%)	Developer (number)	Average (%)	Investor (number)	Average (%)
Building type												
Residential	22	73	6	55	20	74	44	90	18	72	2	50
Commercial	0	0	0	0	0	0	3	6	2	8	2	50
Specialty	8	27	5	45	7	26	2	4	5	20	0	0
Industrial	0	0	0	0	0	0	0	0	0	0	0	0
Agricultural	0	0	0	0	0	0	0	0	0	0	0	0
Infrastructure	0	0	0	0	0	0	0	0	0	0	0	0
Average project size												
< €10 million	20	67	7	64	18	67	27	55	14	56	1	25
€10 - €19 million	4	13	2	18	4	15	10	20	8	32	0	0
€20 - €39 million	3	10	2	18	1	4	2	4	2	8	0	0
€40 - €59 million	0	0	0	0	0	0	5	10	0	0	1	25
€60 - €79 million	0	0	0	0	0	0	1	2	1	4	0	0
€80 - €99 million	1	3	0	0	1	4	2	4	0	0	0	0
≥ €100 million	2	7	0	0	3	11	2	4	0	0	2	50
Province												
Drenthe	2	7	3	27	0	0	1	2	0	0	0	0
Flevoland	3	10	0	0	2	7	2	4	0	0	0	0
Friesland	3	10	0	0	0	0	2	4	1	4	0	0
Gelderland	7	23	4	36	6	22	8	16	1	4	0	0
Groningen	3	10	0	0	1	4	3	6	1	4	0	0
Limburg	2	7	0	0	1	4	0	0	1	4	0	0
Noord-Brabant	0	0	0	0	0	0	2	4	0	0	1	25
Noord-Holland	1	3	0	0	5	19	7	14	4	16	2	50
Overijssel	4	13	2	18	4	15	5	10	4	16	0	0
Utrecht	1	3	2	18	8	30	8	16	7	28	0	0
Zeeland	0	0	0	0	0	0	0	0	0	0	0	0
Zuid-Holland	4	13	0	0	0	0	11	22	6	24	1	25

Legend:

West		30		18		56		57		68		75
Noord		27		27		4		12		8		0
Oost		37		55		37		27		20		0
Zuid		7		0		4		4		4		25

7.7.2 Questionnaire (II)

Factors	S_j Crisp value
Factor 1: Costs ----- Conventional construction method	0,77
Factor 1: Costs ----- Prefab construction method	0,79
Factor 1: Costs ----- Conceptual construction method	0,79
Factor 1: Costs ----- Modular construction method	0,76
Factor 2: Sustainability ----- Conventional construction method	0,73
Factor 2: Sustainability ----- Prefab construction method	0,75
Factor 2: Sustainability ----- Conceptual construction method	0,77
Factor 2: Sustainability ----- Modular construction method	0,75
Factor 3: Flexibility ----- Conventional construction method	0,56
Factor 3: Flexibility ----- Prefab construction method	0,56
Factor 3: Flexibility ----- Conceptual construction method	0,56
Factor 3: Flexibility ----- Modular construction method	0,57
Factor 4: Safety ----- Conventional construction method	0,71
Factor 4: Safety ----- Prefab construction method	0,72
Factor 4: Safety ----- Conceptual construction method	0,74
Factor 4: Safety ----- Modular construction method	0,73
Factor 5: Quality ----- Conventional construction method	0,80
Factor 5: Quality ----- Prefab construction method	0,79
Factor 5: Quality ----- Conceptual construction method	0,79
Factor 5: Quality ----- Modular construction method	0,78
Factor 6: Exploitation / operating (cost related) ----- Conventional construction method	0,76
Factor 6: Exploitation / operating (cost related) ----- Prefab construction method	0,79
Factor 6: Exploitation / operating (cost related) ----- Conceptual construction method	0,77
Factor 6: Exploitation / operating (cost related) ----- Modular construction method	0,77

Threshold	0,7

Attributes	Type of client											
	Governmental body (number)	Average (%)	Educational body (number)	Average (%)	Healthcare body (number)	Average (%)	Housing corporation (number)	Average (%)	Developer (number)	Average (%)	Investor (number)	Average (%)
Building type												
Residential	10	67	0	0	4	33	26	100	7	64	4	80
Commercial	0	0	1	100	0	0	0	0	3	27	0	0
Specialty	5	33	0	0	7	58	0	0	0	0	1	20
Industrial	0	0	0	0	0	0	0	0	0	0	0	0
Agricultural	0	0	0	0	0	0	0	0	0	0	0	0
Infrastructure	0	0	0	0	1	8	0	0	1	9	0	0
Average project size												
< €10 million	10	59	1	100	8	67	14	54	14	56	1	20
€10 - €19 million	5	29	0	0	2	17	3	12	8	32	0	0
€20 - €39 million	1	6	0	0	1	8	4	15	2	8	3	60
€40 - €59 million	0	0	0	0	0	0	0	0	0	0	0	0
€60 - €79 million	1	6	0	0	0	0	2	8	1	4	0	0
€80 - €99 million	0	0	0	0	0	0	1	4	0	0	0	0
≥ €100 million	0	0	0	0	1	8	2	8	0	0	1	20
Province												
Drenthe	2	12	0	0	0	0	1	4	0	0	0	0
Flevoland	2	12	0	0	0	0	0	0	1	9	0	0
Friesland	0	0	0	0	0	0	0	0	0	0	0	0
Gelderland	6	35	0	0	2	17	3	12	0	0	1	20
Groningen	2	12	0	0	1	8	2	8	0	0	0	0
Limburg	0	0	0	0	0	0	3	12	0	0	0	0
Noord-Brabant	1	6	0	0	0	0	1	4	0	0	0	0
Noord-Holland	1	6	0	0	0	0	6	23	2	18	2	40
Overijssel	2	12	1	100	6	50	1	4	2	18	0	0
Utrecht	0	0	0	0	2	17	5	19	3	27	2	40
Zeeland	0	0	0	0	0	0	0	0	0	0	0	0
Zuid-Holland	1	6	0	0	1	8	4	15	3	27	0	0

Legend:

West		24		0		25		58		82		80
Noord		24		0		8		12		0		0
Oost		47		100		67		15		18		20
Zuid		6		0		0		15		0		0

7.7.3 Chi-Square Goodness of Fit test

What_is_your_gender?

	Observed N	Expected N	Residual
Male	68	63,6	4,4
Female	4	8,4	-4,4
Total	72		

Test Statistics

	What_is_your_gender?
Chi-Square	2,565[a]
df	1
Asymp. Sig.	,109

a. 0 cells (0,0%) have expected frequencies less than 5. The minimum expected cell frequency is 8,4.

What_is_your_age?

	Observed N	Expected N	Residual
30-39 years	9	13,8	-4,8
40-49 years	23	23,0	,0
50-59 years	24	26,6	-2,6
â‰¥ 60 years	16	8,7	7,3
Total	72		

Test Statistics

	What_is_your_age?
Chi-Square	8,152[a]
df	3
Asymp. Sig.	,043

a. 0 cells (0,0%) have expected frequencies less than 5. The minimum expected cell frequency is 8,7.

What_is_your_level_of_education?

	Observed N	Expected N	Residual
Professional education (MBO)	5	3,0	2,0
Higher professional education (HBO)	44	43,1	,9
University (WO)	23	25,9	-2,9
Total	72		

Test Statistics

	What_is_your_level_of_education?
Chi-Square	1,602[a]
df	2
Asymp. Sig.	,449

a. 1 cells (33,3%) have expected frequencies less than 5. The minimum expected cell frequency is 3,0.

How_many_years_of_work_related_experience_do_you_have?

	Observed N	Expected N	Residual
< 5 years	1	3,0	-2,0
5-9 years	2	3,5	-1,5
10-14 years	3	5,4	-2,4
15-19 years	8	11,4	-3,4
20-24 years	18	20,2	-2,2
â‰¥ 25 years	40	28,6	11,4
Total	72		

Test Statistics

	How_many_years_of_work_related_experience_do_you_have?
Chi-Square	8,778[a]
df	5
Asymp. Sig.	,118

a. 2 cells (33,3%) have expected frequencies less than 5. The minimum expected cell frequency is 3,0.

Which_type_of_organization_are_you?

	Observed N	Expected N	Residual
Governmental body	17	14,8	2,2
Healthcare body	12	13,3	-1,3
Educational body	1	5,4	-4,4
Housing corporation	26	24,2	1,8
Developer	11	12,3	-1,3
Investor	5	1,9	3,1
Total	72		

Test Statistics

	Which_type_of_organization_are_you?
Chi-Square	9,126[a]
df	5
Asymp. Sig.	,104

a. 1 cells (16,7%) have expected frequencies less than 5. The minimum expected cell frequency is 1,9.

What_is_your_occupational_level?

	Observed N	Expected N	Residual
Managing board	9	7,4	1,6
Manager	32	31,5	,5
Excecutive	16	15,3	,7
Consultancy	9	10,4	-1,4
Others, namely:	6	7,4	-1,4
Total	72		

Test Statistics

	What_is_your_occupational_level?
Chi-Square	,832[a]
df	4
Asymp. Sig.	,934

a. 0 cells (0,0%) have expected frequencies less than 5. The minimum expected cell frequency is 7,4.

In_which_province_is_the_organization_located_in_which_you_are_(mainly)_active?

	Observed N	Expected N	Residual
Drenthe	3	3,1	-,1
Flevoland	3	3,6	-,6
Gelderland	12	13,4	-1,4
Groningen	5	4,1	,9
Limburg	3	2,0	1,0
Noord-Brabant	2	1,6	,4
Noord-Holland	11	9,8	1,2
Overijssel	12	9,8	2,2
Utrecht	12	13,4	-1,4
Zuid-Holland	9	11,3	-2,3
Total	72		

Test Statistics

	In_which_province_is_the_organization_located_in_which_you_are_(mainly)_active?
Chi-Square	2,299[a]
df	9
Asymp. Sig.	,986

a. 5 cells (50,0%) have expected frequencies less than 5. The minimum expected cell frequency is 1,6.

What_is_the_average_project_size_of_the_organization?

	Observed N	Expected N	Residual
<10 million euro	41	42,9	-1,9
10-19 million euro	10	13,8	-3,8
20-39 million euro	11	4,9	6,1
40-59 million euro	1	3,0	-2,0
60-79 million euro	3	1,0	2,0
80-99 million euro	1	1,9	-,9
â‰¥ 100 million euro	5	4,5	,5
Total	72		

Test Statistics

	What_is_the_average_project_size_of_the_organization?
Chi-Square	14,503[a]
df	6
Asymp. Sig.	,024

a. 5 cells (71,4%) have expected frequencies less than 5. The minimum expected cell frequency is 1,0.

Please_choose_the_building_type_that_is_mainly_used_in_your_organizations_portfolio

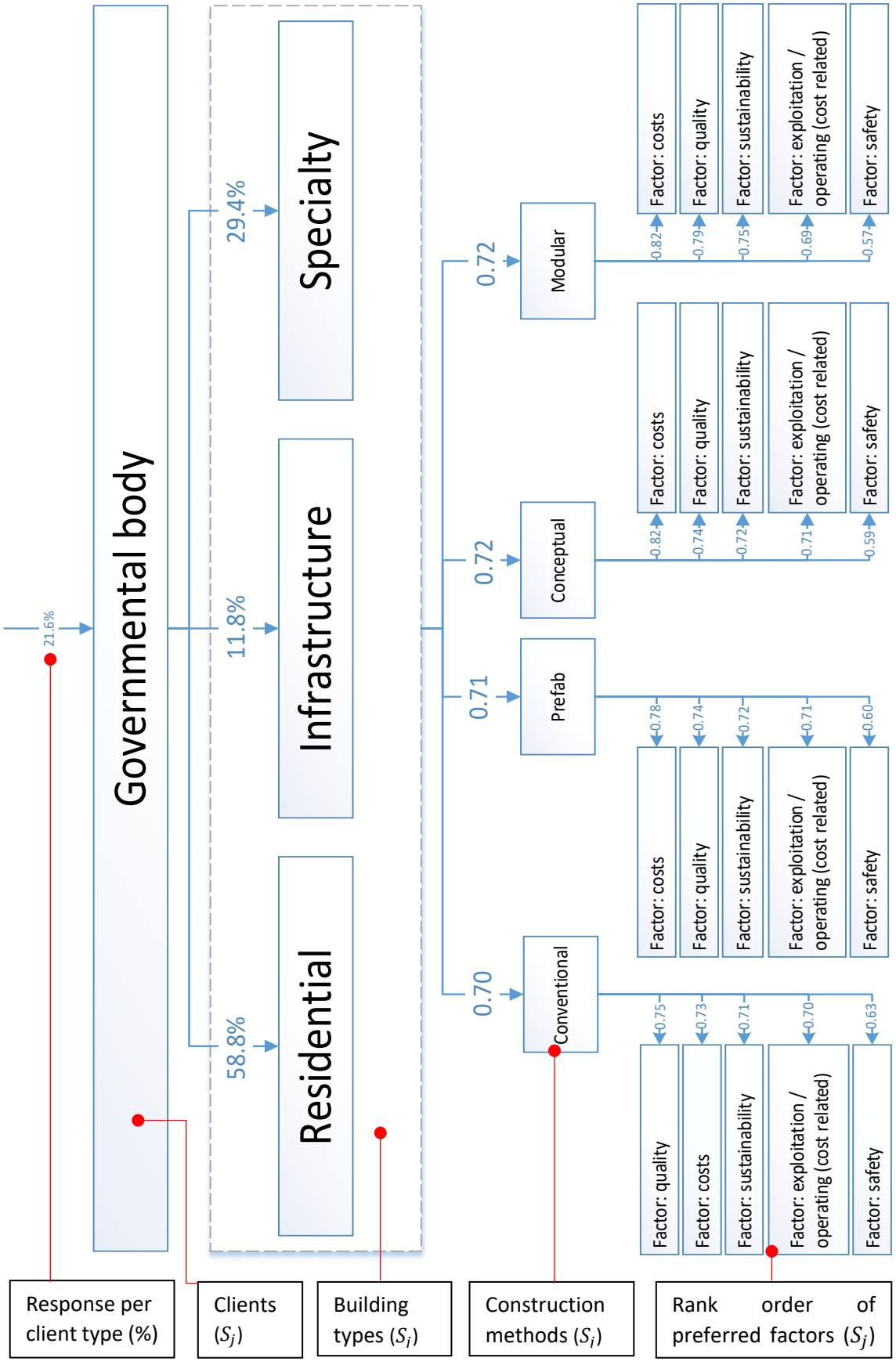
	Observed N	Expected N	Residual
Commercial	4	3,5	,5
Residential	51	55,2	-4,2
Specialty	13	13,3	-,3
infrastructure	4	,0	4,0
Total	72		

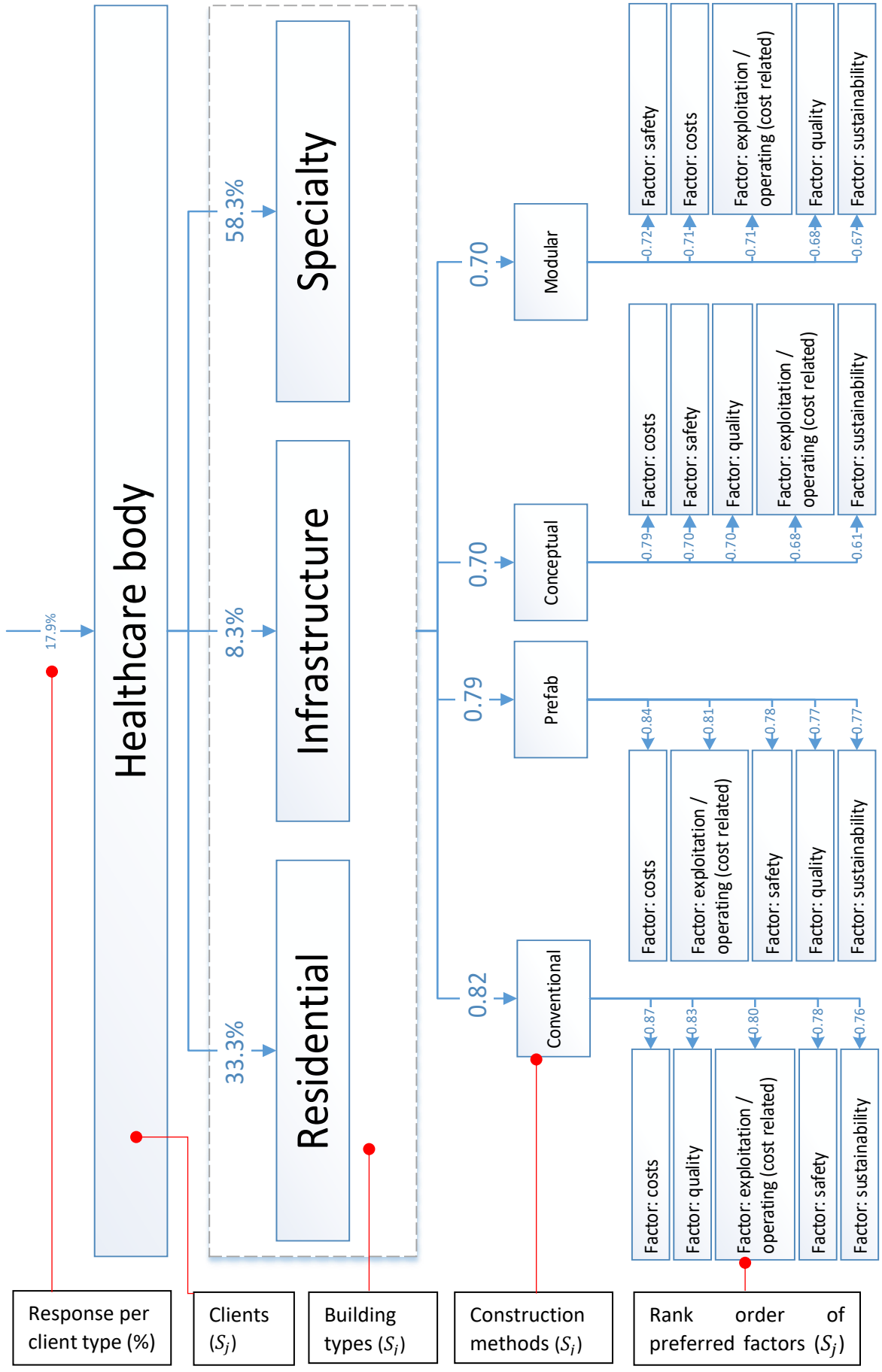
Test Statistics

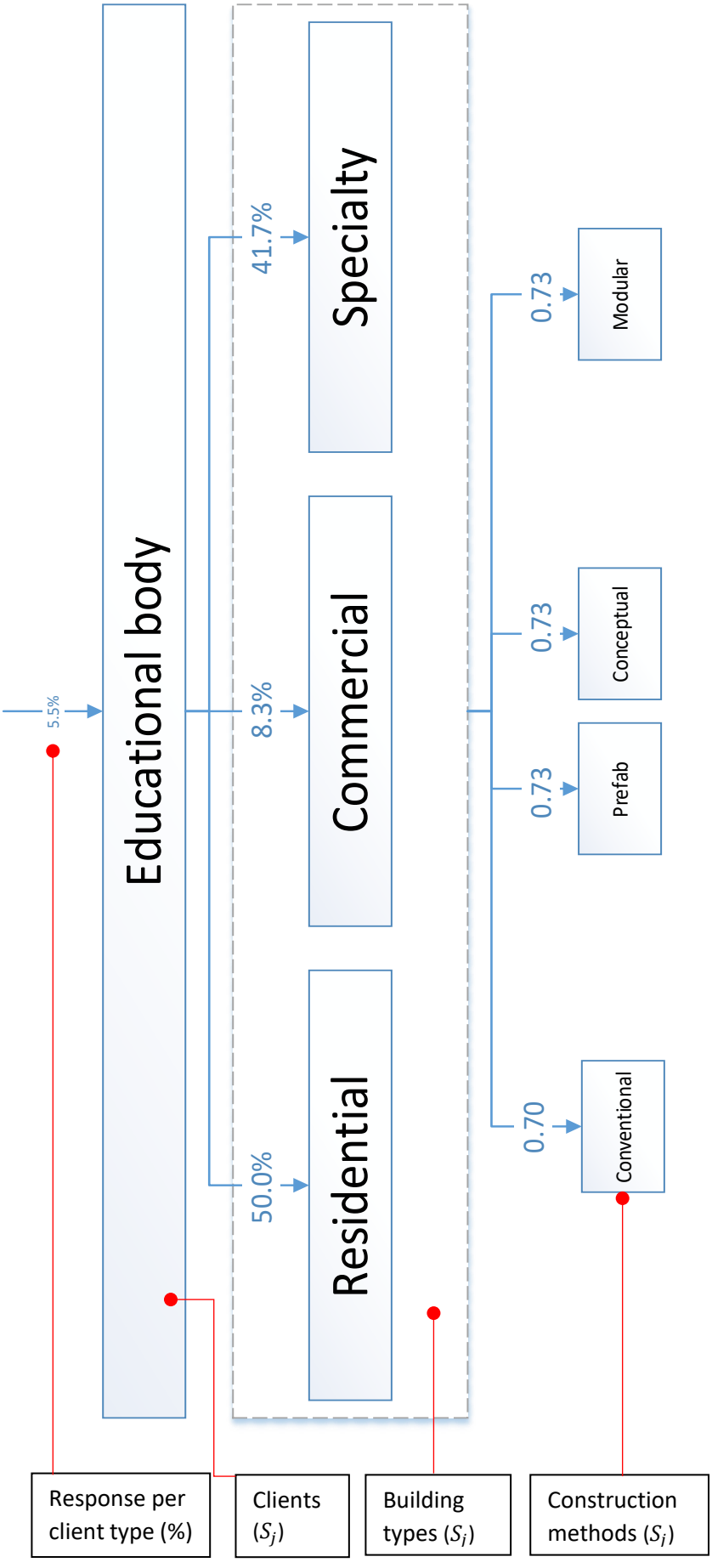
	Please_choose_the_building_type_that_is_mainly_used_in_your_organizations_portfolio
Chi-Square	22214,861[a]
df	3
Asymp. Sig.	,000

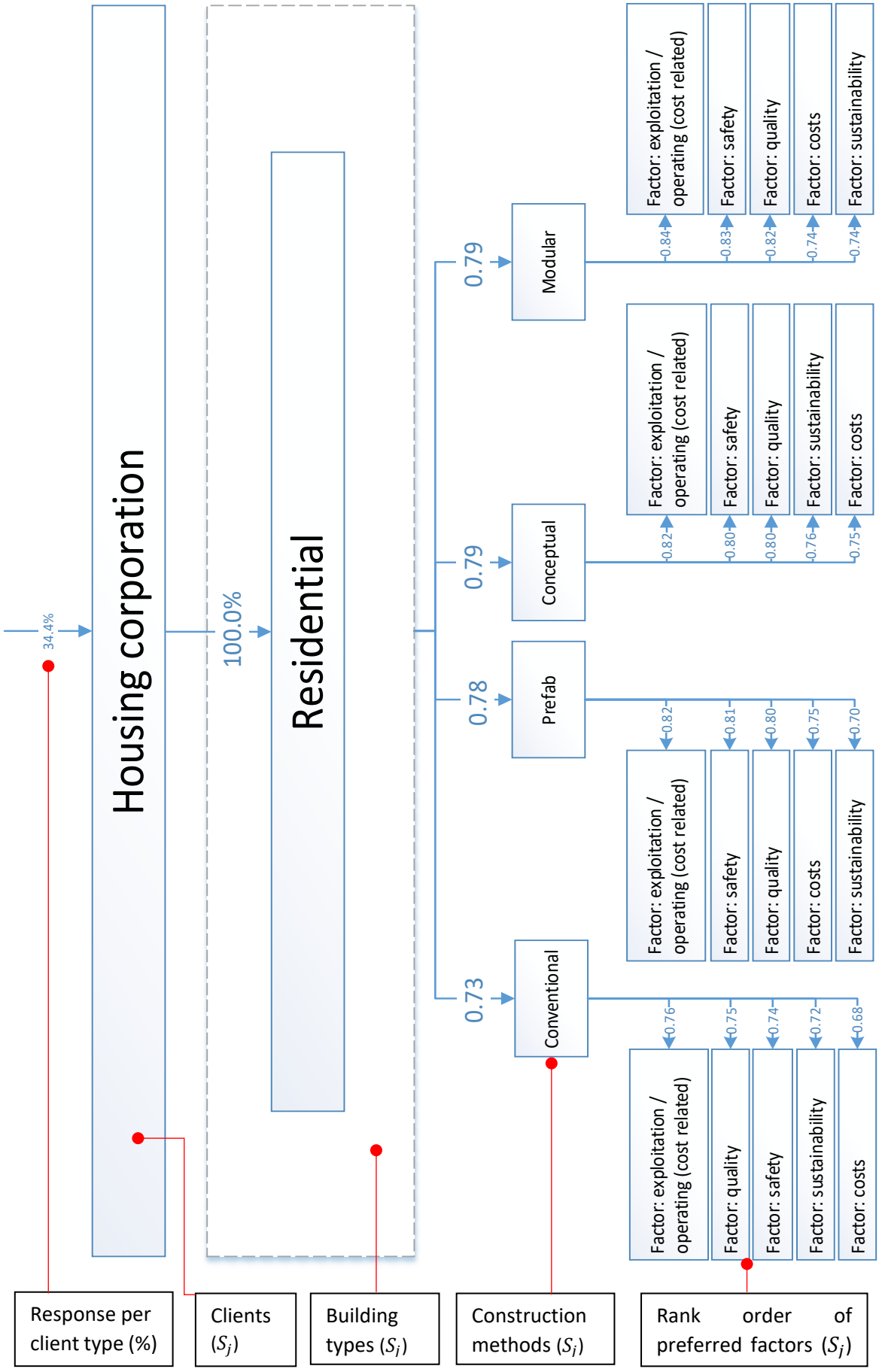
a. 2 cells (50,0%) have expected frequencies less than 5. The minimum expected cell frequency is ,0.

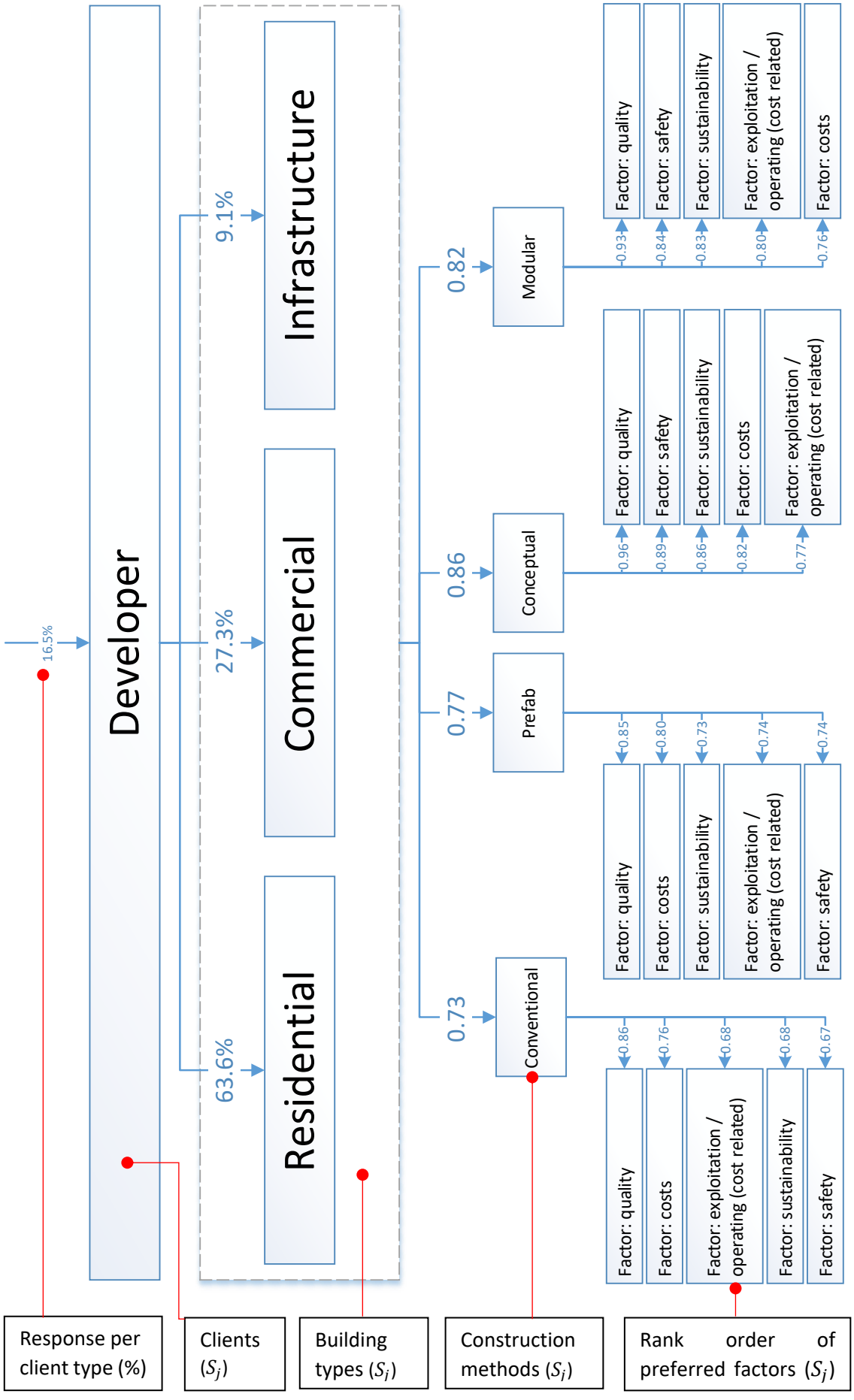
7.7.4 Tree-diagram (per client)

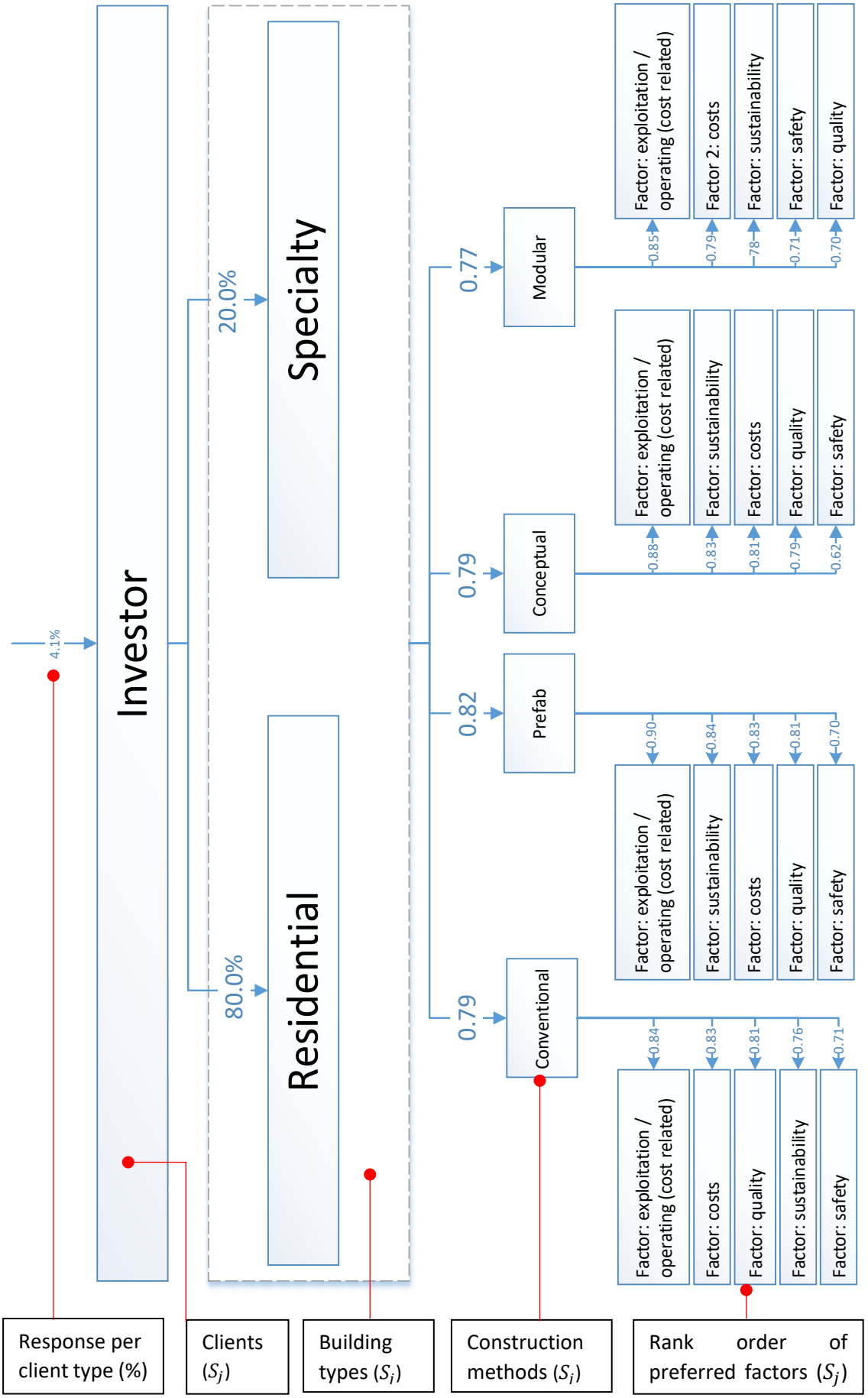



Healthcare body
17.9%
58.3%
8.3%
33.3%
Specialty
Infrastructure
Residential
0.70
0.70
0.79
0.82
Modular
Conceptual
Prefab
Conventional
Factor: safety
Factor: costs
Factor: exploitation / operating (cost related)
Factor: quality
Factor: sustainability
0.72
0.71
0.71
0.68
0.67
0.79
0.70
0.70
0.68
0.61
0.84
0.81
0.78
0.77
0.77
0.87
0.83
0.80
0.78
0.76
Response per client type (%)
Clients (S_j)
Building types (S_i)
Construction methods (S_i)
Rank order of preferred factors (S_j)


Educational body
5.5%
41.7%
8.3%
50.0%
Specialty
Commercial
Residential
0.73
0.73
0.73
0.70
Modular
Conceptual
Prefab
Conventional
Response per client type (%)
Clients (S_j)
Building types (S_i)
Construction methods (S_i)


34.4%
Housing corporation
100.0%
Residential
0.79
Modular
0.79
Conceptual
0.78
Prefab
0.73
Conventional
Factor: exploitation / operating (cost related)
Factor: safety
Factor: quality
Factor: costs
Factor: sustainability
Response per client type (%)
Clients (S_j)
Building types (S_i)
Construction methods (S_i)
Rank order of preferred factors (S_j)


16.5%
Developer
9.1%
Infrastructure
27.3%
Commercial
63.6%
Residential
0.82
Modular
0.86
Conceptual
0.77
Prefab
0.73
Conventional
Factor: quality
Factor: safety
Factor: sustainability
Factor: exploitation / operating (cost related)
Factor: costs
0.93
0.84
0.83
0.80
0.76
0.96
0.89
0.86
0.82
0.77
0.85
0.80
0.73
0.74
0.74
0.86
0.76
0.68
0.68
0.67
Response per client type (%)
Clients (S_j)
Building types (S_j)
Construction methods (S_i)
Rank order of preferred factors (S_j)


Investor
4.1%
20.0%
Specialty
80.0%
Residential
0.77
Modular
0.79
Conceptual
0.82
Prefab
0.79
Conventional
Factor: exploitation / operating (cost related)
Factor 2: costs
Factor: sustainability
Factor: safety
Factor: quality
Factor: costs
0.85
0.79
78
0.71
0.70
0.88
0.83
0.81
0.79
0.62
0.90
0.84
0.83
0.81
0.70
0.84
0.83
0.81
0.76
0.71
Response per client type (%)
Clients (S_j)
Building types (S_i)
Construction methods (S_i)
Rank order of preferred factors (S_j)