Configurable housing:
End-user participation in the design process

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Abstract - Configurable housing is a recently developed method in which the end-users configure their home and influence the building by participating in the design process. The purpose of this research is to study the current situation of configurable housing in the Netherlands. The results will serve as a basis for a design of configurable housing in the graduation lab.
Through the analysis of reference projects information is found on the process, system and choices of configurable housing. Theories and models are developed which are compared to different sources. Process models show that a lot of opportunities lay in combining them. By comparing the reference projects a configurable method is devised focused on collective housing.
The research concludes that configurable housing has a lot of opportunities for application in collective housing. By developing a configurator with certain steps the end-users gain more influence in the design process and the apartments will become better fitted to their wishes.

Keywords: Configurable housing, end-user participation, customizable, co-commissioning, collective private commissioning, consumer oriented development, building systems, open building.

1. Background
In 2060 there will be 1 million extra households according to a CBS research from 2012(Duin & Stoeldraijer & Garssen, 2013, p. 11). Besides that there is a drop in housing production since 1973, and will probably continue due to the economic crisis (Otter, 2013, p. 10). In these times of crisis project developers and housing cooperatives are unwilling or unable to cope with the still ongoing population growth. The risks for investing in a large scale housing project are too high. Our society seems to become more and more pluralistic, and therefore a single type of house is insufficient. New forms of living emerge, like living and working combined, urban villas and group living.
A rising trend nowadays as an alternative to project development is private commissioning. This self-build method allows end-users to buy a lot and develop their own house. Study shows people are more interested in owning a house and the government is stimulating this(Woude, 2012, pp. 10-12). The problem with this method of development is the lack of available land and knowledge in construction (Noorman, 2006, p. 10). A lot of sites in the Netherlands are owned by developers and waiting for plans (Plateau, 2013, p. 5). This results in low offer and high prices. Most people don't know how to deal with the process of designing and building a house.
Instead of these unsuitable methods in housing development we should search for new forms. There is already a shift from a supply-driven to a demand-driven housing production. Large-scale Contractors are developing on-line housing configurators where end-users are able to configure their homes. Another important hype is CPC, Collective private commissioning. In CPC a group of clients act as commissioner and lead the project. By skipping the developer a financial benefit of 20% is created (Noorman, 2006, p.).

This paper examines the current situation of configurable housing in the Netherlands. The analysis leads to the development of a configurable method in housing development. In order to study configurable housing the research is divided into 3 subjects. The first is the *process*: What role do the end-users have in the design process? Important subjects here are the moment when certain decisions are made, who the decision made and what parts of the building where affected by the decision. The last will come back in the second subject about the *system*: Which systems can be used in configurable housing? This part will be about the division of the building layers in a configurable and fixed part, and the typical systems derived from this. The last subject is about the *choice* the end-user has. How does the configuration work? What type of choices can be made, which building parts are configurable and the balance between configurability and systematics. The 3 subjects embody the process, the system developed by the architect or developer and the choice made by the end-user. The research will conclude in a configurable method for developing housing. The research aims at collective housing in urban areas.
This research will lead to more insight in configurable housing and the configurable method contributes to the general debate. A configurable method in housing development is also a very current subject because of the economic crisis and stagnated housing development.

2. Method

The research is based on the analysis of reference projects and a conclusion in the form of a configurable method. The scheme of the research method is shown in figure 1. The first step is selecting the reference projects and collecting information about these projects. Next is the analysis of the projects on certain subjects related to the process, system and choice. The developed theories and models from this analysis are compared to relevant theories in literature on their similarities and differences. By comparing the reference projects a conclusion is made in the form of a configurable method. Tips and ideas found in the reference projects during the collection of data and analysis are added to the conclusion.

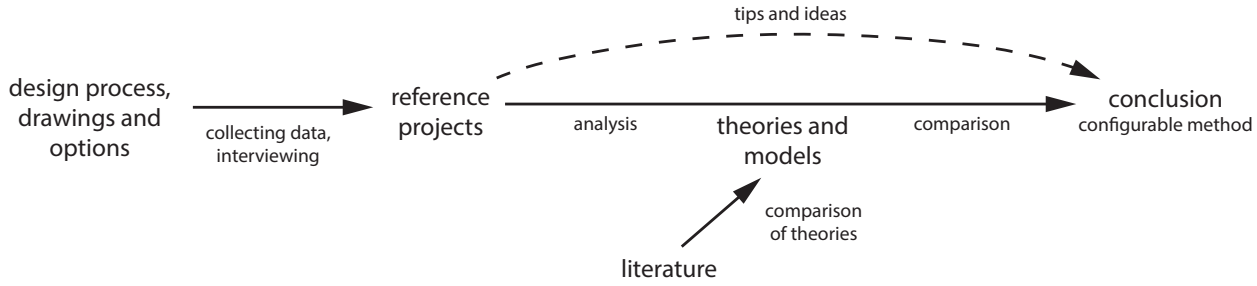

figure 1. Research method (author)

2.1 The reference projects

In figure 2 the selected reference projects are shown by subject. For the subject of process the projects are chosen based on some process model types in which end-users have influence. For each process model 2 relevant and current projects are chosen. Although the TeninOne project is not situated in

The process:	**The system:**	**The choice:**
Superlofts, De Hoofden	Superlofts, De Hoofden	Wenswonen, Heijmans
Patch 22, Frantzen et al.	Patch 22, Frantzen et al.	Deelplan 14, DP6
TeninOne, Roedig.schop architekten	TeninOne, Roedig.schop architekten	Myownhome, VolkerWessels
Wenswonen, Heijmans	E_3, Kaden Klingbeil architekten	Smartcollectie, BAM Woningbouw
Deelplan 14, DP6	Next 21, Osaka gas	Livinghomes
Nautilus, Hein de Haan	Nagakin capsule tower, Kisho Kurokawa	NikeID
	Habitat '67, Moshe Safdie	Audi configurator
	Les Marelles, Georges Maurios	
	Domino 21, J.M. Reyes	

figure 2. Selected reference projects per subject (author)

the Netherlands it is important due to the high amount of collective private commissioning projects in Berlin. Most projects are recently developed or still in progress at the time of this research. For the second subject the reference projects are selected on their potential of being a configurable system and on the variation of systems. This variation results in a variety of solutions which can be compared, to look beyond the obvious solutions. For the subject of choice some projects are selected in which configuration by the end-user is done. The first four projects are typical Dutch housing configurators. The second three are configurators in different or related disciplines, namely shoes, cars and prefabricated homes. These could provide new ideas and insights for housing configuration. For the analysis of the projects information is needed about the design and construction process, the drawings and the options in the configuration. This information is collected by using books, articles and internet websites. It is sometimes difficult to find information due to the fact that some projects are still in progress. Therefore interviews are held to find additional and specific information.

2.2 The analysis in 3 subjects

The process

The design and construction process of each reference project is studied and all phases and steps are written down. The projects are related to process and contract models which are then compared to those in literature. The following subjects will be discussed: The amount of influence of the end-users, the moment the end-users are introduced, managing the influence, decision points of building layers and financing the design phase. The projects are analyzed on these subjects.

The system

For the analysis of the configurable systems 8 building layers are devised and compared to literature. Typical plans of all the reference projects are made using the building layers, of which an example is shown in figure 3. The building layers are then divided in a configurable and fixed part. These configurable systems are subsequently valued on their configurability.

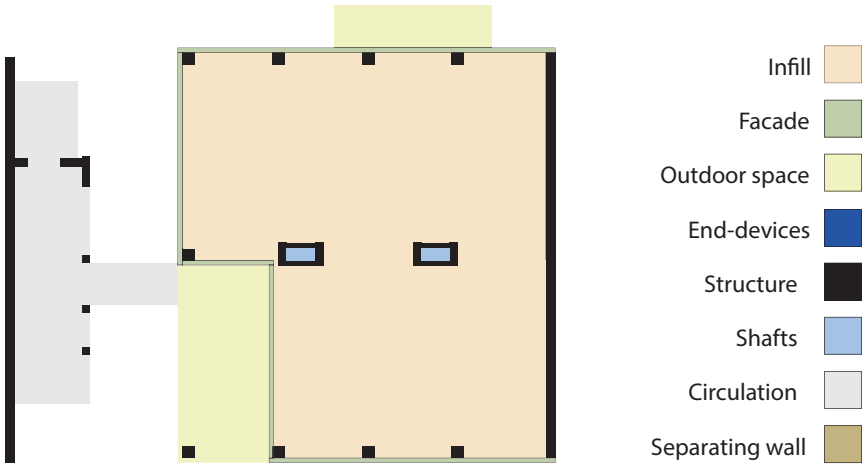

figure 3. Example of the typical plan of the E-3 project (author)

The choice

In the analysis of the choice of the end-users all steps in the configuring process of each reference project are written down. 7 types of choices are devised and compared to literature. The balance between options and systematics is studied of all projects by looking at each step individually. Other subjects are the common steps in configurators, customer priorities and the price influence.

2.3 The configurable method

In order to conclude the research a configurable method is formed for collective housing in urban regions. This configurable method is based on the comparison of the reference projects on certain subjects with the criteria for collective housing. These criteria will depend on the subject discussed. On the subject of process models a combination of 2 models is made as a conclusion. For the second paragraph a target of configurability is devised out of the configurable systems. Each building layer is then studied individually to find the best solutions for configurable housing. 3 reference projects are compared on factors relative to the building layer. In the last paragraph a conclusion is made in the form of 5 steps for a configurator. These 5 steps, including sub-steps and other information, results from the comparison of the reference projects. In all reference projects ideas and tips are found. For instance the Superlofts project stimulates own initiatives to manage the influence of the end-users. These sort of principles and ideas can be included in the configurable method.

3. Results

3.1 The process

Process models

process models are forms of housing development with different distributions in commissioning among the actors. Relevant in this research are those in which the end-users play a part. 6 important process models are:

Private commissioning (PC). In this form the end-users develop their own house by acquiring a lot and initiating the project. The possibilities are to commission an architect and contractor to design and build their house, to buy a design from a catalogue or to build the house themselves. The end-users have a lot of responsibilities and carry all the risks.

Collective private commissioning (CPC). A group of end-users act as commissioner and lead the project. After finding a lot they commission an architect, advisor and contractor to develop the project according to their wishes. The end-user group carries all the risks.

Co-commissioning (CC) is a model in which the group of end-users and the developing actor share the risks of development. In the Superlofts project the architects explains this as CPO 2.0, a next level form of Collective private commissioning. Co-commissioning is a very newly developed type of design process where the architect is often the initiator and developer of the basic concept of the plan. The end-users are introduced later in the process and have much less influence on the design than in Collective private commissioning.

Consumer-oriented development (COD): Another recently developed process model is consumer-oriented development. This is basically a more demand-driven type of project development, in which the end-user is able to configure a pre-made design. The configurator and the options are adjusted to the probable wishes of the end-user. Although it gives a feeling of control, the end-user has little influence on the design.

Project development (PD): The developing party acquires the lot and develops the project. They make all decisions and carry the risks. The end-user buys the house or apartment from drawings or after completion.

Participatory development (PD) is a hypothetical process model related to the configurable method. It is a combination of co-commissioning and consumer-oriented development and is named participatory development, for the participating role the end-user has. The end-user participates; has a pre-managed say on a lot of aspects in the design but less influence on the design and construction process.

Noorman describes the same kind of process models (Noorman, 2006, p. 7). Instead of project development she names it serial construction. Woude adds two process models to this list; Social Personal Commissioning (SPC), and Multiple Commissioning (MC) (Woude, 2012, pp. 150-160). Social Personal Commissioning is a variant on Consumer-oriented development for it concerns rental space instead of sellable homes. The tenants configure their home in the same way as in Consumer-oriented development. Problems arise when there aren't enough tenants or when a tenant moves out. In Multiple Commissioning the end-users are able to decide which kind of process and amount of influence they want within a single project. The plurality of the process forms the name Multiple Commissioning. This type of project needs some scale to be efficient and incorporate all process types.

Amount of influence end-user

As a result of the research to the design process of configurable housing some process models are defined and arranged according to the amount of influence the end-user has in the design process. This also means that the amount of influence of the developing actor decreases accordingly, as shown in figure 4. The reference projects are classified in the Collective private commissioning, co-commissioning and consumer-oriented development types of process models.

The configurable method is shown in figure 4 as an intermediate form of Co-commissioning and Consumer-oriented development and is named participatory development. It combines the configuring element of Consumer-oriented development with the balanced amount of influence of the end-users in Co-commissioning.

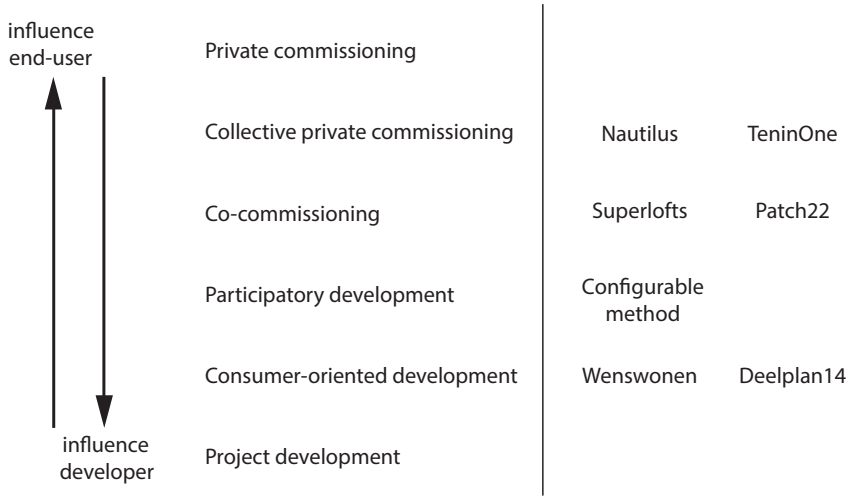

figure 4. Process models arranged in infuence of end-user (author)

Contract models

For each building process a contract model can be defined, as shown in figure 5 and 6. A contract model defines the contractual relationships, the planning, the distribution of risks and the tasks of actors (Wamelink & Bennekom, 2010, p. 113). In figure 5 the contract models for the configurable method and the Superlofts project are made as a result of the research and in figure 6 the traditional and project development models are shown (Wamelink & Bennekom, 2010, pp. 117-122). A Collective private commissioning building process like the TeninOne project has the traditional contract model with the end-users group acting as the commissioner. A project like Wenswonen has the project development contract model.

In the contract model of collective private commissioning (traditional) the end-user group is initiator and contacts all other actors. The end-user group lacks the knowledge of construction and management to be successful in this role, and therefore the architect should act as initiator and intermediary as shown in the configurable method. In the project development contract model the developer or cooperative distributes all tasks to the other actors and has therefore a lot of unwanted influence on the project. By reducing their role to that of investor the influence is limited and left to the architect and more importantly, the end-users.

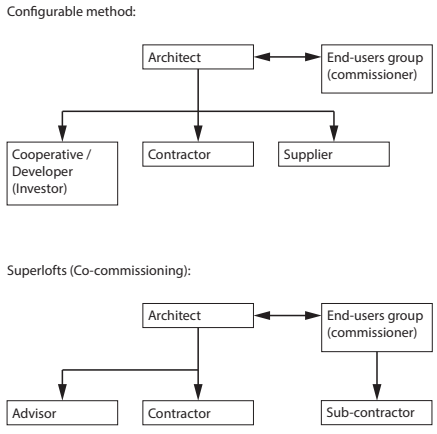

figure 5. Contract models (author)

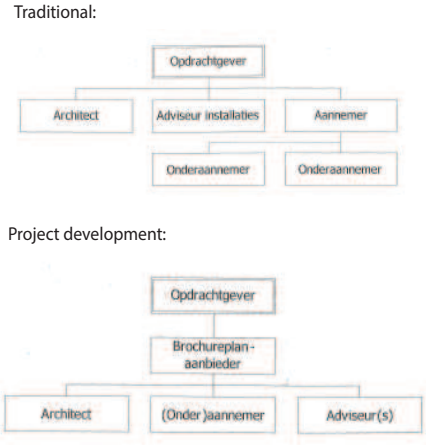

figure 6. Contract models (Wamelink & Bennekom, 2010, pp.117-122)

Moment of introducing the end-user

The moment the end-user is introduced in the design process is an important aspect in the building process of configurable housing. From that point the end-users start influencing the design and will become financially bound to the project.

In figure 7 the design phases are put in sequence with the moments of introduction shown of each reference project. The moments seem related to the amount of influence of the process models (figure 4). In the CPC model the end-users are introduced before the design is made and can take part in the initiation as well. This gives them the opportunity to influence the entire design. In co-commissioning the end-user is introduced after the preliminary design, in the detailed design phase. Therefore the influence is limited to more specific aspects of the already made design, like the type of floor or the divisions in the facade. In consumer-oriented development the end-user is introduced when the design is practically finished. This design includes certain options from which the end-users can choose from.

Another option could be an early involvement but more controlled influence on the design, by giving the end-user options to choose from. This results in a combination of co-commissioning and consumer-oriented development: The configurability is increased and the influence is more easily managed.

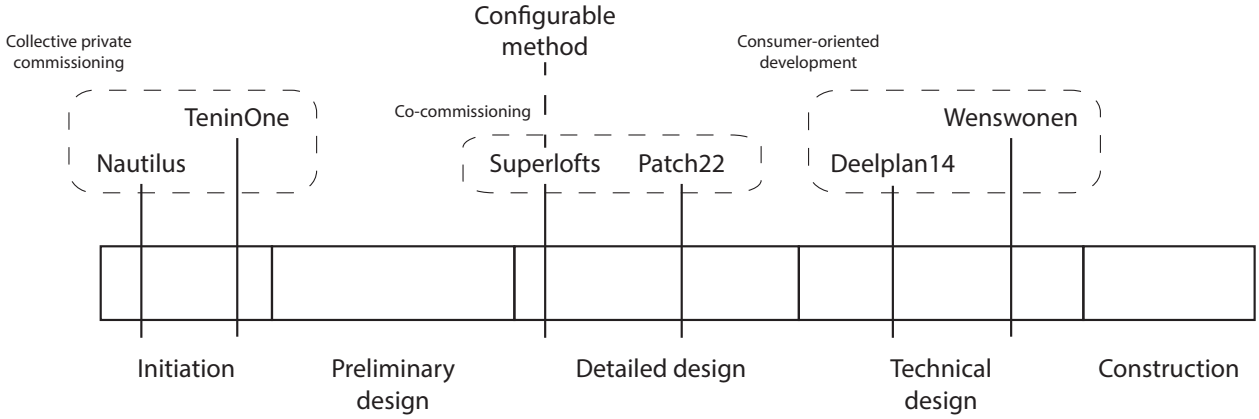

figure 7. Moment of introducing end-users (author)

Influence managed

For each process model seems to be a different way of processing the end-users influence. The most obvious is a *personal meeting* between the architect and end-user, which is mainly used in private commissioning. These meetings are also used in collective private commissioning but, since a lot of end-users must be consulted, they are limited to a short time and only the infill of the individual home is discussed. In the Nautilus project these discussions with individual end-users are called *consultation hours.* The most common manner for both collective private commissioning and co-commissioning are *group meetings or workshops*. In these meetings the entire group is brought together for discussion about certain subjects and decisions. A common problem for these process models are the disagreements within a group. The architect has to act as a mediator in these discussions. To prevent disagreements and save time these problems can be solved by preparation. For instance preferences of each end-user about certain subjects could easily counter disagreements. Group meetings can be held at the architect's office or, as in the TeninOne project, at the end-users current home. In this way the architect and other end-users get a sense of the lifestyle of that end-user. In the workshops of the TeninOne project the end-users present their individual infill designs, created in the consultation hours, to the group. In this way ideas are created for the final designs. In the Nautilus, TeninOne and Superlofts projects *own initiatives* by end-users have been started from discussions in the workshops. These initiatives are a great way of enhancing the quality of the project and should be

encouraged. Another manner in which end-users participate in the design process are *task groups*. A small group of end-users is responsible for a certain task, for instance a sustainability task group. In this way the end-users are able to influence the design and the architect can relinquish tasks. Due to the limited professionalism of end-users the scope of the task group should be restricted. In consumer-oriented development the end-users influence is much more regulated by using *configurators*. This digital tool uses steps and options and is further discussed in chapter 3.3. The tool isn't reserved for this process model and can be adopted by others. In both the Superlofts and Patch22 projects in the co-commissioning process model the infill is *self-build* by the end-users. This special type of influence is completely independent from the total design and building process. The end-users are responsible for the design and the construction of the infill.
Concluding can be stated that there are different tools of managing the influence of the end-user, which are related to the process models but not reserved. In the configurable method different tools can be adopted or combined. For instance using the configurator tool doesn't exclude group meetings or own initiatives. While managing the influence a balance must be found between the more time consuming but involved options on the one hand, and the quick but excluded on the other.

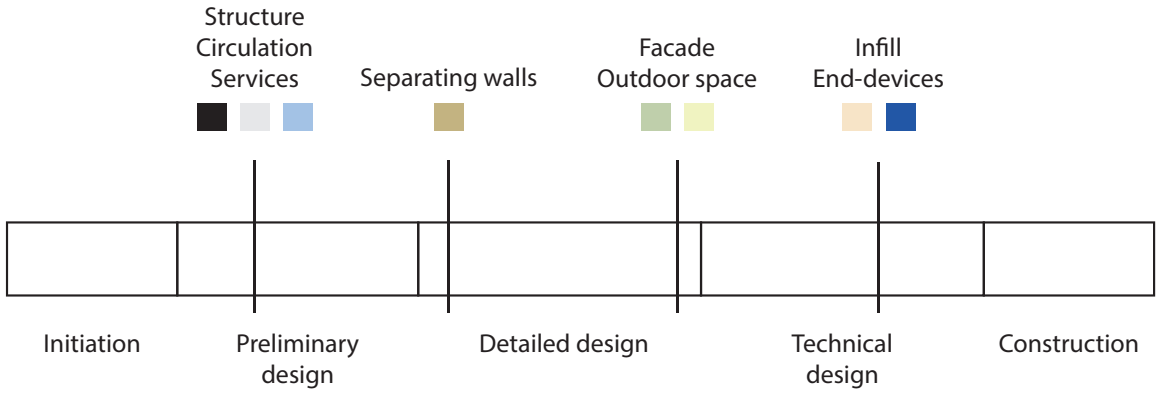

figure 8. Common decision points of building layers (author)

Decision points of building layers
In each design process building layers have to become definitive at certain moments and are called *decision points*. This is important in configurable housing since it is not always the architect who decides. In this research 8 building layers are defined and further explained in chapter 3.2. The common decision points of the reference projects are shown in figure 8. In most reference projects the fixed layers are decided early in the design process, and create a frame in which end-users configure the other layers. These fixed layers are mostly the structure, circulation and services layers and are decided in the preliminary design phase by the architect. In order to start the detailed design phase the separating walls have to be decided and the allocation of houses or apartments has to be done. After these decisions, done by the end-users, the architect and other actors can start making drawings. The next decision point is at the end of the detailed design phase prior to the building application. For the building application all building layers must be definitive, excluding the infill and end-device layers. These can be configured later, provided they will comply with building regulations. The facade and outdoor space are decided at this point by the architect or end-user. The decision point for the infill and end-devices layers is determined by the moment of contract and the party constructing these layers. In case the infill and end-devices are constructed by another contractor or by the end-users themselves, like in the Superlofts and Patch22 projects, the decision point is independent from the design process. If these layers are constructed by the main contractor they have to be decided prior to the contract.

Financing:
A problem in collective private commissioning and co-commissioning is financing the design phase. The end-user isn't yet financially bound to the project as in private commissioning and a developer won't cover all costs as in project development. These costs include the work of the architect, advisors and in some cases the contractor. Common in the reference projects is a *pre-investment* made by the architect or initiator of the project. In the Superlofts project a group of architects cover all the costs made in the initiation and preliminary design phase. The same sort of pre-investment is seen in the Nautilus and Patch22 projects. In the Nautilus project the early design phase is partly financed by *investors,* like a housing cooperative or project developer. They can be contracted to finance the design, but also for *backstop*. Backstop is the ensuring by investors to buy all leftover houses or apartments which aren't sold. This guarantee prevents stagnation of the building process. Another tool in financing the design phase is the *outsourcing of tasks* to other actors in the process. In the Patch22 project a contractor is selected early to share the risks and tasks in the project. An advantage of this is the accurate price generation of the apartments.
The moment the end-users are introduced to the process they are mostly not yet ready to sign a contract. To contractually bind them to the project a *pre-payment* is made. These differ in the reference projects. In the Superlofts project a participation agreement is signed and an amount of 1000€ is paid. For the Nautilus project only 25€ is paid for registration into the group. In Patch22 the amount for registration is set to 5000€. With these payments a part of the costs made so far are covered. In the Nautilus project an additional payment of 16000€ is done to cover all development costs. The pre-payment is subtracted from the total price, for which a *buy-option contract* can be made and which is signed in a more definitive phase in the design process. In the Superlofts project a *buyers association* is created for the end-users group. Before construction starts the commission and lot are transferred to the buyers association.

3.2 The system

Building layers

For the research to configurable systems the buildings will be divided into 8 different building layers which are important in configurable housing. These layers can then be assessed on their configurability by end-user. In figure 9 the 8 layers are illustrated. In his doctoral thesis B. Leupen does research to the permanent and changeable parts in buildings. For several cases Leupen uses 5 layers to define the framework and generic space, or fixed and configurable part (Leupen, 2002, p. 32). The layers are developed according to the function of the elements, and are structure, skin, infill, serving elements and circulation. When comparing the 5 layers of Leupen to the 8 layers in this research we conclude that 4 layers are the same: the structure, facade, infill and circulation. The serving elements layer of Leupen is divided in end-devices and shafts in this research. The separating walls and outdoor space layers are extracted from the 4 basic layers due to their importance in configurable housing.

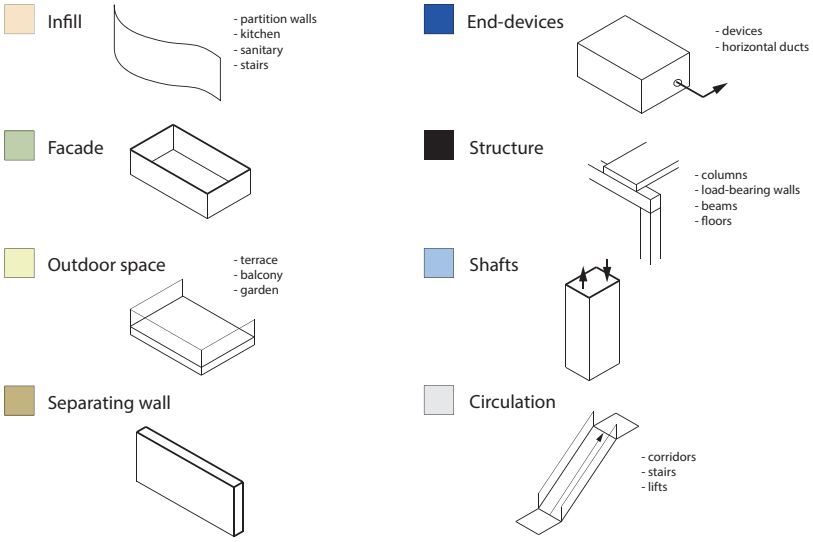

figure 9. Building layers (author)

Configurable systems

For each reference project the building layers are assessed on their configurability. An example is given of the Marelles project in figure 10. The building layers are divided in a configurable part on the left and a fixed part on the right. Not every building layer can be completely assigned to one or the other. For instance the outdoor space in the Marelles project can be configured by the end-user, but is limited to certain parts and sizes. Therefor this layer is set halfway between fixed and configu-

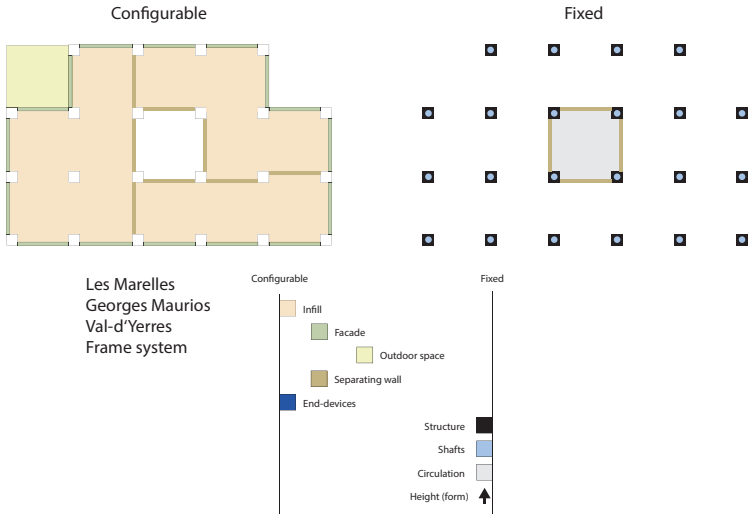

figure 10. Configurable and fixed in the Marelles project (author)

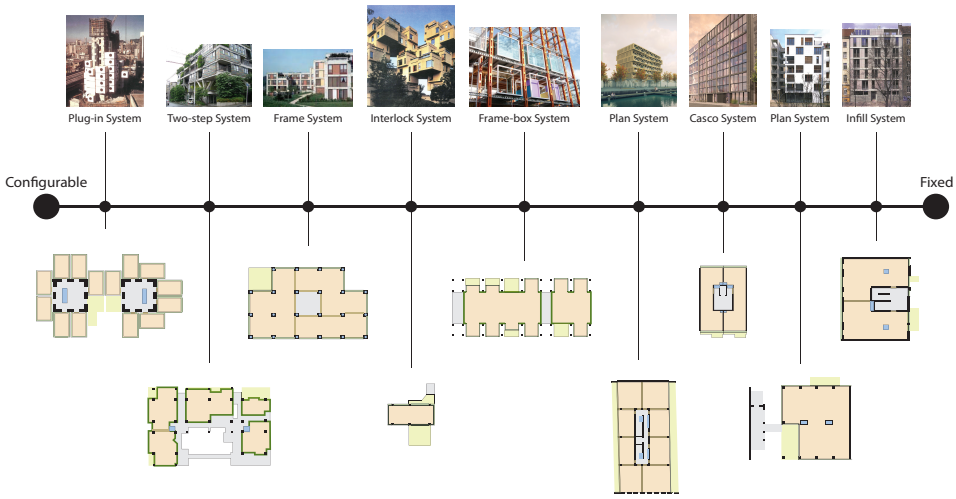

figure 11. Configurability of reference projects and systems (author)

rable. The configurability of a project depends on the number of configurable layers, and the matter of configurability of these individual layers. By doing so the reference projects can be ordered by configurability as shown in figure 11. On the left end are the most configurable projects and on the other end the most fixed. Each project can be seen as a different configurable system, named after the technical organization of the project. The plug-in system of the Nagakin capsule tower is the most configurable system. This doesn't mean it is the most suitable system for the envisioned configurable method. Further evaluation of each building layer is necessary to achieve this. What we can conclude is a realistic target of configurability for each building layer in the configurable method. In figure 12 the building layers are divided in configurable and fixed. From the analysis it seems feasible to set the first 5 building layers to configurable. Since the outdoor space is partly situated in collective areas it is not fully configurable by every end-user. The structure and shafts are fixed layers due to the vertical dependence, and because there is no desire to configure these layers. Circulation areas are mostly fixed, excluding the independent parts of each end-user. The height has a fixed size but is configurable in the number of floors chosen.

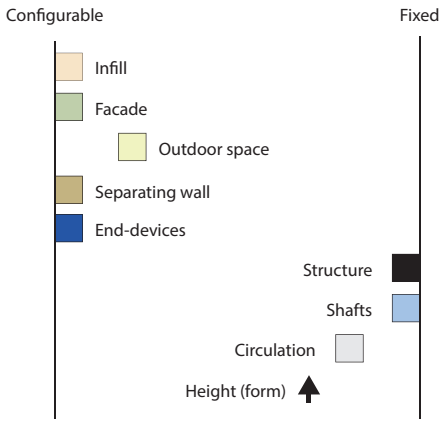

figure 12. Configurable and fixed in the configurable method (author)

By evaluating the reference projects on each building layer the best solutions for the configurable method can be chosen. For practical reasons the separating walls are included in the Structure layer and the shafts and end-devices are combined in a Services layer. For each layer the 3 most suitable projects are compared. The configurability of the layer is always decisive. Next are other factors relevant to that layer on which the reference projects are compared.

Structure

The Casco system of the Superlofts project is an efficient and cheap method for housing but excludes the possibility for configurable sizes. In the slightly more expensive method used in Patch22 with columns and separating walls, different sizes are possible. In the last reference project prefabricated modules are used to create different sizes, but this is dependent on the underlying apartments. The plan system is most configurable and therefor e the best solution.

Facade

The curtain wall used in the Superlofts project has not many options due to its unilateral form and inflexible frame. Both the Next21 and Patch22 projects have different possibilities for the end-users. The cold construction in the Next21 project is unsuitable in colder climates and therefore the last project seems the best option.

Infill

For the infill layer the Superlofts and Patch22 projects are most suitable. The plug-in system is an interesting solution but is limited by its size. The first two are very similar but differ in that the Patch22 project has a raised floor with tile grid. These tiles create a systematic tool for configuration and is therefore the better option.

Services

The most common solution for services in housing is that used in the TeninOne project. A disadvantage here is that the end-devices must be placed at the shafts and is therefore not configurable. A better solution is the usage of a raised floor as in Patch22. Another option is leading the ducts via the columns and beams but this results in an unadaptable system.

Circulation

A typical solution for circulation in housing like that in the Superlofts project is unsuitable for housing with configurable sizes. Two suitable solutions are those in Next21 and E_3 which are approximately equally evaluated. Each have different advantages and either one can be chosen or combined.

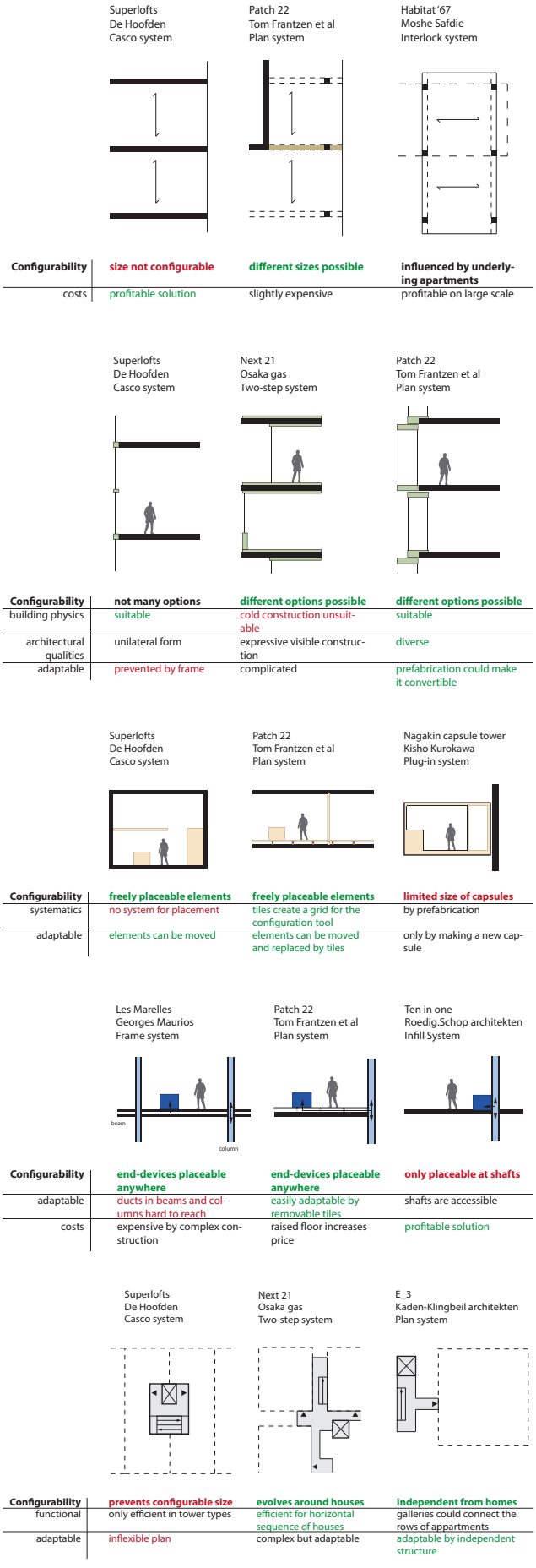

figure 13. Evaluation of building layers (author)

Outdoor space
The first relevant project is Next21 in which the outdoor space is configurable within the structure. Disadvantageous for the building physics in this solution is the swinging insulation line. The second project isn't fully configurable due to the underlying apartments. The Domino21 project is most suitable due to its independence.

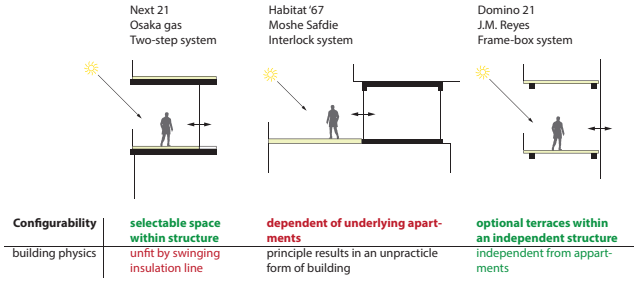

figure 13. Evaluation of building layers (author)

3.3 The choice

Types of choices.

During the research to the reference projects 7 types of choices are extracted: Location, size, type, division, addition and material. In figure 14 an overview is given of the types of choices of each reference project. The reference projects are set vertically and the types horizontally. Grey pieces mean the type of choice is present in the configurator, while at white pieces not. Some reference projects aren't bound to a location and therefore this can't be configured. Choices of type and material seem to be very common and size very rare. Choice of upgrading of technical devices can mainly be found in product-like configurators. The most desirable configurator would include all 7 types of choices, to give the end-user maximum configurability. Woude also defines some types of choices in the book Community Architecture (Woude, 2012, p. 222). In addition to the already mentioned types he adds choices about the process, collective functions, urban plan, outdoor space, choice of architect and architecture. In these types certain physical parts of the end-users home are included as well as subjects of the building process. It is therefore not applicable as a theory about types of choices in general, but still a good summary of the choices in configurable housing.

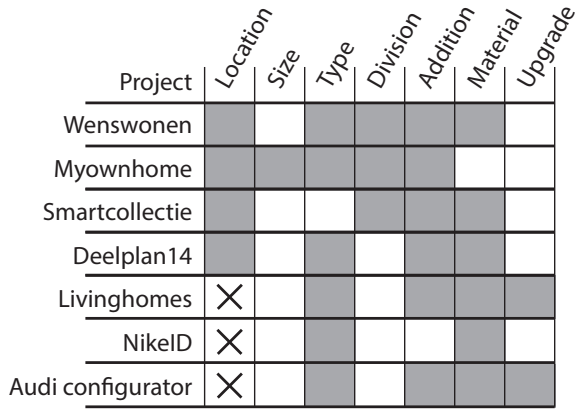

figure 14. Types of choices in reference projects (author)

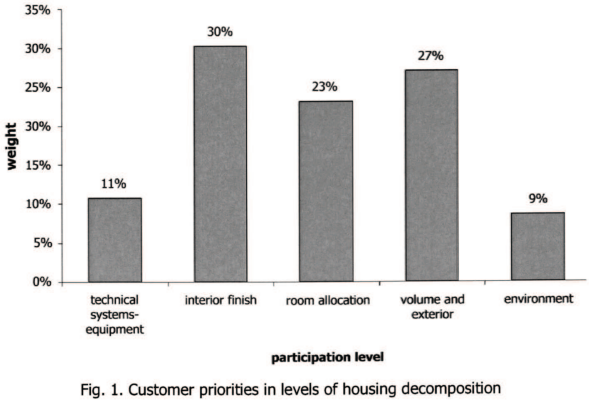

figure 15. Customer priorities (Eekhout, 2005, p. 116)

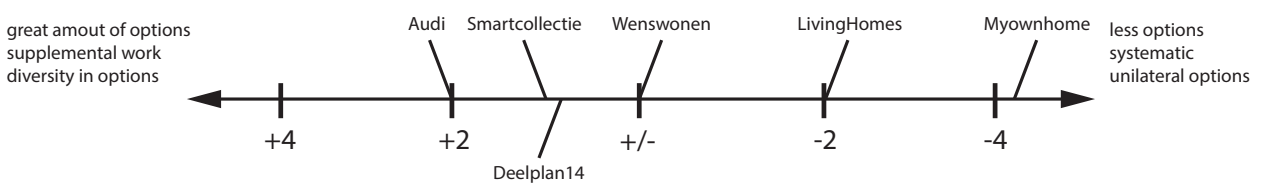

figure 16. Balanace between options and systematics (author)

Parts to be configured
When studying the reference projects a variety of building parts can be configured. Most common are the facade, roof and infill of the homes. From the section of system analysis we can understand this is a logical phenomenon because these choices don't effect the fixed layers of the building. By choosing a location the lot is automatically chosen. In the case of Myownhome and Livinghomes the kitchen and bathroom can also be configured. In the Livinghomes configurator the flooring and bathroom tiles can even be chosen, but this is of course due to the level of finishing of the home. The matter of production scale is also an important factor in the amount of parts to be configured. The Audi configurator seems to have an endless amount of configurable parts like the engine, color, wheels, seats, mirrors, lights, A/C etc. In the NikeID configurator every part of the shoe can be configured, but only in material. Still this configurator is able to create a unique shoe for every user. In figure 15 a study is shown to customer priorities in housing (Eekhout, 2005, p.116). 3 subjects stand out which refer to the infill and exterior of the home and the types of choices of material, division and size. These are therefore important subjects in the configurable method.
Balance of options and systematics
An important fact in configuration is the balance between the options for the end-user and the systematics of the project. More options and more diversity in options means more work for the designers and a more complicated project. There is also a limit to which the amount is still useful to the user. On the other end is a very systematic configurator in which a low amount of options result in less design work and a simple system. Unfortunately this cannot be experienced as very configurable by the end-user. In figure 16 the balance is shown for the reference projects. By valuing the steps in the configurators by +,+/- or - for the amount of options, the balances of reference projects are evaluated. The Myownhome project is very systematic and has a low amount of options for each choice. The difference between the options is also low which results in very unilateral designs. The end-users may wonder if they have really configured their own home. The advantage is that the systematic project is easy to design and build, which also results in low prices. A project with a great amount of options is the Audi configurator. The supplemental work for designing and building all options is absorbed by the scale of production. This would be unfeasible for housing projects. The Wenswonen project seems to be in balance. In the step in which the division of the infill is configured the end-user has sometimes around 30 options to choose from and seems a bit too much. The difference in cladding material is quite low and could be extended. An amount of 3 to 8 options with high diversity seems to be appropriate and will be an aim for the configurable method.
Price influence
A common tool in the studied configurators is the indication of the price. A lot of choices have a direct influence on the price which is shown in a price table. The downside of this tool is that expensive options tend to be less chosen and may threaten the diversity of the project. Therefore there should also be different options which do not influence the price of the house in the configurable method. Another useful tool is the indication of energy label and energy efficiency in the table, which can be found in the Livinghomes and Audi configurators.
Steps
The configurators in the reference projects use steps to configure the homes. In each step a building part is configured by one or more types of choices. Undermentioned are 3 reference projects and their simplified steps.
Wenswonen: 1. location 2. house type 3. infill division 4. facade division and material 5. garage/ storage additions.
Myownhome: 1. house width 2. location 3. house type 4. infill division 5. facade division and additions 6. kitchen material 7. bathroom material.
Deelplan14: 1. location 2. roof type 3. house extensions 4. facade material.

Steps	Parts	Time of decision	Configurable layers	Sub-steps	Type of choice	No. of choices	price influence
Step 1: location	building section	start DO	Separating wall Circulation	choose height section and side	location	3x section, 2x side 6 in total	higher price for more desirable sections
Step 2: size and shape	blocks in grid	start DO	Separating wall Circulation	choose length of plan	size	unlimited	price per block
				choose number of floors	size	unlimited	price per floor
				choose voids	size	unlimited	voids lower price
				choose special blocks	type	2 types, unlimited	no price influence
Step 3: infill modules	infill elements	DO, TO or independent	Infill End-devices	choose infill type	type	6 types	
				choose size and type of module	size and type	5 modules per type, 30 in total	price per module
				choose materal of module	material	3 materials	no price influence
				choose upgrades	upgrade	3 upgrades for appliances	upgrades raise price
				place the module in the house	division	unlimited	no price influence
Step 4: facade	facade parts	end of DO	Facade Outdoor space	choose facade material	material	4 materials (3 choices)	no price influence
				choose technical specifications	upgrade	3 upgrades	upgrades raise price
				choose type of facade	addition	5x add-on, 3x balcony,15 total	balcony and out raise price
Step 5: collective space	terraces	end of DO	Outdoor space	fill in preferences for functions	type and size	5 types	higher price when chosen
				fill in preferences for spaces	type	5 types	no price influence

figure 17. Steps of configuration in the configurable method (author)

The most common first step in these projects is the location. Following is the house type or size, which is related. Both the Wenswonen and Myownhome continue with the infill division as next step, and the facade is a common last step. The Wenswonen project adds a garage/storage step and the Myownhome project some interior materials. In figure 17 the steps in the reference projects are translated into 5 steps in the configurable method. As a fifth step the collective space can be configured because of the importance in collective housing. For each of the 5 steps the building part, decision point and building layers are indicated, which are discussed in the previous text. The steps are then divided in sub-steps which relate to a type of choice. For each sub-step an appropriate number of options and the price influence is indicated based on the analysis in this chapter.

Location

Choosing a lot is the most common first step in configurators. Since the configurable method is focused on collective housing and the sizes are configurable, a building section is chosen instead of a lot. In the TeninOne project the end-users are able to pick a floor, which have different price factors. This is due to the higher desirability of the upper levels opposed to the lower levels. The same difference in desirability will most likely exist between south or west oriented apartments and north or east oriented apartments. Therefore a building section is chosen of upper, middle or lower apartments and south/west or north/east oriented apartments.

Size

In most reference projects the size is only partly or indirectly configurable, although the volume of the house is an important subject in configuration (Eekhout, 2005, p.116). In order to meet these desires of configurability both the length and number of floors should be configurable. The width is left out to guarantee sufficient daylighting in the apartments. To control the choices in lengths of the apartments, measurable blocks can be used. In this manner a tool is created in which blocks can be added horizontally and vertically, and have a fixed price. When multiple floors can be chosen the floors will need voids and stairs to physically and visually connect them. The voids are also chosen in blocks and lower the total price. In the Patch22 project separate units can be chosen and connected to create work and living areas. These separate units are translated to special blocks which can be placed within the configured sizes.

Infill

The division of the infill is configured in the reference projects by choosing from some standard layouts. These divisions are quite similar to each other and aren't able to react to the specific wishes of the end-users. The diversity of specific wishes asks for an unlimited amount of possible layouts, which is systematically possible by using freely placeable modules. This principle simplifies the configurator tool thus created for the infill division. By using different types and sizes of modules the diversity is increased. In the Myownhome project the material of the infill can be chosen which is,

according to the research of Eekhout, the most desirable subject of participation (Eekhout, 2005, p.116). By adding 3 material types to the selectable infill modules these wishes are met. The self-design tool by the placement of modules can be complicated for end-users. In the Patch22 project several example layouts are created which can be modified. They function as a startup and to show what is possible. In case the different types and sizes of modules aren't sufficient for the specific wishes of the end-users custom modules can be designed by the architect.

Facade

In nearly all reference projects the configuring of the facade seems to be a very important subject. It is the image and expression of the house or product, and the most visual element of the configurator. It differentiates the houses from each other. The demand for differentiation and individuality is apparent in the NikeID configurator, in which the color of all parts of a shoe can be chosen. Collective housing should have a feasible amount of materials to choose from while still be satisfactory for the end-users. To prevent a favorite choice of all end-users whereby an unilateral facade results, The prices of all material options have to be the same. In the Deelplan14 project the material and type options are different for every end-user to strengthen the diversity. By simply leaving one option out for every end-user, diversity in the facade is created, and the configurator can suffice with 4 options. The same interdisciplinary view on the NikeID configurator can be done on car configurators like that of Audi. In this configurator a lot of choices can be made on the performance of the car, which aren't spatial or visual. The end-user, or in this case the customer, can choose to upgrade the engine for a certain price. The choice to pay for better performances is left to the end-user. The same principle could be adopted for the energy performance of the facade, which seems to be a desirable choice for the end-users. A third sub-step in the configurable method is the type of facade, which is another way of diversifying the project. Types like add-ons, balconies and loggias could be chosen and simultaneously able the end-users to configure the width of the apartments.

Collective space

An extra element in collective housing is the collective space of additional functions and outdoor areas. In chapter 3.1 is discussed how these kind of choices are made in workshops in CPC and co-commissioning projects. These choices can be adopted by the configurator in the form of preferences. Decisions on collective spaces can then be made, based on the preferences of all the end-users. The preferences will also prevent discussions and disagreement within the group.

4. Discussion

Conclusion

This paper has given some insight into configurable housing in the Netherlands. The greatest advantage of configurable housing is the many different options whereby the configured house fits much better to the wishes of the end-users. The housing answers to the demand and is specially made for each user. By combining the end-users in a group and applying a pre-made configurator a lot of risks are avoided and a financial benefit is created. The pre-made design consists of some fixed and configurable layers, and is therefore highly regulated. The configurator ables the end-users to control their design with devised steps. The differently configured houses or apartments create a lot of variety in the facade.

But configurable housing has some disadvantages. The most important is the extra work that has to be done to design the different options. These need to be well targeted at the wishes of the end-users, to prevent options from being not chosen. The design process in which the end-users participate also asks for extra time and attention. A risk is the stagnation of the process by disagreements within the group. The financing of the early design stage has to be well thought out. Another important subject is the flexibility of the building layers. A configurable layer isn't necessarily adaptable in the future. To sell the house to a next user, some layers like the infill need to be flexible to adapt the house to

different wishes. The temporality of the project needs to be kept in mind.

Recommendations

Opportunities for configurable housing lie in the application in collective housing and the development of a product for industrial building. Most configurators are made for single family homes or products. The adaptation to collective housing could enhance the quality of apartments and make them better fitted to the wishes of end-users. By combining the configurator with co-commissioning process models the end-users gain more influence in the design process, which is better regulated. The development of a fabricated product for configurable homes has also opportunities. Connecting every option to a prefabricated element could result in a feasible product. This opportunity isn't thoroughly studied in this research.

Also interesting and unanswered by this paper is the state of process models like CPC and co-commissioning in the Netherlands. A further research to the design process of these kind of projects could give some more insight. Especially for the co-commissioning which is quite new and unknown.

The configurable method in this research can be useful for further research or development of configurable housing. It can be used as concept for a project or generate new ones. The method contains a lot of useful ideas and principles which can be adopted within another concept.

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