Improved row houses for seniors

The transformation of existing row house dwelling to houses suitable for all ages, especially older people, with the help of wooden structures.

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Abstract

Seniors are staying longer in their own home. A lot of the post war houses are not very suitable to cope with the demands of older people. This research describes the possibility of making an easy to construct wooden addition to existing Dutch row houses. This way older people can stay longer in their own home and age comfortably in their own environment. The research is done mainly with the help of literature studies and research by design. The results describe measures that should be taken into account while designing for seniors; characteristics of after war row houses that should be considered when adding an extension and different kind of wooden structures that can be used to design an addition.

Keywords

Row housing, senior housing, wood construction, CNC, wooden connections, house renovation
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**Introduction**

**Background**

The Dutch population is aging, in all regions of the country the average age of the population increases. In regions such as Zeeland and Limburg the percentages of aged people can be more than 24% of the total population. (Van Duin, De Jong, & Broekman, 2006) A cause for the ongoing increase of older people is the babyboom; the first fifteen years after the second world war a lot of children were born. In the 60's and 70's the amount of newborn decreased again. Nowadays a lot of those babyboomers are (close to) retiring and are getting older. Another cause for the increase of older people is that the living quality of people improves and therefore people tend to live longer. (Jong, 2005)

Currently the Dutch government changed their policy towards housing for seniors. In the past a lot of people who are getting older went to a senior housing complex, but from 2013 the goal is to let people live in their own home for as long as possible. The government wants to adjust the intensity of their care to the personal situation of older people. This way the older people can decide longer on their own life and usually stay longer in their own home. (Aedes-Actiz Kenniscentrum Wonen-Zorg, 2015) It also means that citizens have to take care for themselves more. When older people stay longer in their own house, some of the daily tasks get more difficult. 27 percent of the people over 75 has trouble walking stairs and 15 percent has trouble taking a bath or a shower, so adjustments are often necessary to keep their living environment safe and comfortable. (Platform31, 2015) This is the responsibility for the home owners themselves. Some adjustments are small and easy to install, like door-locks that are easier to use or a louder doorbell with a light, but also bigger changes can be necessary, like a bathroom and a bedroom on the ground floor.

A big part of the Dutch housing stock is build in the 50's 60's and 70's of the last century. After the second world war there was a big housing crisis and there were more then 1.5 million houses build. (Siraa, 1989) A lot of those houses are row houses, a typical Dutch phenomenon. These houses are often not very energy efficient and need an upgrade to make them more sustainable and energy efficient and to prevent them from being demolished. More than 5 million houses have energy label C or lower and of the houses built in the first years after the war half of them even E or lower. (BouwdetailWijzer, 2012; Centraal Bureau voor de Statistiek, 2012)

Currently the use of wood in construction is increasing, due to; the awareness to use more renewable materials; the lower carbon footprint; the natural appearance and current technological improvements such as fillet to factory manufacturing and CNC milling machines that makes working the wood a lot more efficient and affordable. (Planet Ark, 2015; reThink Wood, 2015; Wood Solutions, 2013) Therefore it is relevant to investigate the possibilities of building a wooden construction against the current houses.

These subjects were the motives for this investigation:

**How to transform existing row house dwelling with the use of wooden structures, in order to make it adaptable for people of all ages, especially older people?**

The question of this research is divided in different sub questions; the first part is about the target group, what are the housing wishes of older people? In order to transform a house to a better suit one for all ages, especially older people, it
is important to know what the demands and wishes are for older people which they usually lack in the current row-housing stock. In addition of that a part will focus on how the extra demands can be implemented in row-housing. The second question is on the current housing stock: How can an addition be connected to the current row-housing stock? The last question of this research is about the structure and construction of the addition of the transformation. What wooden construction is best suitable for an addition to the current row houses? By answering these questions an insight is given on how to fabricate a wooden housing extension which is suitable for people of all ages and easy to build against an existing row house.

Method
This research paper consists out of different components that discuss different sub questions derived from the main research question. The emphasis of the research method is different in each of the components.

The first part of this research is about what makes a house suitable for older people. The most important research method for that is literature research. And the investigation will be about what the most common problems for older people are, when they are living in their own home and what solutions there are available for those problems. Also a part that is on how the extra program for the older people can be added to an existing row house. In this part the research the focus is on research by design to investigate the possibilities on adding extra program.

After the program, the research will focus on how to construct against an existing building. A literature study with different construction methods as cases will be the base of this chapter.

The Third subquestion is about how the construction can create different solutions for different family compositions. Research by design, case studies and literature will all be a part of the investigation.

Limits
This research focuses on the transformation of a typical Dutch row house into a house which is suitable for all ages, especially older people, by adding a wooden structure.

So the focus will be on adding a structure to existing houses. Although the structure will partly be made to improve the energy sufficiency of these houses, this paper will not go into detail on climate systems or insulation values. To make an extension suitable for as many houses as possible, the possibilities and limitations will be investigated on standardized types of houses with often thousands of units build alike. Because a big part of the current housing stock is build after the second world war, a couple of those systems will be discussed, together with the traditional housing system in the Netherlands. Only row houses are discussed. The focus will be on the construction and the facade of those houses, because the wooden construction will be placed on the outside: solutions to make a the interior of the house suitable for older people are very specific for each house and will therefore not be part of this research. To make this research focused enough the construction material is decided on forehand; wood. This because it is a building material which has a small carbon footprint, is light, easy to work, has a warm appearance, and can be cost effective. The focus lies on the connections the could be made and not on the types of wood or material properties.
Results

Chapter 1.

How can the needs of senior people be added to existing row houses?

This chapter is divided into two parts, first the specific needs of senior people regarding home comfort are discussed, with a focus on the bedroom and bathroom. Also the demands of families that aren’t met at some row houses are discussed. After that the discussed program will be implemented to a row house, to investigate how this can fit to existing houses.

What are the needs for seniors (and also for families) in current row houses?

Seniors

There are different problems people are facing when they get older. The main problem is that they get less mobile. But most people want to live in their own home for as long as possible. Different studies show that from the people aged between 57-61, 75% wants to stay in their own home as long as possible and from the people aged between 72 and 77 84% wants to stay home. (Doekhie, De Veer, Rademakers, Schellevis, & Francke, 2014) 70% of the people older than 75 even want to stay in their own home until the end of their live. (Van Iersel & Leidelmeijer, 2010). The most important reasons for that are: They are attached to there own neighborhood; They like the environment and house they are living in; They want to stay close to their family. A couple of reasons for people to move are; their house is not a zero step house; their house is only reachable by steps or possible need for care in the future. (Van Iersel & Leidelmeijer, 2010)If senior people want to move it is often because of reasons closely related to the difficulties of getting older. The most important factor is mobility, older people often have problems walking stairs, whereby reaching the bathroom and bedroom get difficult since they are most of the times upstairs. A stair-lift can be a solution for this problem and is often used, but not everyone wants to have a stair-lift, for example because they don’t dare or like to take a stair-lift. So an alternative would be to move the bathroom and bedroom downstairs with an addition to the house.

Bedroom

A couple of interventions in the bedroom to help older people live at home for as long as possible are; a spacious bedroom, with at least 1.1 meter of space between the bed and walls, makes sure a person can get to the bed easily, even if they need a rollator or a wheelchair. (Haak, 2005) Extra space for a possible lifter, which can help immobile people get in and out of bed easily, these lifts often also need a beam or other structural element to be attached to. Enough space for windows makes the room more attractive. An other factor that should be considered is the connectivity with activities related to the bedroom, for example a direct access to a bathroom and the living room reduces the walking distances inside a house. Smaller interventions like lighting with a sensor underneath the bed, a phone next to the bed, remotely controlled windows and sliding doors can also help to increase the comfort inside the house. (Lang zult u wonen, 2015; Overleg Samenwerkende Ouderenbonden, 2013)

Bathroom

The bathroom can be one of the most dangerous places in the house, especially for older people. Because it is often wet, the chance of slipping is bigger than in the rest of the house. Most measures to make a bathroom better suitable for older people are small and easy to install. The most significant issues to reckon with are that the bathroom should be close to the bedroom and also on the ground floor. Also it is important that all the functions of the bathroom can be accessed with a wheelchair, a shower without a shower basin and a sink which is reachable in a wheelchair are examples of ways to make a bathroom better accessible, together with making the bathroom spacious.
enough. Wheelchairs need a free space to rotate of around 1.5 meters in diameter and in the bathroom there should be enough room to rotate a wheelchair. (Haak, 2005)

Small adjustments to help increase the comfort and safety in house are for example: a shower seat, a shower mixer with a maximum temperature, clamps for support to get up, an anti-skid floor and a shower wall bar. (Lang zult u wonen, 2015; Lekker blijven wonen, 2014; Overleg Samenwerkende Ouderenbonden, 2013)

Rest of the house
In the rest of the house the adjustments are often the same as mentioned before, also barriers should be as low as possible, and everything should be easy to access with a wheelchair or rollator. Other adjustments like railings and bars in the kitchen, kitchen equipment on working height, doorhandles where you can’t snag to and remotely controlled curtains and solar shading. (Lang zult u wonen, 2015; Overleg Samenwerkende Ouderenbonden, 2013)

Additional advantage of making an addition for the bathroom and bedroom can be that the garden will become smaller, when people get less mobile it will be harder to keep the garden maintained. Wood also has a warm and natural feeling, which is often appreciated by older people. It can even help to reduce stress levels and lower the heart rate. (Aube, 2013; Kelz C, Grote V, & Moser M, 2011)

General
Important issues that have to be taken into account are the daylight and the building speed. Older people often don’t really like to have a lot of disturbances in their own homes, and therefore it is desirable to make an extension that is easy to make in just a couple of days in order to have as little disturbances as possible. Daylight can be an important factor for the health of senior people. Older people need up to three times more daylight than young people to see properly for normal house tasks and even more to do strenuous eye-tasks. Often even during the day there is not enough light in the living room to see good enough for older people to maintain a good day and night rhythm. (Mandemaker T., Schoutens A.M.C., & Van Hoof J., 2007) So when improving houses with an external extension, it is important to make sure that there will be enough daylight coming into the house.

Families
Most row houses are designed in the first place for families, so for most people these houses fit well. The only problem families are sometimes facing, especially with some older row houses, is that the houses get a little bit too small. Especially the ones build after the second world war and before the seventies were quite small, because building materials and financial resources were scarce. (SEV, 2004) For bigger families there is often need for more bedrooms or a study room and some more room in the living area. For smaller households these houses are often good suitable.

How can the extra program be implemented in the added structure?

The most substantial intervention for making a row house better suitable for older people is creating the opportunity to make a bedroom and a bathroom at ground floor level, so older people can keep living longer in their own home. There are different ways of implementing that program. In the next schemes different variants are compared to each other. All the variants are starting from an average house layout of 6 meter wide, with a nave of 3,6 meter with the living functions and upstairs the big bedroom and an aisle of 2,1 meter with the hallway, stairs and kitchen and on the first floor a bathroom and small bedroom. (Liebregts, 2014) The different variants are compared to each other in floor plan and in section. The suitability of the variants for older people, but also families are compared with each other.
<table>
<thead>
<tr>
<th></th>
<th>Amount of facade</th>
<th>Walking distances</th>
<th>Can fit the complete program</th>
<th>Daylight accessibility</th>
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<tr>
<td><strong>Notes</strong></td>
<td></td>
<td></td>
<td>All programatic demands can be fitted in the house, dependant on the length of the extension and garden</td>
<td>Extension can block a part of the daylight, dependant on the depth and amount of glass used</td>
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<td><strong>Figure 2:</strong> Scheme of the possible ways to attach the program to an existing house (own image)</td>
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<td>Minimal facade, because the maximum area is put against the house</td>
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<td>Lot of facade area, because the extension is away from the house and there is a corridor placed</td>
<td>Bigger walking distances, because the corridor is between the two building parts</td>
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<td>Lot of facade area, because the extension is detached from the house</td>
<td>Big walking distance (dependant on the place of the extension) seniors also need to go outside</td>
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- **Amount of facade**
  - Partly against the house but for the biggest part not, more facade area needed
  - Big part against the facade, but the corners give extra facade area
  - Minimal facade, because the maximum area is put against the house
  - Lot of facade area, because the extension is away from the house and there is a corridor placed
  - Lot of facade area, because the extension is detached from the house

- **Walking distances**
  - Small walking distance for the bedroom, but the bathroom is further away
  - Small walking distances, because most of the extension is close to the existing house
  - Minimal walking distance, because all the functions are close to the existing house
  - Bigger walking distances, because the corridor is between the two building parts
  - Big walking distance (dependant on the place of the extension) seniors also need to go outside

- **Can fit the complete program**
  - All programatic demands can be fitted in the house, dependant on the length of the extension and garden
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- **Daylight accessibility**
  - Extension can block a part of the daylight, dependant on the depth and amount of glass used
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- **Notes**
  - An acces to the garden should be made
  - Maybe less usable for a family, when the house is sold again
  - Less usable for a family, when the house is sold again
The differences in qualities of the different variants seen in floor plan are not very big, most of the scores are comparable to each other. Especially the three variants on attachments completely against the existing house don’t really very much. The variant where the extension is semi detached from the house has some more facade area, which could lead to higher costs, more material usage and less energy efficiency, but that option could be more easy to connect and therefore be just as expensive as the others. The complete detached option has the advantage that it would be easy to place, but also the big disadvantage that the occupants need to go outside first before they can reach their bedroom.

Ways of attaching

Attaching the extension directly to the existing house creates short walking distances and less square meters of facade, but daylight distribution to the living area can be an issue.

Attaching a double floor extension can also give more room in the house for a family, for seniors it won’t have any extra value. Also in this scenario the daylight distribution should be taken into account.

A double high room can improve the daylight distribution when there is a lot of glass used.

An extension not attached to the existing makes sure there will be enough daylight coming into the living room, but the occupants need to go outside to go to their bedroom.

A corridor connecting the house and the extension prevents seniors from having to go outside to reach their bedroom, but the walking distance is bigger then when the extension is attached to the house, also more square meters facade are needed to build this extension. It is however easier to connect to the current housing, because just a small part needs to be connected.

Figure 3 to 7: Section schemes of possible ways to attach the program to an existing house (own images)
The different ways of attaching displayed before all have positive and advantageous and disadvantageous aspects. The detached option will mostly provide enough daylight and is easy to place, but has the big disadvantage that the occupants must go outside to reach their room. The corridor solves that problem, but there is relatively a lot of facade area. The variants attached to the house have less facade area, but in these options daylight accessibility can be an issue.

Choosing for a single or double story attachment is dependable on the current occupants and their needs. When there is a family living in the house that needs more bedroom and living room space, and also wants to be prepared for when they get less mobile. A double floor extension is the best solution. For senior people without any children living at home, a single story extension probably would be sufficient. Also a combination of options can be made, making the house adaptable for future uses.
Chapter 2.

What are the connection possibilities of the current row housing stock?

To create an extension suitable for normal row houses, it is important to investigate how a normal row house building looks like. When the differences and similarities are known, the transformation can be adjusted to the characteristics of these houses. There are a lot of different row houses in the Netherlands, but a lot of them have similarities. Especially houses that are build in a certain period have can be quite alike. A big part of the current housing stock in row houses is build between 1950 and 1970. After the war a lot of houses needed to be build, because they were demolished by the war, but also because there was an increase of the population, called the Babyboom. After the war the housing production started slow, but from the 50’s the production increased from 40 000 houses in 1950 in a year till 100 000 houses build in 1964 in one year. In total there were 1.5 million houses build in the Netherlands after the second world war. (Siraa, 1989; Wikipedia, 2014). Partly due to institutions like ‘het bouwfonds’ and the building centre the ‘doorzonwoning’, a very rational, typical Dutch row house was developed. In 1960 the building centre developed five books ‘Keuzeplannen’ were designs of houses, including row houses were shown. These houses could be build without the interference of an architect. These houses and variations of these houses were build a lot in these years. As well as standardize houses of big building companies, who had developed there own building system. (Hulsman & Kramer, 2013; Platform31, 2013) These non traditional building systems make up a big part of the current housing stock, roughly the made use of three types of building methods: stack work construction, poured concrete construction and prefabricated construction.

- Stack work construction
  + Airey
  + Pé-Gé
  + Pronto
  + MUWI
  + BBB

- Dry construction building
  + Coignet
  + BMB
  + VAM
  + VANEG
  + Rottinghuis
  + Bouwvliet

- Poured concrete construction
  + Wilma 2
  + RBM
  + Korrelbeton
  + Heykamp L

Stated above are fifteen of the building systems who build the most houses in the Netherlands after the war. To get a better insight in how these system houses were build, a couple of them will be further explained. This selection is based on the amount of row house projects done with the system; how representative the building system is for the building method and there is made sure there is a system from every type of building method. The first two are stack construction, the third one is a prefabricated building system, the fourth one is a cast construction and the fifth one is a traditional building method (that will be explained later). Note that the main load bearing walls were a construction could be placed against are also walls which row houses share with their neighbors, so it is not always possible to connect to the complete with of those walls.

Next pages: The 3D image shows a couple of houses in a row, in different stages of the construction. On the left side of the image is shown if the facades are relatively easy to remove or not. On the right side of the image the different parts of the construction are shown. The image below the 3D shows the floor plan and section, the image on the right the vertical sections in detail and in the right bottom corner a horizontal section is shown. The darker parts in that section mean are stronger elements and the lighter ones are less strong.
The main building principle of the Pé-Gé system is a stack construction. The building walls are made out of structural B2-blocks, the weight carrying inner walls are made out of floor height wooden panels. The wooden floors are for the biggest part prefabricated and the facades are made out of brickwork and prefabricated window frames. The structural B2 blocks are also placed in the facade, making a connection possible on a larger surface then only the separating walls. (Van Elk & Priemus, 1970)

Only the parts were a wooden facade element is placed no connection with a new structure can be made. B2 blocks however are probably not strong enough to support the weight of the new construction, so the connection must be for stability only. A big part of the facade is wooden frame and windows, so this part is relatively easy to take away to make a connection to an extension.
The Airey houses also have a stack construction with B2-blocks as construction of the separating walls, characteristic is the bearing facade made out of concrete framing elements with small concrete facade elements attached to them. The floors are constructed out of steel girder with wooden beams. (Platform31, 2013; Van Elk & Priemus, 1970)

Because the construction is so much divided in the walls and there is as little material used as needed, adding new loads would probably be problematic. Taking a part of the facade away can be possible, but a supportive element would be necessary to replace the concrete framing elements.

Figure 9: Sections plans and 3D of the Airey system (Van Elk & Priemus, 1970) edited
Vaneg is a building method based on heavy prefabricated concrete elements mounted on site. The load bearing house separating walls as well as the other load bearing walls and the not bearing walls are made out of concrete. Also the floors are made out of prefabricated panels. The facades are often made out of wooden prefabricated facade elements, with lining element, a damp-proof layer, insulation and a exterior layer from weatherproof material. (Platform31, 2013; Van Elk & Priemus, 1970)

Because only the walls perpendicular to the facade are load bearing, there is just a small area were the construction is close to the facade. But the construction elements are stronger than the building blocks from the Airey and Pé-Gé system. The facades are relatively easy to remove.
Heykamp is a poured concrete construction method where the constructional walls are made with standardized wooden formwork and the floors with a wooden formwork with a steel frame. The facades are build up with a cavity wall, half bat thick brickwork and wooden window frames. The ends of the walls close to the facade are load bearing and have a thickness of 18 centimeters. (Van Elk & Priemus, 1970)

A connection to the extension could be made there, but there need to be some bricks removed before the concrete construction can be reached. To make a connection of the facade with an extension, bricks need to be removed, this makes it harder to remove (parts of) the facade easily.
Traditional building system: in this system the walls and floors are not made with standardized form-work. Mostly the walls are build from bricks, but poured concrete and sandstones were also used. In this example wooden floors are used, but poured concrete was also used. (Van Elk & Priemus, 1970)

In most cases brick walls are not suitable to make a connection, so no big loads can be placed to the wall unless there is a layer of concrete (depending on the size). Also the facade is often not easy to remove, since there is one or multiple layers of brickwork in front of it. Placing a lightweight facade layer against those bricks could be possible.
There are a lot more building companies, with different building methods than the ones discussed before, but a lot of the buildings, especially the ones build after the second world war, are alike to these building principles.

**Traditional building**

Also a lot of buildings in the Netherlands are build with traditional building methods. There is a tradition of building with bricks in Netherlands for a long time, and still a big part of the average build low-rise buildings in the Netherlands is build with bricks as facade material and a concrete construction.

A traditional building is a building where the load bearing walls are build with bricks or brick sized sandstone or build with poured concrete construction poured in a not standardized formwork. The floors are build with poured concrete construction poured in a not standardized formwork or made out of wood. (Van Elk & Priemus, 1970)

Often a connection with an extension can be made, but little forces can be absorbed, also depending on if the construction is made out of concrete or brickwork. Also the not lead bearing facades are made with bricks, so it is quite work extensive to remove (parts) of the facade to make an attachment.

There is a long tradition of building with brickwork in the Netherlands, so the row houses often have different widths and lengths, between 1910 and 1970 the width was on average around 6 meters, usually reached by using two naves. Later the houses were spanned once, making a possible wall in the middle of the house not structural. (Liebregts, 2013) Also the variety of widths of the houses became bigger and on average the widths of the house became smaller. To investigate the differences in height, width, length, roof corners and sizes of walls, these data were measured from different housing project.

In the Appendix A there is a schedule with a large number of systematically build houses and their sizes. The first floor is generally lower than the ground floor, with a difference of about 20 centimeters. Were the ground floor is often about 2,5 till 2,8 meter and the first floor 2,3 till 2,6 meters. The width and depth have more differences and vary from 4,6 till 6,3 meters in width and 5,8 till 11,4 meters in length. Most of the roofs have corners between 30 and 40 degrees. These numbers make difference for how the program could be put against the construction and how the construction need to be dimensioned in order to fit to the existing houses.
Chapter 3.

3. What kind of wooden connections are suitable to make an extension to current houses?

To create an extension that can be an improvement for the current building and adaptable to the people who live in it in time, it is important to investigate what the needs for the construction are and what kind of construction fits the best for those needs.

In this chapter First the different possible parts and their specific demands for the extension will be discussed. The main demands of these parts are the weight, the strength and the ability to fit well to the house. These demands are specified for each possible part in a schedule.

Secondly different kind of connections are explained by the way they can be manufactured.

And after that for the different parts of the construction the possible connections will be discussed.
<table>
<thead>
<tr>
<th>Specific demands for the different building components</th>
<th>New exterior layer</th>
<th>Construction extension part</th>
<th>connection extension to house</th>
<th>Adaptable connections</th>
<th>Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specifics</strong></td>
<td>Older row houses often don't have insulation values that make a house energy efficient, so to make a house more energy efficient, the insulation value of the facades should be improved. An extra layer of insulation on the outside can improve that.</td>
<td>To house the extra functions that are needed for the transformation of houses into houses also suitable for older people, an extra construction needs to be added.</td>
<td>At a couple of points the extension of the house will be connected to the current house, the place and type of connection that can be applied is dependant on the sizes and type of construction of the current houses.</td>
<td>To make a house which is suitable for all ages, included older people, a part of the house should be adaptable to changing needs of a certain group of people. So some of the connections in the construction should be made flexible of demountable to be able to change the configuration of the building.</td>
<td>The type of foundation needed depends on the weight of the construction used, a light construction is preferred, because then the foundation doesn't need to be completely made out of concrete, which costs more time and money.</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>The construction of the exterior layer should be light, because that way the current construction can support it, if the exterior layer is too heavy, it will need a stronger construction, which means that an extra construction should be added.</td>
<td>The construction of the extension needs to be able to stand on its own and it needs to be able to support the floors. Therefore it needs a substantial construction. It also needs to be light so the foundation can be kept to a minimum.</td>
<td>D.N.A</td>
<td>A lighter foundation is cheaper than a heavier foundation.</td>
<td>A lighter foundation is cheaper than a heavier foundation.</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td>The new facade, with an extra insulation layer can be put on the construction of the existing house, so the construction doesn't need to be very strong. It should however be strong enough to support its own weight.</td>
<td>Because the building need to be able to support two floors, the construction and the connections need to be strong.</td>
<td>The connection between the house and the extension needs to be quite strong to absorb a part of the forces. The biggest part of the forces however will be absorbed by the construction of the extension itself.</td>
<td>This is dependant on where in the extension adaptable connections will be applied. Floor elements should be quite strong, facade or wall elements can be less strong.</td>
<td>The foundation should support the whole extension, so should be very strong.</td>
</tr>
<tr>
<td><strong>Fit well to house</strong></td>
<td>Because the new exterior layer comes over the current facade, the layer should be manufactured to fit right onto the current facade. This means that the form of this layer will be different for every house type.</td>
<td>If the extension is placed completely against the wall of the existing house, those connections should be able to fit to the house, but most of the construction is not precisely depended on the current house.</td>
<td>On this point the extension and the existing house come together, so it is really important that the two parts fit together well.</td>
<td>This is dependant on where in the extension adaptable connections will be applied, when applied against the existing house it should fit better to the existing house then when not against the house.</td>
<td>The foundation is placed next to the current building, so it doesn't really has to fix against the building.</td>
</tr>
</tbody>
</table>
In the schedule the demands for different parts of a possible construction are explained. The exact demands for a specific construction depend on the house the extension is suited for, but in general these points should can give a guideline on what should be taken into account.
Figure 16: division of different kinds of connections divided by the way they are machined (own image)
Types of joints

In this part different kind of joints are discussed, these joints are divided by the way they have to be worked, in 2 dimensions 2,5 or 3 dimensions. These joints can all be made by trained woodworkers, but nowadays the wood is often worked on CNC machines. The type of the form of wood (panels of beams) and the type of working there need to be done defines the type of wooden connection that could be used.

Not worked joints (Butt joints)

The butt joints are the most standard types of joints and most used type of joints in the building industry. The butt joint is simply putting the end of a piece of wood against another one, the joint gets it’s strength from external connection elements. This could be glue, but in building construction it is often a steel or aluminum frame or plate connecting the two ends of a wooden element. (udemyblog, 2015) This kind of connection is often used, because there is a minimal amount of woodworking necessary to make the connection. The external joints can be used for beamed elements and for paneled elements. External materials for jointing are especially suitable for connections between wood and other materials.

Worked joints

All the joints other than the Butt joints, are joints that need a certain amount of woodworking to make strength in the connection. These joints are divided into different categories, depending on the way they can be produced and if there are panels or beams used.

In the next scheme the two types of CNC machines, nesting and point to point milling, are put against the amount of axes a machine has, to give an overview on what machine is used for what kind of working.

Nesting

Beam elements are usually made with point to point CNC machines and panel elements with nesting CNC machines. Nesting machines are most suitable for panels and blocks of wood. Blocks of wood are not very useful for construction purposes, but panels are. There is a big variety of nesting CNC machines, from small 3 axis machines with little power and only a single head, till big industrial sized 5 axis machines, with different drilling and cutting heads, sometimes even working at the same time. While the size, speed power and functionalities can vary, the basic principle of these systems are the same. A wooden panel is put on the flat working table, simple machines use glue, double sided tape or clamps, but the professional ones mostly use vacuum pods connected to a van pump to keep the wooden panels on the right place. There are two types of machine configurations that are mostly used nowadays, moving table and the moving gantry, the moving table is mostly used and in this configuration consists out of a table that is movable in the x direction, a stationary gantry with on that a drill that can be moved in the z direction on a rail that moves in the y direction. In the moving gantry variant the gantry moves in stead of the table. These machines mostly have a 3axis system, but could also be equipped with a4 or 5 axis system, these can be useful for some very specific notches, but
are usually more expensive and are mostly suitable when milling 3D blocks, and not for relatively flat panels (Albert, 2008; Morin, 2006)

2.5D worked connections / 3Axes
2.5D connections are comparable to 2D connections, but the differences are that notches, bevels and embossing can be created, these can be made with a CNC milling machine, just as the 2D worked connections, but it usually takes some more time to notch than to cut in the wood. The advantage is that a lot of different connections can be created with a CNC mill.

4 Axes
There are also nesting machines who have 4 axes, this way it is possible to make notches into two of the sides of the panels, because only two of the four sides of the panels can be modified. Therefore 4 axed nesting machines are not often used

5 Axes
The most possibilities to work wooden panels are given by a CNC mill with 5 axes. All sides of the panels can be modified. But mostly only on thick panels because the drilling head of the CNC machine need to have some spacing between the nesting plane and the panels. Also 5 Axed machines are mostly more expensive than 3 Axed machines

Joints worked in two directions are not only suitable for connecting sheets of wood to each other, they can also be a good method for making a beam column connection. With a 3axed CNC mill, a lot of these connections can be made from wooden sheets. Examples for those constructions are the wikiphous and the 100% CNC cut post-disaster shelter for Haiti of Pieter Stoutjesdij (Stoutjesdij; WikihousNL, 2015) These kind of connections are easy to connect and fast to make, but there is often quite a lot material necessary to make the construction firm enough.
Between a beam and a column, most of them consist out of columns, if necessary rising to the floor above, with holes or notches in them. The beams often have bulges who fit into the notches of the columns, some of those connections are connected in a way that they are strong in every direction. These connections can be used fine for making strong structures, they can be very fast to build, often look elegant and are strong enough. Because the elements need to be worked with extensive machines, the costs of these connection could mount up.

2.5D worked connections / 3Axes

A 3 axis point to point milling machine can already make a lot of connections out of beams. Only undercuts can’t be made. These machines are mostly easier to manage and cheaper than bigger 4 or 5 axis milling machines, but not as easy as most nesting milling machines.

4 and 5 Axis

To make modifications to all sides of a beam (except for the underside) a 5 axis milling machine is necessary. A four axis milling machine can make undercuts on two opposite faces.

Generally the more axes a machine has, the more expensive it is. But of course also the other functions count, for example the speed, power, kind of drills and the size of the machine.
Connections of added facade layer

Most roofs of the houses build in the Netherlands with a sloped roof are made with roof tiles, (Huisfocus, 2015) when an additional layer is placed the roof tiles can be easily removed. A layer with wooden construction and insulation material can be added which can partly lean upon the house separating roof walls and partly on the new construction of the addition.

When there is a facade out of brickwork the extra layer can be put against the bricks, so they don’t have to be removed. When the extra layer is strong enough to support its own loads and those of a part of the roof part no big connections with the main construction of the existing building need to be made, only to make the construction stable.

When the facade is not made out of brickwork, but less strong, adding an extra insulation layer will be different, then the best thing could be to remove the facade and place an improved one instead. This is all dependable on the exact structure of the house.
### Construction extension part

In the construction connections, not connected to the existing house, were beams and columns or walls and floors come together, there are multiple connections possible. In the schedule on the left different kind of jointing types are compared.

### Demountable part

When a the function of the extension changes, for example from bedroom to living room, or the first floor is no longer in use and the occupants want a higher living room. A part of the construction has to be able to be removed, so there need to be some parts of the construction who are demountable. Connections with steel plates and bolts through the wood could be demounted, but often this is gets quite hard after a couple of years. The different kind of wood on wood connections could all be a solution to make a connection demountable, but it is always important to keep in mind that wood could warp, that could make it harder to demount it again. By designing a demountable part, the type of wood is an important criteria.

<table>
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<th>Description</th>
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<td>2 Axes / Not worked joints (beams)</td>
<td>Can be an option, advantage is that the elements are often not heavy, so easy to instal manually. Disadvantage is that panels are not as strong as beams, so more construction elements are needed to construct the extension. Joints made with external connecting elements can be a good solution for making these connections. When the corners an the elements are straight, for example steel or aluminum standardized elements can be used to connect the parts. The downside can be that the connections are esthetically sometimes not very appealing and the construction time on site will be bigger.</td>
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<tr>
<td>3 axes</td>
<td>Can be an option just as good as the one above. Although the connections can be less strong as the 2D worked ones. Is a good option, strong connections can be made, making the construction fast to make.</td>
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<tr>
<td>4/5 axes</td>
<td>Has not an advantage compared to the options above, but are more difficult to fabricate. For a connection were four or more element come together these connections are suitable.</td>
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Figure 23: possible wood connections for the extension part (own image)
Connections between the existing house and the extension

The connection between the roof corner and an added part is dependable on the type of construction of the current house, the facade covered material and the kind of roof. But when a construction is fitted to the roof, there should be a connection to the main construction. To test the possible ways of constructing to the house an example of a detail of a house is taken. The example is from the Heykamp L system houses, because this is a relative strong construction and makes use of widely used construction materials. (Van Elk & Priemus, 1970)

When constructing a beam to the second floor construction, a couple of problems are revealed. First of all, most of the facades in the Netherlands are made out of brickwork. The construction is behind that brickwork, so parts of the brickwork need to be removed. Also most of the times, roofs are hanging a little bit over the construction. This can cause some problems when a beam would be put against the second floor construction, depending on the roofing materials this can cause some problems. When the construction and insulation layers are put in front of the construction it should be all demolished before it is possible to place the beam, but it is often that only the gutter and the roofing plates are in front of the construction, that way the insulation and construction can stay at place for the biggest part and the transformation will be a lot less radical. The alternative could be that the wooden beam is only placed to the load bearing walls. So the beam would be placed lower.

There are different kind of ways a wooden construction, the most obvious solution is to use a steel or aluminum frame to connect the concrete and the wood, since these materials are not very easy to connect, especially when there is a beam perpendicular on the facade.

When the construction of the house is not strong enough to convey some of the forces of the extension a part of the wooden construction can be put linear to the house. This way there is no need for a strong construction of the house itself, but more material is needed. Placing the extension directly to the construction is only possible when a part of the facade is relatively easy to remove. There is still an other connection part needed to connect the wooden construction to the, often, concrete construction.

The connection of the wooden construction to the existing house on the first floor is comparable to that of the second floor. The main difference is that on the first floor the construction in the second and third variant need a beam on top of the connection, to reach the second floor, therefore the connection has to carry more and has to be stronger.
The connection of the ground floor also deals with the same obstacles as the other connections, but on the ground floor the connection needs to be connected to the foundation. How the foundation will be formed is dependable on the weight of the construction, when the construction is lighter, the foundation can be less extensive. But also the type of ground under the house is important for the type of foundation. For a light building on a good ground a shallow foundation can be used with only lanes of concrete, otherwise a pile foundation or slab foundation will be necessary. (Livios, 2015)
Conclusion

The question this research is investigating is: How can wooden structures help the transformation of existing row house dwelling to houses suitable for all ages, especially older people? To answer this question the research was divided in three parts.

In the first chapter the target groups are discussed; mostly senior people, but keeping also families in mind. The wishes of those people were explained, and with that program possible configurations were investigated. Making an extension for a spacious bedroom and bathroom downstairs for older people is a prober solution to co-op with mobility problems older people can get. This extra program can be fitted to the current house as close as possible, this way the walking distances for older people are as small as possible and the facade area of the extension is kept to a minimum. This could give a couple of difficulties which should be resolved when designing an extension: Placing an extension to the living room can reduce the daylight access. Also there should always be an access to the back garden so the extension can’t be the whole width of the house, or should have an own exit to the garden. Placing the extension attached with a corridor could partly solve those problems, but will need more material and causes bigger walking distances. It is concluding from this research alone not possible to point out one type of extension which is better than the other ones. And it depends on the design that will be made with it.

Choosing for a single or double story addition to the house depends on the size of the current house: how much extra room is needed. And the demands of the occupants: When there is a family living in the house that needs more bedroom and living room space, and also wants to be prepared for when they get less mobile. A double floor extension is the best solution. For senior people without any children living at home, a single story extension probably would be sufficient.

The second part of the research dealt with the current housing stock, by investigating different kinds of standardized houses problems and opportunities for connecting a wooden structure are explored. These findings can give handles to designers when designing an extension against any type of standard row houses.

It is important to realize that it is not easy to put a heavy load on the existing construction, smaller loads are possible depending on the construction; poured concrete construction and dry concrete construction houses are stronger and therefore better suitable than stack work construction or traditional brickwork constructions. Although it is alway dependable on the sizes of the construction and the possibility to connect to the construction.

The possibility to connect to the construction depends on the type of facade the house has, this is also the case for the possibility to open up the facade to the extension when an open space is desired. A brick facade is harder to remove than a light element facade.

The third part of the research discusses wooden structures and how they can be connected to each other and the current building. The

For the connection between the extension and the existing house the most logical solution is probably to use an external connection piece of another material, making a link between the concrete or bricks and the wood. This because wood doesn’t connect very easy to concrete.

The choice of connections in the extension itself is less obvious, there are three solutions which are quite feasible:

- External connection pieces, these can be strong and cheap, but not always very fast to make or esthetically pleasing.
- 2D worked panel joints (3 Axed CNC mill) can be machined relatively fast and also be connected manually and quite fast. These connections can also be esthetically pleasing, but are not the strongest, so more material is necessary.
- 3D worked joints (3,4 of 5 axed CNC mill) are more difficult to machine than 2D worked
joints, are also fast to connect and can be as nice as 2D worked joints.

In this investigation the exact costs and the exact strengths of the different connections are not taken into account. Therefor it is not possible to propose one solutions for this issue. This is different for each specific case.

The connections against the facade can best made with external connection pieces, because that’s the easiest way to connect wood to concrete. The connections between the wooden parts themselves could be connected by 2 or 3 axed machined connections (nesting) These are fast to make and connect. Also 3 axed machined beams can be a solution, these are stronger, but also mostly heavier. So the decision depends on the strength necessary for a specific building.

There are certain possibilities for extensions against an existing row house. As already stated in the introduction there is a need for housing solutions helping older people stay longer at home, a lot of older people also want to stay in there own home and environment as long as possible. It is possible to connect to the existing housing stock and wood offers different possibilities and connections to make a proper extension. Which exact conclusion there will be used depends on the specific house and is mostly up to the designer.

Further research

This research has given an insight on the possibilities to connect a wooden structure to existing houses, in order to make them better suitable for senior citizens.

An insight has been given on the demands of seniors. These are averages so they doesn’t comply to every senior. The conclusions given on the attachment on the extra program can also be a personal preference.

The advantages and disadvantages of different attachments of the program were given. Further research on the exact costs should be made to give a clearer conclusion. Also the sizes and specifics of a house, together with the personal preferences of the occupants have influence on the exact program and way of attachment, this could not be implemented in the research.

The chapter on the current housing stock has given a brought view on different kind of row house building methods, but when a connection has to be build against a specific house, more research should be done on the exact strengths of the building.

The research done on the wooden construction provided a general division on wooden connections based on the way they can be digitally manufactured, for each of those way, there are still innumerous possible connections available, so there could not be appointed a single way of connecting which is best. Further research specific on a kind of connection is needed in order to give clearer conclusions.

This research provided a couple of handlebars where more research on specific cases could benefit from.
References


## Schedule of different after war houses with their sizes

### Maten veelvoorkomende keuzewoningen

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<td>7100</td>
<td>2820</td>
<td>2620</td>
<td>2200</td>
<td>35 graden</td>
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