This thesis treats a research to the willingness to pay for different attributes in sustainable renovations. In this reflection, it will first concisely be explained why this topic has been chosen. The next step is to explain the methodology employed in this research and the things that I would have done differently next time. Then the results are presented and the validity of these results is reflected. We end with the relevance and utilisation potential of this research and a set of a recommendations.

MOTIVATION

Prior to starting my current graduation research, I participated in the team of Prêt-à-Loger, which represented the TU Delft in the Solar Decathlon 2014 in Paris. In this global university competition which revolves around the development of sustainable housing, our team was awarded with the 3rd position. Together with two other students, I was responsible for a research of the market viability and the affordability of our product. The final product of Prêt-à-Loger was a toolbox that enables housing associations and private homeowners to sustainably renovate their existing dwellings, in this case row houses. This toolbox consisted of a set of attributes with different features and different costs. When the opportunity presented itself to continue with this theme I grabbed it with both hands and choose the field of sustainable renovations for private homeowners as my research scope. As most sustainable renovation solutions focus on the housing associations while private homeowners own the largest part of the housing stock, I decided to focus on the last group. The way homeowners perceive the quality of attributes in sustainable renovations and their willingness to pay for these attributes, is the central theme of this thesis.

INTRODUCTION

To which extent do different attributes in sustainable renovations of the post-war (<1979) terraced-housing stock affect the willingness to pay for private homeowners?

This is the main research question. It should be said that the research question has been changing continuously during the 1 year trajectory. The initial goal of this research was to assess the willingness to pay of private homeowners for certain attributes in sustainable renovations and translate this willingness to pay into an increase in market value. To do this, I had to measure the unconscious decision making behaviour of homeowners. This way I wanted find an ideal set of sustainable attributes that would boost a maximum value increase of the dwelling. During the research I became more and more aware that ‘the art of appraising’ is a whole science in itself hence I had to narrow down my scope and become more realistic with my goals. This is why I finally just researched the willingness to pay for certain attributes in sustainable renovations, as this would already (most probably) provide me with very interesting research results for the scientific world, for private homeowners and for construction companies doing sustainable renovations such as BAM.

METHODOLOGY

The research was divided into two parts. The first part with some theoretical research questions and a part with practical research questions. In the part with the theoretical research questions I tried to find more information about the way that people make choices, as I aimed to map the unconscious decision making behaviour of people. It was also important to do more
research to existing models of sustainable renovations. For this reason a case study with the sustainable renovation models of BAM and Prêt-à-Loger was conducted. With the conclusions coming from these theoretical research questions, I knew that for my methodology I needed a method that would map these unconscious decisions. This was the Discrete Choice Method which employs vignettes to map the unconscious decision making of people. With the help of one of my graduation tutors (Clarine van Oel), we made a list of attributes to be researched. This list was based on the possible attributes out of the renovation models of BAM and Prêt-à-Loger and was narrowed down with the help of literature and some questions. At the same I created in collaboration with BAM a 3D model in Sketchup, where I merged the 3D model of BAM and Prêt-à-Loger and created a new model containing all the to be researched attributes in different layers. Once this model was finished, I could switch on and off manually the different layers representing the attributes and export the right model representing one vignette to Lumion. This had to be done 100 times as I needed to make 100 vignettes. Lumion is 3D software that enables its users to make rather realistic visualizations in static format or in movie format. I finally created 100 vignettes, each of them containing 8 different renders, i.e. 800 renders in total. These 8 renders per vignette were merged together into a movie in windows moviemaker and a price label was attached to complete the vignette. The vignettes were then integrated in the questionnaire that was constructed in Collector and the questionnaire was published and sent out to the VEH: Vereniging Eigen Huis’ (Dutch Homeowner Association). The VEH sent the questionnaire to a total of 5,000 people during a three week period in the summer of 2015. 422 people filled in the questionnaire and around 170 people completed the entire questionnaire and assessed the vignettes. As we speak, the VEH has sent the questionnaire to another 5,000 respondents who are currently filling in the questionnaire. These results will be integrated during the P5 and used to boost the validity. Afterwards, the results were imported into SPSS, coded, transported to SAS, again coded and then the research results were finally visible.

All of this sounds very smooth, although I can assure everyone that it did not go that easily. The biggest challenges that came along on my path were:

- As I had to merge the 3D models of BAM and Prêt-à-Loger, it turned out that the 3D model of Prêt-à-Loger was not designed very properly. It was designed in Revit and individual components were set into locked groups, hence it was impossible to alter or delete layers without deleting more half of the model. This resulted into the fact that I had to redesign all the attributes of Prêt-à-Loger myself and this was very time consuming.
- The visualization of the renders was another challenge. As the model was built in Sketch-Up, it was first attempted to render the 3D model in Kerkythea, a visualization plug-in for Sketch-Up. The quality of the renders was rather poorly, so a new program was searched. In the end someone of BAM gave me the software for Lumion, an Autodesk render program that creates really high quality renders. The problem with this program was that it was so good, that my laptop could not run the program without crashing. I installed the program on one of the desktop computers of the TU Delft, however this computer crashed as well every time I tried to start Lumion. Someone from ICT stated that it had something to do with the video card, therefore I bought another video card online and we tried to mount it into the TU Delft desktop computer. As it did not fit, we had to find another solution. All of a sudden someone from the ICT came with a very heavy desktop computer from the basement. This computer was able to make the renders without crashing continuously. Next time, I would definitely inform myself in advance what kind of hardware and software I need in order to conduct the research and I would base my decision to continue with the research on the required initial investment and/or effort I have to do. In the end, it all turned out well, however I should have prepared myself better for this.
- A challenge that occurred in the software Lumion was that the initial plan was to create 100 videos, with every video representing a vignette. In the video, the respondent would be
virtually guided through the house and see the different attributes during the virtual tour. At the end of the video, the respondent would then see a price label. In every question, the respondent would have to choose between the two videos and click on the video that appealed to him the most. I thus started rendering in Lumion videos with virtual tours. Not only was this a lot of work as it required a lot of camera points, the disappointing thing was that not every video that was produced by Lumion would boast the same image quality. This would lead to respondents having their unconscious decision making system being influenced by the image quality of the video rather than by the actual attributes present in the video. In order to overcome this problem, I had work with static renders. In order to show all attributes from different angles and give a similar experience as with a ‘walk through virtual tour’, it was necessary to render 8 different images for every vignette. With 100 vignettes, this meant that 800 renders had to be made. Although it was terrible work and it took weeks to complete, it succeeded and the renders came out in equal quality.

- As it took me so many months to create the correct 3D model and the visualizations, everything in between my P2 and P4, including the theoretical research questions, the description of the methodology, etc, remained rather untouched until summer 2015. This resulted into the fact that during the summer and the beginning of September still a lot of work on the theoretical research, the problem statement and the methodology had to be done in order to finish the thesis on time for the P4. Next time I would definitely try to keep working simultaneously on the background research and the theoretical part as well as the practical part, in this case, the 3D visualizations.
- When the renders had to be integrated into Collector, I could not find any way to do it. As a quick, however not ideal solution, I decided to upload the videos to Youtube and redirect the people through links from the questions to the videos representing the vignettes in Youtube.

RESULTS & VALIDITY

In the end all the effort was worth it, as the research has yielded rather interesting results. The new open kitchen that was one of the attributes researched in the this thesis had a significant preference (p<0.105) over its control parameter ‘new closed kitchen’ on all three price levels (+5%, +10%, +15%). In addition, the attribute ‘pv panels’ scored (almost) significant over ‘no pv panels’ among the population group with ‘higher than average income’. A renovation model with these attributes included could boost a WTP of 8 to 10% above the usual market price. This is very interesting information for contractors.

An interesting finding was that the respondents had a marginal significant preference for the Prêt-à-Loger façade over the old North façade, whilst on the South side it looked like there were less people opting for the Prêt-à-Loger façade then for the old façade, although this result was not significant. There can be three explanations for this:

1) People do not like the installation boxthat is placed next to the door to the kitchen. These installations could also be moved to another place, for instance under the roof construction of the house;
2) People don’t like that they lose a small window next to the door that connects the kitchen to the garden;
3) A combination of these two points.

Further research would have to assess whether the installation box, the loss of glass or a combination between the two is responsible for this result.

The following things that have been found in the literature were confirmed through this research:
1) When it is difficult to differentiate two products based on their excellence, extrinsic cues such as price become more important (Zeithaml, 1988). We have seen this in the assessment of the WTP for several of the attributes, such as for the Floor/Wall heating system in comparison with a heating system based on radiators.

2) There is a presumption that people put more emphasis on quality than on energy savings in sustainable renovations (van Eck, 2008). We have seen this in the example of the ‘new open kitchen’ in comparison to the ‘new closed kitchen’. Although this attribute does improve energy efficiency through the installation of new sustainable kitchen gear, it also has a big effect on the aesthetics and the comfort as the kitchen becomes integrated in the living room and the living room thus becomes much larger. This was the only attribute parameter that was chosen significantly over the control parameter, for all three price levels (+5, +10%, +15%).

3) The above mentioned finding about the kitchen concurs with the findings of former RE&H student Arjan Bogerd. Arjan found that an increase in comfort is usually very highly appreciated by its residents (2009), as we have seen with the attribute parameter of the ‘new open kitchen’.

**SCIENTIFIC RELEVANCE**

This research can be an important follow-up on the researches of Thomas Dekker and Annelinda van Eck, both graduated within the Master of Real Estate & Housing. Annelinda van Eck (2008) found out that homeowners value quality and financial benefits much higher than possible energy efficiency which is beneficial for the environment.

Also in earlier researches, such as in a research of Anke van Hal (2006), the importance of a tool that makes sustainable construction an auditable tool has been emphasized. Wobben & Hooglander (2006) state that consumers are willing to pay extra for a house that consumes less energy. And a research done by Banfi et al. (2006) in Switzerland corroborates these results, implying that homeowners opt for a house with sustainable attributes over a normal house, at least in a hypothetical situation. These are very interesting findings and an important first step. With this research these findings are confirmed and insights is gained in the contribution that different attributes have in sustainable renovations to the quality perception and the willingness to pay for private homeowners.

I hope that the next generation of researchers can use these findings and continue in the areas where there are still question marks:

- Why is that on the South side, the old façade is chosen over the façade of Prêt-à-Loger. Does this have to do with the installation box, with the reduction of glass area, a combination or another factor?
- If the glasshouse would be cheaper and better visualized, would it then become an attractive option for private homeowners?
- How can this willingness to pay for these attributes in sustainable renovations be translated to a scientifically justifiable increase in market value?

**SOCIETAL RELEVANCE & UTILISATION POTENTIAL**

As hundreds of thousands of people in the Netherlands alone are living in unsustainable, post-war <1979 row houses, the new insights in which sustainable attributes are preferred by
homeowners can help in making the product more customized, cheaper and more valuable. We will list the different stakeholders that can benefit from this research:

**HOMEOWNERS**

For homeowners there can be several benefits coming from this research. Construction companies such as BAM could start adjusting their renovation package based on the outcome of this research. If construction companies do so, then sustainable renovation packages will be more tailor-made and will align better with the desires of private homeowners. In addition, if only (for homeowners) relevant sustainable attributes are included, the price of a renovation package can go down a lot. As sustainable renovations are currently still rather expensive for most homeowners, this would be welcome benefit. Furthermore if a private homeowner opts for a sustainable renovation package that is popular among a bigger group, this package would automatically be more valuable as well. This value could be translated to the market value of the dwelling and cause a bigger market value increase for the homeowner. It is also important to understand that this cannot only benefit Dutch homeowners, but homeowners all over Europa as there are 36 million row houses scattered over Europe.

**THE ENTIRE ARCHITECTURE, ENGINEERING & CONSTRUCTION INDUSTRY**

When there is more knowledge about the client’s desires, firms in the AEC industry can adjust their products and become more successful. This way they will sell more sustainable renovation packages, thus earn more money and more people will have employment.

**SOCIETY**

As we can be seen in the problem statement of this thesis, society as whole needs to transition into a more sustainable way of living. As the building industry is one of the biggest polluters and dwellings form a big part of the building industry, it is clear that our dwellings are a key stone to improve in order to become more sustainable. The findings of this research can aid in diffusing sustainable renovations, as they can become more attractive for private homeowners.

**THE SCIENTIFIC WORLD**

This research can benefit the scientific world. All graduate students, PHDs or other types of researchers will be able to replicate the research or use the research results for their own work. As I tried to research something that was still unexplored, I expect that it will be quite useful for other people.