Master thesis
Judith Wolswinkel (4150821)
Supervised by Hilde Remøy & Alexander Koutamanis
29/06/2017

INNOVATION OF CONSERVATION

Towards Energy Efficient Monuments

COLOFON

MBE graduation labaratory
Adaptive Reuse

Supervisor 1: Hilde Remøy
(Real Estate Management)
Supervisor 2: Alexander Koutamanis
(Design & Construction Management)
Supervisor 3: Rizal Sebastian
(DEMO Consultants)

Judith Wolswinkel
st.nr. 4150821
judithwolswinkel@gmail.com
Klooster 32, 2611RW Delft
tel nr. 0629504800

Delft University of Technology

INNOVATION OF CONSERVATION

TOWARDS ENERGY EFFICIENT MONUMENTS

Monuments are often not energy efficient, yet improving the energy performance without harming the cultural values is still a complex process. By only conserving a building without making adaptations, a mismatch can arise between the demand of the user and the building. Next to that, using Building Information Modeling (BIM) to assess the suitability of different energy conservation measures on the ground of appearance and effectiveness, is not common in the management of monumental real estate. The aim of this research is to design a BIM-based strategy that supports the creation of a renovation plan for a monument, which increases the energy performance of the building and conserves the cultural values. Therefore, the main research question is: How can the use of BIM support decisions on the optimization of energy performance and cultural value in Dutch national monuments? The result of this research is a BIM-based strategy, which design is based on the outcomes of a literature study, expert interviews and two case studies: Paushuize and Westergasfabriek. Creating a BIM model of a monument and inserting the monumental values and the energetic characteristics of the building components in the model is beneficial for: (1) framing the design space, (2) analyzing the building areas where energy conservation measures are directly applicable and effective, (3) preserving cultural values, (4) managing the renovation design process, (5) creating renovation design options, (6) analyzing the impact of the design options on the cultural values and thermal performance of the building, and (7) supporting decisions on the implementation of a renovation design option.

Keywords: Monuments, Conservation, BIM, Energy Efficiency, Cultural values, Renovation, Strategy

1. INTRODUCTION

Monuments are historic buildings that are built in the past and considered important to conserve and keep in shape. They are considered to be the tangible remaining of the cultural and societal history (Nusselder & Dulski, 2008). Therefore, cultural values are the core of the conservation interest (Mason, 2008). Monuments are linked to the historical period of construction, where often human comfort and energy efficiency were less taken into account (Silva & Henriques, 2016). However, the building needs to meet the demands of the current occupants regarding human comfort, such as temperature regulation and fresh air.

Buildings account for more than one third of the total European annual energy consumption (Pérez-Lombard, Ortiz, & Pout, 2008). The biggest potential to reduce the energy consumption lies in refurbishing the existing building stock (Jansen, Storck, & Van der Weijden, 2012). This also counts for monumental buildings (Georges, Haase, Houlihan Wiberg, Kristjansdottir, & Risholt, 2015). Refurbishing monuments and increasing their energy performance requires measures that often have a negative impact on the cultural values. Therefore, the combination of preservation of monumental buildings and the enhancement of their energy performance is often seen as conflicting. Finding a measure that will improve the energy performance of the monument without negatively influencing the cultural values of the building is still a complex process (Franco, Magrini, Cartesegna, & Guerrini, 2015). This research shows that it is possible to reduce this complexity.

For creating a design of a new building, Building Information Modeling (BIM) is often being used. A BIM model is a virtual model of a building, which is digitally constructed and contains precise geometry and relevant data (Azhar, 2011). It can support the decision-making in the design phase, because BIM can help the user to assess different design alternatives on the ground of the impact on the appearance of the building and its energy performance (Garagnani & Manferdini, 2013).

However, BIM is not commonly used for the creation of renovation designs for monuments since these kind of buildings are often more difficult to model in 3D, due to their irregular shapes, unusual building elements and deviating thermal properties. Due to the development of automated technologies, the creation of a BIM model of an existing building becomes less expensive and labor intensive (Franco et al., 2015).

In this research, a BIM-based strategy is designed that can support the design process of an energy renovation plan for a monument which is optimized on the conservation of cultural values and improving the thermal performance.

2. PROBLEM STATEMENT

Monuments are often not energy efficient, yet improving the energy performance without harming the cultural values is still a complex process. By only conserving a building without making adaptations, a mismatch between the demand of the user and the building can arise. Next to that, Building Information Modeling (BIM) that can assess the suitability of different energy conservation measures on the ground of appearance and effectiveness is not commonly used in the management of monumental real estate.
Therefore, the main research question is: How can the use of BIM support decisions on the optimization of energy performance and cultural value in Dutch (national) monuments?

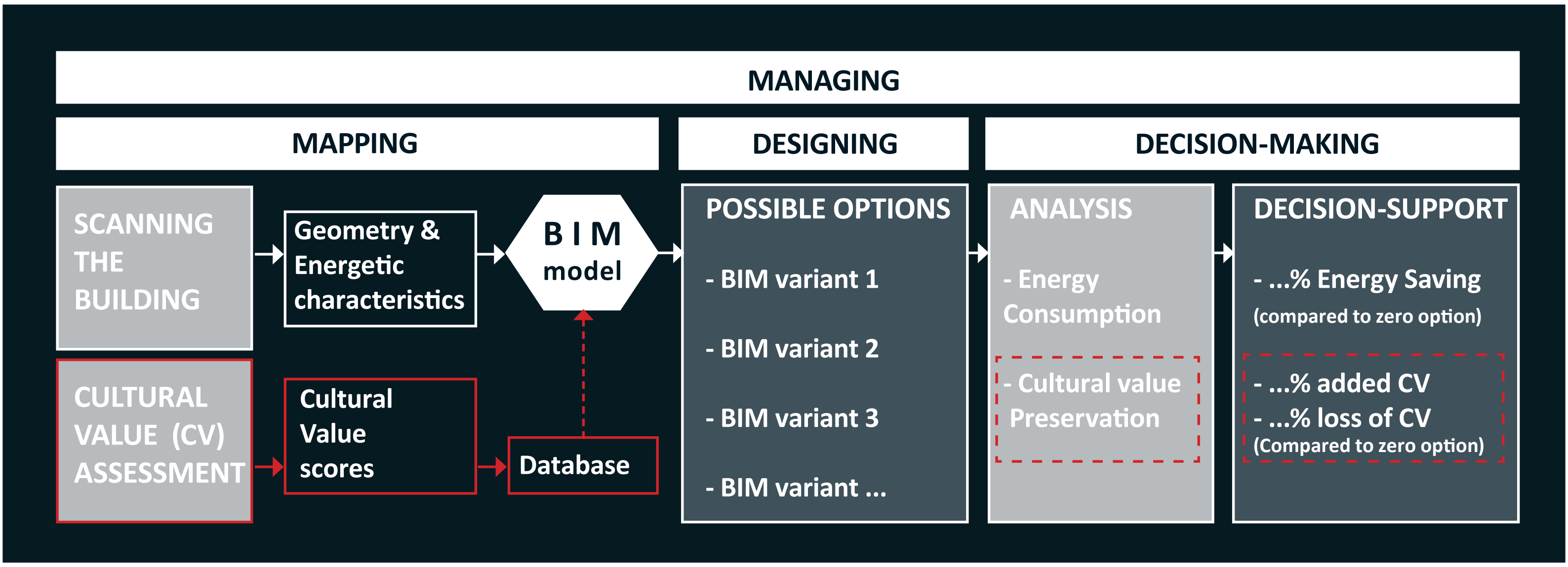
3. THE CONCEPTUAL MODEL

The conceptual model of this research is based on the concept of a similar research project, P2Endure, which is conducted for the European Commission. Within the P2Endure research, a BIM-based strategy is designed, that can support decisions on different energy renovation designs for existing buildings (DEMO B.V., 2016; Sebastian, 2017). For this research, the P2Endure concept is expanded on its applicability by making it also suitable for monuments. The expanded conceptual model is visualized in figure 1, whereby the red highlighted boxes reflect the added aspects in order to make the strategy applicable for monuments.
The conceptual strategy consists of implementing the energetic characteristics of the building components of the monument and the cultural value scores in a BIM model of the monument. Subsequently, renovation design options can be created in BIM, which can be analyzed on their impact on the energy consumption and the preservation of the cultural values. The results of the analyses will be expressed with key performance indicators on energy saving and added/loss of cultural value, which can support the decision upon the implementation of a design option. Design options with a high percentage of energy saving and a low percentage of loss of cultural values will be the most suitable to implement.

4. AIM

The aim of this research is to design a BIM-based strategy that supports the creation of a renovation plan for a monument, which increases the energy performance of the building and conserves the cultural values.

Figure 1: Conceptual model (own illustration)



5. RESEARCH METHODS

This research consist of a literature research, an empirical research and an operational research, which is called a hybrid research (Bryman, 2015).

5.1 Literature research

Existing literature is analyzed to create a starting point for the design of the strategy. Theory about monument conservation, energy renovations and building information modeling are combined to create new findings.

5.2 Empirical research

The empirical research consists of two parts: expert interviews and case studies. Professionals are interviewed in order to test the practical applicability of the theory and to align the design of the strategy with the current conservation practice.

Two case studies are performed with the comparative design as a qualitative research method. The cases are two Dutch national monuments, which are recently renovated in order to improve the energy performance. The first case is Paushuize in Utrecht and the second case is Westergasfabriek in Amsterdam. These national monuments are analyzed on their cultural values, thermal performance and energy renovation possibilities with the following three aims; (1) validate theoretical findings, (2) generate new research findings after a comparison of the two cases and (3) generate data of real cases that can be used in the test phase.

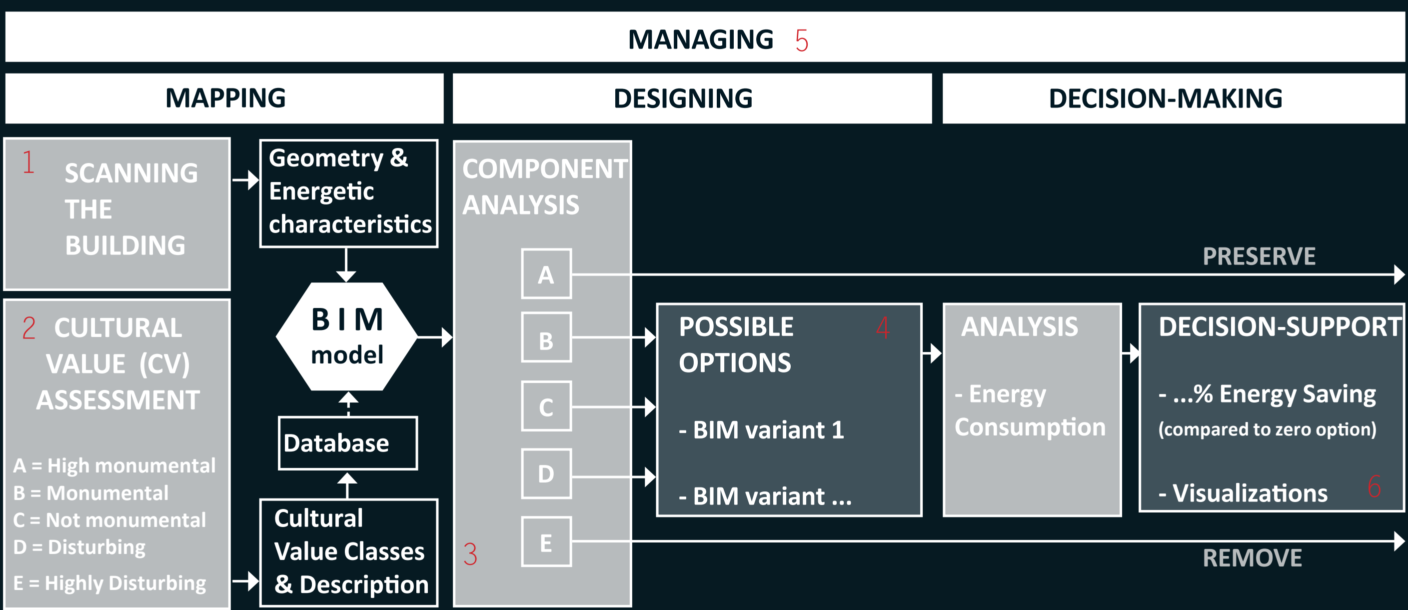
5.3 Operational research

The conceptual design of the strategy needs to be tested, evaluated and optimized in order to create the final design (Dym & Little, 2004). The strategy will be implemented on a test case, Ludwina monastery in Tilburg, and thereafter tested and evaluated. Subsequently, the strategy will be optimized based upon the outcomes of the literature research, case studies and evaluations of the tests.

6. RESEARCH RESULTS

The outcomes of the different research methods resulted in an optimization of the strategy (see figure 2). The optimized strategy will be described and subsequently explained with the results of the literature, empirical and operational research.

Figure 2: The optimized strategy (own illustration)



6.1 The strategy
The use of BIM can support the decisions on the optimization of energy performance and cultural value in Dutch (national) monuments if the following actions of the designed strategy are taken (see figure 2):

(1) Scan the monument on its geometry and energetic characteristics, create a BIM model and implement the energetic characteristics.
(2) Perform a cultural value assessment and determine into which cultural value class (A-E) the building components belong.
(3) Implement the cultural values in the BIM model and scope the design area, based on the cultural values. The high monumental components need to be preserved and the highly disturbing elements need to be removed.
(4) Create energy renovation design options in BIM, supported with digital analyses on the thermal values and cultural values.
(5) Manage the design process by sharing the enriched BIM model with every stakeholder and divide responsibilities of the stakeholders on building components in the BIM model. Make sure that the high monumental building components will be preserved and become unable to change.
(6) Make a decision upon a design option supported with the outcome of the impact analyses on the two variables. The impact on the cultural values can be determined by observing the visualizations of the BIM models of the design options and the effect on the thermal performance can be measured by performing energy analyses of the BIM model.

Each described action will be elaborated in the following paragraphs.

6.2 Scanning the monument
In order to apply the new strategy, a BIM model has to be created of the monument. Creating a BIM model of a monument can be done by hand, however this process is time-consuming. To decrease the creation time, it can be done in a more automated way, through the application of laser scanning. In this technique, a laser scans the geometry of the building whereby the output of the scan is a digital 3D point-cloud, which can be transformed into a BIM model trough automatic feature extraction (Yastikli, 2007). The process of creating these automated models still has its limitations because the automatic feature extraction software is not effective yet. As a result, a large amount of the geometric data still has to be implemented by hand (Franco et al., 2015; Jalaei & Jrade, 2014; Yastikli, 2007). Because of this limitation, the process of creating the 3D model is still time-consuming and a costly operation. However, the trends, such as optimization in automation and the reducing costs of the required instruments, are promising that it will become less expensive and less time-consuming in the future (Garagnani & Manferdini, 2013; Previtali et al., 2014).
When the BIM model is created, it has to be enriched with data of the energy performance of the building components. Determining the thermal performance on the basis of basic index numbers of materials will not be very accurate for monumental buildings. For example, a wall composed of brick 200 years ago does not have the same thermal properties as newly composed brick walls. The data can be measured instead, with thermal sensors and Infrared Thermography (IRT). IRT is a powerful tool to detect the external temperature of the building envelope and to detect thermal bridges and heat losses (Edis, Flores-Colen, & de Brito, 2012; Lagüela, González-Jorge, Armesto, & Arias, 2011). When the digital BIM model is enriched with the energetic characteristics of the building component, an energy analysis can be simulated and the outcome can be compared to the real thermal performance of the building. If the outcome of the digital simulation does not deviate much from the real thermal performance, it is possible to work with the BIM model as a simulation model (Franco et al., 2015).

6.3 Cultural value assessment
In order to incorporate the cultural values in the design of a renovation plan, they need to be analyzed by an historian. An historian (Dutch = Bouwhistoricus) is an expert who indicates the cultural values of a monument after an interior and exterior inspection (Hendriks & van der Hoeve, 2009; Nusselder & Dulski, 2008).
The cultural values of a monument can be divided in tangible and intangible cultural values. The tangible cultural values are represented by the building components that are the tangible remaining of the cultural and societal history. The indirect and relational values are the intangible cultural values (Bouchenaki, 2007; Ruggles & Silverman, 2009; Stephenson, 2008; Tomaszewski, 2003).

6.3.1 Theoretical cultural value assessment methods
Four Dutch theoretical methods for the cultural value assessment of monuments are analyzed and compared:

1: The Sustainable Monuments calculation model (developed by research institute NIBE (2008))
2: The Cultural Historical Value measurer (developed by Beers (2004))
3: The Cultural historic aspects with conservation factor (developed by Schrieken (2000))
4: The Building archeological research guidelines (developed by Hendriks & Van der Hoeve (2009).

The main difference between the methods is that the first three methods quantify the cultural values in order to express the cultural values in a number, while the fourth method bases the assessment on a qualification of the building components in three different monumentality classes; high monumental, monumental or not monumental.

6.3.2 Validating the practical applicability of the methods
Based upon the outcomes of the expert interviews, it can be concluded that the process of quantification of monumental values, which is applied in method 1, 2 and 3, is appreciated by all the involved stakeholders that need to take the cultural values into account except for the historians. The historians who need to assess these values, dislike this approach and are often not willing to work with these kind of qualification methods. They believe that the cultural values are not quantifiable (Dulski, 2017).
Next to this, theoretical method 4 is outdated according to an interviewee. The method is written in 2009 and the interviewee is convinced that the three classes are not sufficient anymore. Building components can also have a negative influence on the cultural values of a monument and therefore, two different classes should be added; disturbing and highly disturbing (van Bommel, 2017). The interviewee is planning to rewrite method 4 and implement this adaptation.

In both analyzed cases, the cultural value assessment formed the starting point of the design phase of the renovation plan. The guidelines of method 1 were used to assess the cultural values, however, the values were not calculated but based upon a feeling instead. This confirms that historians are not willing to base the level of cultural values on a calculation. Additionally, in the case of Paushuize, disturbing components were present that had a negative impact on the cultural values. This finding confirmed the theory of the interviewee on the disturbing values.

6.3.2 Choosing a method to implement in the strategy
Since the qualification method is preferred in practice over the calculation methods, the Building archeological research guidelines are chosen to implement in the strategy with the additional classes of disturbing values. The following five classes are defined:

Class	Meaning
A	High monumental value
B	Monumental value
C	No monumental value
D	Disturbing the monumentality
E	Highly disturbing the monumentality

Table 1: Classes of monumental values and meanings

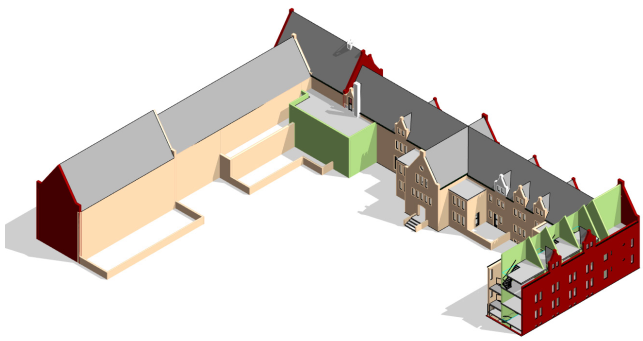


Figure 3: Cultural values of walls visualized with colour schemes in the BIM model of the test-case (own illustration).

6.4 Implementation of cultural values
Once the cultural values are assessed, they need to be incorporated during the design phase of the renovation plan. To be able to incorporate the values, they need to be implemented in the BIM model. After successfully implementing the cultural values in the test-case, it can be concluded that it is possible to implement information about the monumental values in a BIM model.
The cultural values need to be preserved and are therefore the starting point of the design phase. This means that the cultural values determine the adaptability of the monument, which in turn determines to what extent the energy conservation measures can be applied. This is also called: the tolerance for change (Logan & Reeves, 2008; Nusselder & Dulski, 2008; Vieveen, 2013).

Derived from the theory and the case studies, per class of monumentality, the required action is described:

Class	Meaning	Action
A	High monumental value	Preserve, do not amend
B	Monumental value	Amend with respect to the cultural values only
C	No monumental value	Free of action
D	Disturbing the monumentality	Remove if its favorable for the project
E	Highly disturbing the monumentality	Remove

Table 2: Classes of monumental values, meanings and suitable actions.

6.5 Energy renovation design options

When information about the thermal performance of the building components and the monumental classes are implemented in the BIM model, it is possible to work with this data. An automatically generated analysis by using information filters in Autodesk Revit software, can support the creation of the design arguments. It can support the identification of building areas where renovations are directly applicable and where the difficult areas are, by filtering for example all components in monumentality class C (Not monumental, free of action) and a High U-value. By implementing the possible interventions as design options in BIM, the design is flexible and easily changed.

The basic strategies for designing interventions in a monument without harming its characteristics are: (1) analyze the traditional performance, (2) apply reversible interventions, (3) apply minimal interventions, (4) adjust the function of the building on the characteristics and (5) adapt the comfort requirements (Carbonara, 2015; de Santoli, 2015; Dirlich, 2012; 2008; Nusselder & Dulski, 2008; van Krugten et al., 2016).

There are a large amount of energy conservation measures (ECM) available that can increase the energy performance of a monumental building. They can be divided in three categories: adjacent unheated spaces, new installations and insulations. Though, the assessment of the applicability of the measure needs extra attention (Nusselder & Dulski, 2008; Van Hal & Dulski, 2011).

The case studies confirm the theory about the three main strategies on energy conservation measures in monumental buildings. In both cases, the proposed measures were able to subdivide in three mentioned categories. These proposed measures were implementable in the BIM model of the test-case.

6.6 Managing the design process

In order to create a suitable design, the design process needs to be managed carefully. A stakeholder analysis showed that many stakeholders are involved during the design of an energy renovation plan for a monument, especially during the decision-making phase. Examples of these involved stakeholders are the owner, the architect, the municipal monuments committee, the board of mayor and aldermen, and interested parties.

Next to the support of the design process, the enriched BIM model with information about the energy performance and cultural values can support the process management of creating a suitable energy renovation design where many stakeholders are involved. Storing information in one model improves the accessibility of information for all stakeholders. A stakeholder can effortlessly find information about the building component of interest by clicking on the digital BIM component in the computer, instead of searching for the information in different reports. Additionally, visualizing the data with color schemes in a 3D model can improve the communication between stakeholders (see figure 3).

In order to make sure that the most valuable components will be preserved, these components can be ‘locked’ in the BIM model trough inserting them in a workset, whereby none of the stakeholders can amend this component without permission. A workset in the Autodesk Revit software is a collection of multiple building components in the BIM model that is ‘hosted’ by a user. The user who hosts the building components, is the only one that can amend them. By creating worksets and dividing responsibilities in the digital BIM environment, the project manager can steer the stakeholders upon the desired action as a consequence of the cultural value assessment. The restoration architect will remain in charge of the design, and the risk that other stakeholders will negatively impact the cultural values of the building will be diminished.

Next to the fact that BIM can support the management of the design process, the case studies showed that there are other important factors that should be taken into account by the project manager in order to enhance the management of the process.
Both cases showed that an early involvement of the municipal monuments committee in the process is of key importance to reduce the risk of disagreement during the decision-making process. Next to this, both cases showed that flexibility is required in the renovation plan and process. It is not possible to know in advance what will show up during the implementation of the renovation design on a monument.
Additionally, in the case of Paushuize, it was clear which elements were classified as '*high monumental valuable*'. This resulted in clear design restrictions as for example: '*do not amend these building components*'. In the case of the Westergasfabriek, the cultural values were more classified in category B: monumental valuable, yet not of the highest range, less defined and more prone to subjectivism. This resulted in a disagreement in the decision-making phase between the stakeholders.
Therefore, when there are cultural values assessed whereby the possible actions on that component are less defined, the following elements need to be taken into account by the manager:

- The project can require more historical research and thermal advice (more use of consultants).
- The design phase can take more time (implement this in the project planning).
- The project can become more expensive, due to the need of more time and research.
- The design process can take more time due to the possibility of disagreements between stakeholders, (involve the monuments committee in an early stage, clear communication trough visualization).
- The design can require more flexibility (multiple design options).

6.7 Decision-making upon design options
When the design options are created in BIM, a decision has to be made on the implementation of a design option. How this decision can be supported is analyzed in the literature research, empirical research and tested in the operational research.

6.7.1 Theoretical findings on the impact assessment on cultural values and thermal performance
According to Jeong et al. (2015), decisions upon design options regarding the impact on the cultural values would be more supported if the design options are visualized. Visualizations of the design options directly show the impact on the appearance. The historian can judge whether or not it harms the monumental appearance of the building components.
The thermal performance of the design options can be tested with an energy simulation in BIM software, such as Autodesk Revit. The outcomes of the analyses can help the user to decide which measure is the most effective for the building to implement. However, the outcomes of these energy simulations are not very precise. Nevertheless, it can give a good indication about the effectiveness of the design option for the thermal performance of the building (Jalaei & Jrade, 2014; Jeong et al., 2015).
Theoretically, BIM can be used to create good arguments for the decision because of the visualization possibilities and the energy simulation possibilities. The visualizations and simulations will give more insight in the thermal and cultural performance of the design options and can therefore support the decision-making process.

*6.7.2 Empirical findings on the impact assessment on cultural values and thermal performanc*e
It is emerged from the interviews, that working with different design options and analyzing them on the thermal performance is increasingly implemented in practice. The thermal performance of each design option can be analyzed by using other methods than BIM as well, for example Greencalc+. Greencalc+ is a calculation model of the thermal performance of buildings, based on key figures (Agentschap NL, 2010; DGMR, 2011).
The case studies confirmed the theory on the impact assessment on the cultural values through visualizations. In both cases, there was a need for visualizations in order to check whether the intervention had an impact on the appearance and cultural historic values of the building. In the case of the Westergasfabiek, the visualizations were used as a communication medium and as a base for the decisions. In the case of Paushuize, the visualizations were not really used, however afterwards it could have prevented some mistakes in the process.
In addition, the calculation of the impact of the measures on the thermal performance of the building supported the decisions in both cases. The empirical research is in line with the studied literature.

6.7.3 Operational findings on the impact assessment on cultural values and thermal performance

The design options analyzed in the case studies are implemented and tested in the BIM model of the test-case. This led to the conclusion that it is possible to analyze the impact of the measure on the thermal performance, however the model is prone to small errors, which will impact the result. Next to this, the BIM model should be highly detailed in order to be able to assess the impact on the cultural value.

6.7.4 Decision-support

Multiple design options can be created in BIM by duplicating the model. Each design option can be tested along the impact on the energy performance and cultural value, by performing energy analyses and observing the visualizations of the designs. If the BIM model is highly detailed and without any errors, it can support the decision on the implementation of a renovation design variant.

7. LIMITATIONS OF THE STRATEGY

The strategy is applicable, however there are some limitations:

- The creation of a BIM model is currently still a time-consuming and expensive operation.
- The BIM model has to be highly detailed to be able to create visualizations that can be used to assess the impact on the cultural values.
- Building components, such as a secondary window frame which is a typical energy conservation measure applicable for monuments, are not available in the component data base of Autodesk Revit. This emphasizes the fact that BIM is not used commonly for resolving the energy problem of monuments. However, such a family can be created.
- The energy analysis in the Autodesk Revit software provides just an indication and is not very accurate.
- A small defect in the energy model can have a large influence on the results of the energy simulation.

8. CONCLUSION

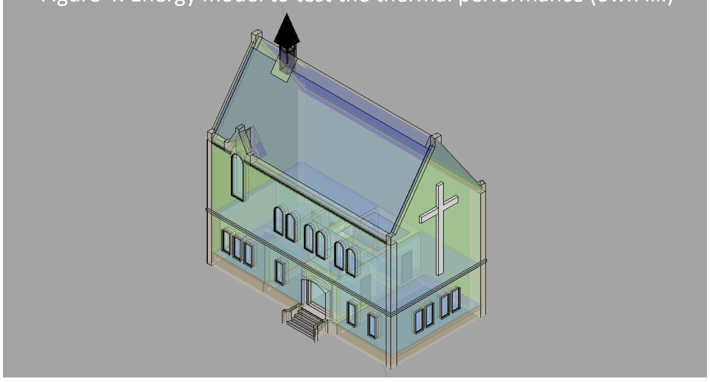
Based upon research findings, it is concluded that the use of BIM can support decisions on the optimization of energy performance and cultural value in Dutch (national) monuments. Information about the energetic characteristics of the building and the cultural values need to be implemented in the BIM model. The values can be qualified in five classes: High monumental (A), Monumental (B), Not monumental (C), Disturbing (D) and Highly disturbing (E). The classes will be implemented in the properties of the building components.

When the information is implemented in the BIM model, all the stakeholders can share and assess the information in one integral model, which can improve the communication. Consequently, automatically generated analyses by using information filters can support the creation of the design arguments and the identification of building areas where adaptations are directly applicable and where they are not. Building components that should be preserved can be locked in the model with the result that none of the stakeholders can amend this component.

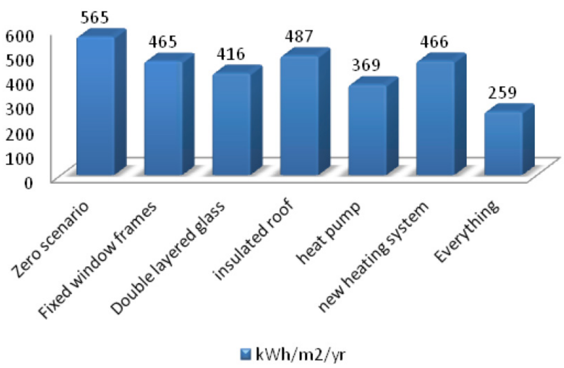
Decisions upon the impact on the energy performance can be supported by results of energy calculations and simulations. Decisions upon the impact on the cultural values can be supported with visualizations.

By implementing the possible interventions as design options in BIM, the design is flexible, easily changed, able to be analyzed on its energy performance and able to be visualized in order to assess the cultural impact. Therefore, the use of BIM can support the managing, designing and decision-making in the design process of a suitable energy renovation plan for a monument.

Figure 4: Energy model to test the thermal performance (own ill.)



Graph 1: Thermal performance of the design options.



9. RECOMMENDATIONS

Based upon research findings, the following recommendations can be made for the practical implementation of the outcomes of this research. Subsequently, recommendations for further research are given.

9.1 Recommendations for practical implementation (utilization potential)

The designed strategy could be applied in practice and has many advantages. However, the process of the creation of the BIM model is not effective yet. Though, the trends are promising and therefore the creation of a BIM model of a monument would become more applicable in a few years and therewith the application of this strategy.

9.2 Recommendations for further research

The applicability of the strategy looks promising, however it is not tested on a real project. Therefore, it is recommendable to perform further empirical research, whereby an energy renovation design process will be managed according to the created strategy. Subsequently, the strategy could be further optimized based on the findings of its applicability.
Additionally, this research is based on two criteria: cultural values and energy performance. However, there are multiple additional criteria that will influence the decision-making upon a renovation design such as cost, time, safety, technical condition, et cetera. Further research can be performed in order to add these additional variables to the strategy.

10. REFERENCES

Agentschap NL. (2010). *Centraal stellen van duurzame energieambities in het gebiedsontwikkelingsprocesGreencalc+* (p. 3). Agentschap NL Ministerie van Binnenlandse Zaken en Koninkrijksre-laties. Retrieved from https://www.rvo.nl/sites/default/files/bijlagen/Greencalc+.pdf

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering*, *11*(3), 241–252.

Bouchenaki, M. (2007). A major advance towards a holistic approach to heritage conservation: the 2003 Intangible Heritage Convention. *International Journal of Intangible Heritage, 2*, 106–109.

Bryman, A. (2015). *Social research methods*. Oxford university press.

Carbonara, G. (2015). Energy efficiency as a protection tool. *Energy and Buildings, 95,* 9–12.

de Santoli, L. (2015). Guidelines on energy efficiency of cultural heritage. *Energy and Buildings, 86,* 534–540.

DEMO B.V. (2016). *P2Endure.* Retrieved from http://www.p2endure-project.eu/Main.aspx?uri=1,2,3

DGMR. (2011). GreenCalc+. Retrieved June 20, 2017,from https://dgmrsoftware.nl/gcplus.php

Dirlich, S. (2012). The building stock and traditional building principles: sustainability assessment for historic buildings (pp. 31–38). Presented at the Proceedings of the 1st International Conference on Building Sustainability Assessment, Porto, Citeseer.

Dulski, B. (2017, February 14). Interview.

Dym, C. L., & Little, P. (2004). *Engineering Design, a Project-based introduction*. New York: Wiley.

Edis, E., Flores-Colen, I., & de Brito, J. (2012). Passive thermographic inspection of adhered ceramic claddings: limitation and conditioning factors. *Journal of Performance of Constructed Facilities, 27*(6), 737–747.

English Heritage. (2008). Energy conservation in traditional buildings. *English Heritage Program*, 1–11.

Franco, G., Magrini, A., Cartesegna, M., & Guerrini, M. (2015). Towards a systematic approach for energy refurbishment of historical buildings. The case study of Albergo dei Poveri in Genoa, Italy. *Special Issue: Historic, Historical and Existing Buildings: Designing the Retrofit. An Overview from Energy Performances to Indoor Air Quality, 95,* 153–159. https://doi.org/10.1016/j.enbuild.2014.10.051

Garagnani, S., & Manferdini, A. M. (2013). Parametric accuracy: Building Information Modeling process applied to the cultural heritage preservation. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XL-5 W, 1*, 87–92.

Georges, L., Haase, M., Houlihan Wiberg, A., Kristjansdottir, T., & Risholt, B. (2015). Life cycle emissions analysis of two nZEB concepts. *Building Research & Information, 43*(1), 82–93.

Hendriks, L., & van der Hoeve, J. (2009). *Guidelines for building archaeological research - The interpretation and analysis of cultural-historical heritage.* The Hague. Retrieved from https://cultureelerfgoed.nl/sites/default/files/publications/guidelines-for-building-archaeological-research.pdf

Jalaei, F., & Jrade, A. (2014). Integrating Building Information Modeling (BIM) and Energy Analysis Tools with Green Building Certification System to Conceptually Design Sustainable Buildings.
Jansen, J., Storck, M., & Van der Weijden, J. (2012). *Build up skills - The Netherlands - Analysis of the status quo* (pp. 2–5). Harderwijk: Intelligent Energy Europe.
Jeong, W., Kim, J. B., Clayton, M. J., Haberl, J. S., & Yan, W. (2015). A framework to integrate object-oriented physical modelling with building information modelling for building thermal simulation. *Journal of Building Performance Simulation*, 1–20.
Lagüela, S., González-Jorge, H., Armesto, J., & Arias, P. (2011). Calibration and verification of thermographic cameras for geometric measurements. *Infrared Physics & Technology, 54*(2), 92–99.
Logan, W., & Reeves, K. (2008). *Places of pain and shame: dealing with 'difficult heritage'*. Routledge.
Nusselder, E.-J., & Dulski, B. (2008). Handboek duurzame monumentenzorg: Theorie en praktijk van duurzaam monumentenbeheer.
Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and Buildings, 40(*3), 394–398.
Previtali, M., Barazzetti, L., Brumana, R., Cuca, B., Oreni, D., Roncoroni, F., & Scaioni, M. (2014). Automatic façade modelling using point cloud data for energy-efficient retrofitting. *Applied Geomatics, 6*(2), 95–113.
Ruggles, D. F., & Silverman, H. (2009). From tangible to intangible heritage. In *Intangible heritage embodied* (pp. 1–14). Springer.
Schrieken, B. J. (2000). *Geloof in transformatie - Een keuze- haalbaarheidsmodel voor de functie na de transformatie van kerken uit de wederopbouw* (M.Sc. thesis). Delft: Technische Universiteit Delft.
Sebastian, R. (2017, June 3). Meeting with the project coordinator of the EU-funded research project P2Endure.
Silva, H., & Henriques, F. M. A. (2016). Hygrothermal analysis of historic buildings: Statistical methodologies and their applicability in temperate climates. *Structural Survey, 34*(1), 12–23. https://doi.org/10.1108/SS-07-2015-0030
Stephenson, J. (2008). The cultural values model: an integrated approach to values in landscapes. *Landscape and Urban Planning, 84*(2), 127–139.
Tomaszewski, A. (2003). Tangible and intangible values of cultural property in Western tradition and science.
van Beers, B. J. (2004). *Herbestemming industrieel erfgoed: Nieuw licht in Eindhoven.* Delft: Technische Universiteit Delft.
van Bommel, B. (2017, July 3). Interview with Bert van Bommel.
van Hal, A., & Dulski, B. (2011). Niet in dogma's denken: Duurzaamheidsambitie en monumentenzorg. *Building Business,(juni/juli), 2011.*
van Krugten, L., van Krugten, L., Hermans, L., Hermans, L., Havinga, L., Havinga, L., … Schellen, H. (2016). Raising the energy performance of historical dwellings. *Management of Environmental Quality: An International Journal, 27*(6), 740–755.
Vieveen, M. (2013). Energiek restaureren - Adaptive energy efficiency in historic buildings, (1), 106–119.
Yastikli, N. (2007). Documentation of cultural heritage using digital photogrammetry and laser scanning. J*ournal of Cultural Heritage, 8*(4), 423–427.

| FOREWORD

This master thesis presents the research I conducted within the domain of 'adaptive reuse' of existing real estate. Adaptive reuse is a research domain of the master track Management in the Built Environment (MBE) at the University of Technology Delft in the Netherlands. The topic of my reasearch is energy efficient renovations of monuments.

During city trips in the Netherlands and other countries, I am mostly interested in the historic buildings. These monuments often reflect the history of the place, local culture and tradition. I believe that every monument tells a story about the past and therefore I find these kind of buildings very interesting. Monumental buildings are more than just functional units because they are also cultural valuable. Due to this interest, I followed some electives at the University of Utrecht in the history of architecture and the conservation of monuments. The content of these electives was mostly focused on preserving the cultural valuable elements of a monument. During my bachelor program and master track at the TU Delft, the focus was more on improving the existing real estate and applying innovative measures.

I believe that the combination of conservation and innovation has numerous undiscovered opportunities that can improve the life cycle of a monument and the management of it. Conservation ensures the preservation of the monument and its cultural values, whereas innovation provides the possibility of applying innovative measures and technologies.

Monuments are often not energy efficient however, applying changes to a monument can have a negative impact on the monumental values. Therefore, the creation of an energy renovation plan for monuments is complex.

My ambition is to research the possibilities for innovating the conservation of monumental real estate, by applying and combining the technical-, cultural- and mangerial knowledge I gathered throughout my studies. By doing this, I want to tackle the complexity that comes along with the creation of an appropriate energy renovation plan for a monument.

Acknowledgements

I would like to express my sincere gratitude to my mentors Hilde Remøy and Alexander Koutamanis for their feedback, inspiration, cooperation and support during every phase of my graduation project.

Furthermore, I am also grateful to Charlot Mulder, who always gave me the opportunity to share my thoughts during the graduation project. I highly appreciate her encouraging attitude and effort to review my report very carefully.

Finally, I would like to thank my on-site supervisor Rizal Sebastian for his assistance and all the other colleagues of DEMO Consultants for their interest and support. Being a graduate intern at DEMO Consultants was an instructive experience.

|| TABLE OF CONTENTS

||| INTRODUCTION

Monuments are historic buildings, that are built in the past and are considered as important to conserve and to keep in its shape. They are considered to be a tangible remaining of the cultural and societal history (Nusselder & Dulski, 2008). Therefore, cultural values are the core of the conservation interest (Mason, 2008). Current users of a monument are not expected to live like original users from, for example, the 16th century. Therefore, there is a need for change in order to make the building suitable for use in the 21st century. However, applying changes to a monument can result in a loss of monumental value. This loss will only be accepted if there is an important argument for it, that compensates the loss (Schunselaar, 2009; van Bommel, 2017). Dutch monuments are protected by the Dutch government in order to prevent the loss of monumental value. Therefore, if one wants to amend a monument, a permit needs to be requested.

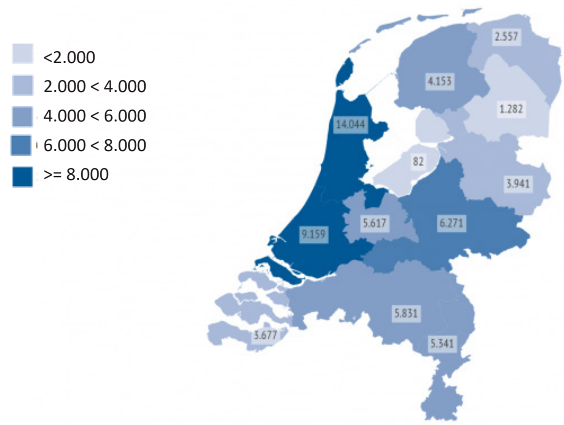


Figure 5: Amount of national monuments (Source: RCE)

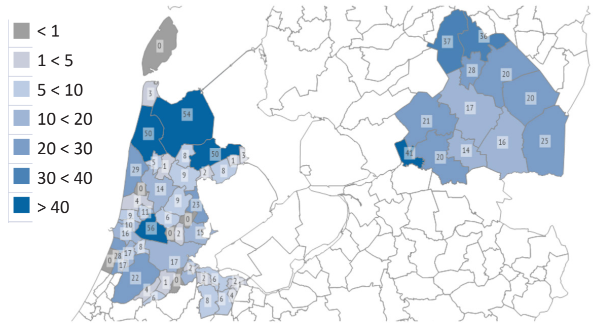


Figure 6: Amount of provincial monuments (Source: RCE)

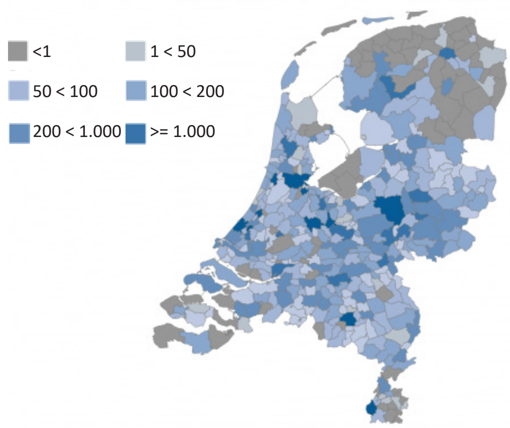


Figure 7: Amount of municipal monuments (Source: RCE)

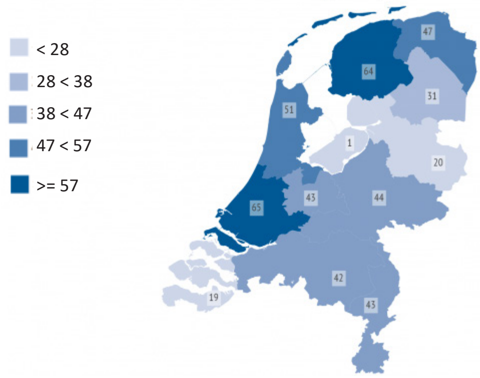


Figure 8: Amount of protected sites (Source: RCE)

2.1 Monuments in the Netherlands

There are four different types of monuments in the Netherlands, each regulated with a different system of protection by the government.

<u>[1] Dutch National Monuments</u> (Dutch: Rijksmonumenten) are buildings of national importance due to their beauty or history (RCE, 2016a). At the end of January 2017, the Netherlands counted 61.955 national monuments (Fig. 5) (Monumentenregister, 2017). The National service of cultural heritage (Dutch: Rijksdienst Cultureel Erfgoed (RCE)) is responsible for the designation and governance of these monuments (Ankone, 2016; RCE, 2016a).

<u>[2] Dutch Provincial Monuments</u> are only present in the province of Drenthe and Noord-Holland. At the end of 2016, there were 844 Provincial Monuments in the Netherlands (Fig. 6) (Monumentenregister, 2016). The Provincial State is responsible for the designation and governance of these monuments (Ankone, 2016).

<u>[3] Municipal Monuments</u> are buildings that are of local importance. Each municipality has a list of protected municipal monuments (Ankone, 2016). In December 2015, there were 55.801 municipal monuments in the Netherlands (RCE, 2016b). The municipality is

responsible for the designation and governance of these monuments (Ankone, 2016) (Fig. 7).

[4] Protected city- and village sites (Dutch: Beschermde stads- en dorpsgezichten) are areas with a special cultural historic character, designated by the minister of Education Culture and Science (OCW) and the minister of Infrastructure and Environment (I&M) in collaboration with the municipalities and the Provincial States. Not every building within these areas is a monument, yet a permit is required to make any change whatsoever. In this way, the conservation of the character of the area can be controlled (RCE, 2017a). At the end of 2016, there were 470 protected areas in the Netherlands (Fig. 8) (RCE, 2017b).

Table 3 provides an overview of the type and amount of monuments and the corresponding governance. Based on this, it is concluded that national monuments are the most common type of monuments in the Netherlands. Therefore, this research focuses on national monuments.

1.2 Refurbishment ambitions in the Netherlands

Buildings account for more than one third of the total annual European energy consumption (Pérez-Lombard, Ortiz, & Pout, 2008). The biggest potential to reduce the energy consumption lies in the existing building stock (Jansen, Storck, & Van der Weijden, 2012). This counts also for monumental buildings (Hoppe, 2009; Georges, Haase, Houlihan Wiberg, Kristjansdottir, & Risholt, 2015). As shown in table 3, there are a lot of monuments present in the Netherlands and refurbishing these buildings, will therefore positively contribute to the reduction of the total energy consumption in the Netherlands. However, an energy renovation of a monument differs from a energy renovation of a normal building due to the interest of preserving the monumental values. The topic of this research is therefore: *Improving the energy performance of a national monument without harming the monumental values.*

Type	**Governance**	**Amount in NL**
National monument	National service of cultural heritage (RCE)	61.955
Provincial monument	The provincial states of the province	844
Municipal monument	The municipality	55.801
Protected city- and village sites	Minister of OCW and the minister of I&M, municipalities and provinces.	470

Table 3: Amount and governance of the different types of monuments in the Netherlands

RESEARCH PROPOSAL

1| RESEARCH PROPOSAL

1.1 Problem Analysis

Monuments are linked to the historical period of construction, where often human comfort and energy efficiency were less taken into account (Silva & Henriques, 2016). However, the building needs to meet the demands of the current occupants regarding human comfort, such as temperature regulation and fresh air. Moreover, the Dutch government stimulates energy renovations in order to reduce the energy consumption and have a more sustainable real estate stock (Lashley, 2016; van Oorschot, Hofman, & Halman, 2016; Visscher, Meijer, Majcen, & Itard, 2016).

The management of monuments regarding sustainability differs from that of new buildings, since both environmental and cultural sustainability should be incorporated. In this research, the following definitions of these two aspects will be applied:
-Environmental sustainability: “Energy efficient building performance which leads to low emission”.
- Cultural sustainability: “The alteration of a building with respect to the necessities of the present era without losing its identity and characteristics”(Yaldiz, 2010).
Monuments are protected by governmental parties in order to safeguard the cultural sustainability. The Dutch environmental law describes the outlines of the conservation of monuments in order to make sure that the non-renewable sources with a certain cultural value will be conserved (Franco, Magrini, Cartesegna, & Guerrini, 2015; RCE, 2016). In order to improve the environmental sustainability, one could apply Energy Conservation Measures (ECM). These are measures such as extra insulation layers or efficient heating systems that will increase the energy performance of the building. However, these measures might have a negative impact on the cultural values of the monument. Therefore, the combination of preservation of monumental buildings and the enhancement of its energy performance is often seen as conflicting ambitions (Franco et al., 2015).

When an owner of a monument wants to apply these ECM, a permit needs to be requested. The permit will be granted if the cultural values are preserved. These cultural values are determined by an historian. However, the outcome of this cultural value assessment can be interpreted differently by the stakeholder that authorizes the permit and the one who is requesting the permit (Garagnani & Manferdini, 2013). Next to that, there are many different ECM available which makes it hard to assess which one is the most suitable or effective. Therefore, it is often a complex process to find an ECM that will improve the energy efficiency of the building and can be permitted.

In order to solve this complexity, it is possible to look at how decisions on ECM are made for newly designed buildings. Nowadays, Building Information Modeling (BIM) is commonly used to support the design phase and decision-making upon design alternatives. BIM is a data and visualization technology that integrates geometry and non-geometry information in a digital 3D model of a construction (Yang & Liao, 2016). A 3D model is only based on geometrical data. This model becomes a BIM model when extra information is linked to it. BIM models are being used for the creation of designs and digital drawings. Next to this, a BIM model can support decisions during the design phase. BIM can also be used to analyze the energy performance of the building if its energy characteristics are inserted in the model. It can help the user of the model to assess the suitability of different ECM based on the impact on the appearance of the building and the effectiveness. However, BIM is not often used in the management of monumental real estate management because monuments are more difficult to model in 3D due to their irregular shapes and highly decorated building components (Garagnani & Manferdini, 2013). New techniques might be able to solve this, for example 3D laser scanners which can create a 3D model of an existing building in a highly automated way (Franco et al., 2015). This can be seen as an opportunity to apply the use of BIM in the management of monumental real estate as well.

⟵
Figure 9: Monumental canal houses Amsterdam (Source: w-dog.net)

1.2 Problem Statement

Monuments are often not energy efficient, yet improving the energy performance without harming the cultural values is still a complex process. By only conserving a building without making adaptations, a mismatch between the demand of the user and the building can arise. Next to that, Building Information Modeling (BIM) that can assess the suitability of different energy conservation measures on the ground of appearance and effectiveness is not commonly used in the management of monumental real estate.

1.3 Aim

The aim of this research is to design a BIM-based strategy that supports the creation of a renovation plan for a monument, which increases the energy performance of the building and conserves the cultural values.

1.4 Research Question

How can the use of BIM support decisions on the optimization of energy performance and cultural value in Dutch national monuments?

1.5 Sub questions

In order to answer the main research question, theoretical, empirical and operational sub questions are defined. The sum of the answers to all these questions forms the answer to the main research question.

<u>1.5.1 Theoretical sub questions.</u>
The theoretical sub questions will be answered within the literature study. The literature study consists of 5 theme's with corresponding sub questions.

Theme 1: (Heritage) BIM
- How can a BIM model of a monument be made?
- How can the thermal performance of a monument be analyzed and integrated in BIM?

Theme 2: Cultural Values
- What is the difference between tangible and intangible cultural values?
- Which existing methods for cultural historic value assessment are available?

Theme 3: Energy Conservation Measures
- What are the current strategies to improve the energy performance of a monumental building?
- What kind of energy conservation measures are applicable in monumental buildings?

Theme 4: Stakeholders
- Which actors are involved in the design process of an energy renovation plan for a monument? What is their main power and interest?

Theme 5: Monuments law
- Which legal steps needs to be taken in order to receive a permit for amending a monument?
- What is recently changed in the law regarding the conservation of monuments?

<u>1.5.2 Empirical sub question</u>
Empirical sub questions will be answered by the outcome of case studies and interviews with experts.

- Is the theory gathered from the literature study applicable in practice?

<u>1.5.3 Operational sub questions</u>
The operational part of this research consists of implementing the information from the literature study and empirical study in the design of the strategy. The focus is on how BIM can support the design process and decision making.

- Is the strategy applicable?
- Can the strategy be improved?

1.6 Research Methods

This research consists of a literature study, an empirical research and an operational research, which is called a hybrid research (Bryman, 2015). Figure 10 provides an overview of the research design.

<u>1.6.1 Literature review</u>
In order to not be accused of reinventing the wheel, it is needed to know what is already known in this research area (Bryman, 2015). To frame the scope of this literature study, multiple themes are identified that need to be researched in the literature, as described in chapter 1.5.1.

1.6.2 Empirical research: Expert interviews and Case studies

Professionals active in the field of sustainable monument conservation have the most state of the art knowledge about energy renovation processes of monuments in practice. In order to test if the theoretical information gathered in the literature research is also valid in practice, stakeholders with different perspectives on these kind of projects will be interviewed, including (restoration) architects, monument committee members and a energy consultant specialized in energy conservation measures for monuments.

Next to the expert interviews, real renovation projects of monuments will be analyzed and compared. The comparative design as a qualitative research strategy entails studying two or more cases by using more or less the same methods (Bryman, 2015). Information about the cases will be gathered by interviewing the stakeholders of the project, using the semi structured interview method. Existing reports and articles will be analyzed as well in order to gather additional information. The aim of the case studies is to get practical insights in the design phase of an energy renovation plan of a monument.

Moreover, real project data can be gathered during the case studies, that can be used to test the strategy.

Case study criteria:

- Energy renovation project of a monument
- The project needs to be (almost) finished (the whole process needs to be analyzed).
- Available information about:
    - o The cultural historic values;
    - o The energy performance;
    - o The possible renovation designs;
    - o The decision-making process.

1.6.3 Operational research: The design of a management strategy

When the literature study, expert interviews and case studies are finished, a strategy can be designed for the optimization on the energy performance and the cultural values of a monument with the use of BIM. Consequently, the strategy has to be tested, evaluated and optimized (Ackoff & Maurice, 1968; Dym & Little, 2004).

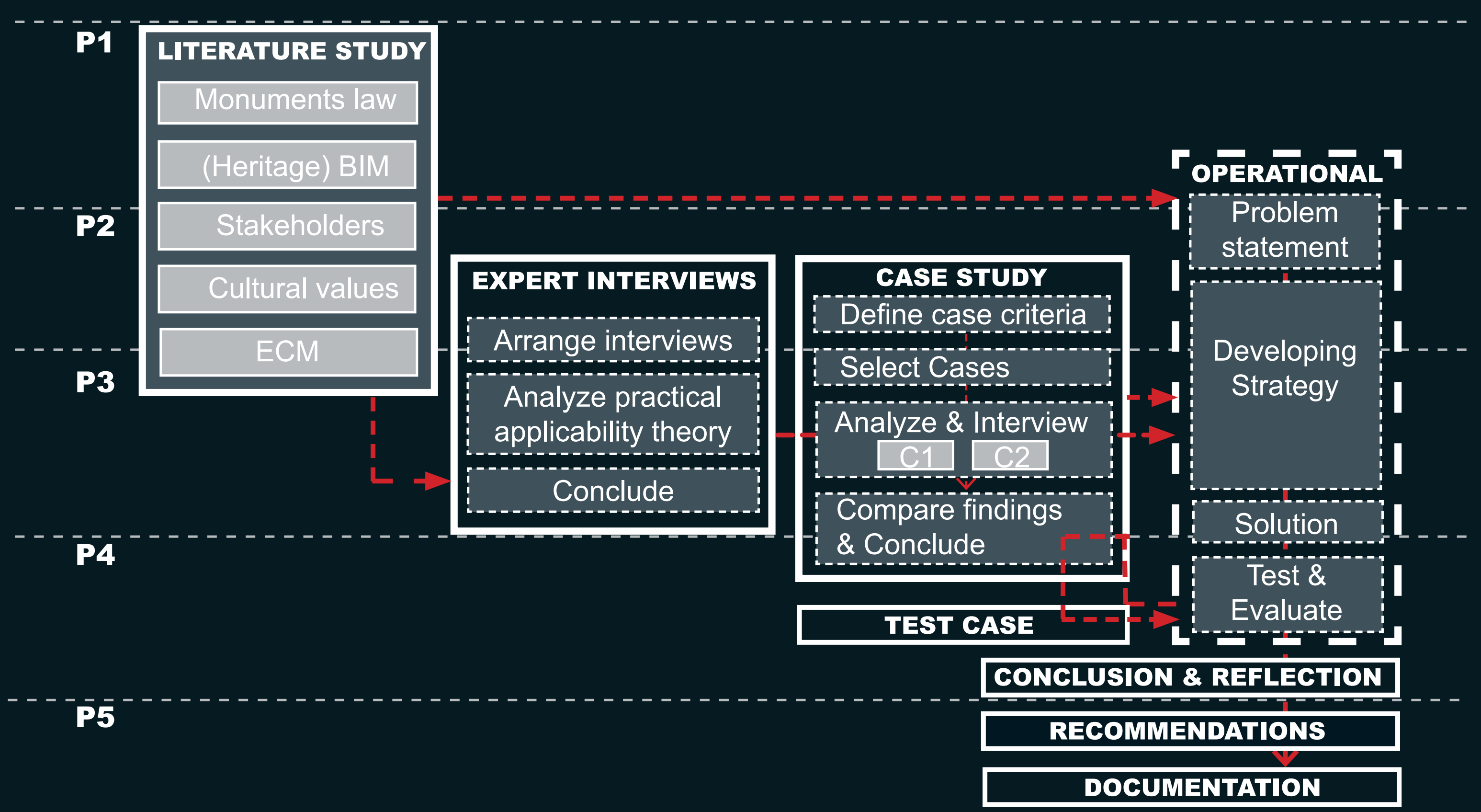


Figure 10: Research design (own illustration).

1.7 The conceptual model

The conceptual model of this research is based on an existing model of a similar research project.

1.7.1 Similar research project P2Endure

A similar research project called P2Endure is conducted for the European Commission. The main aim of P2Endure is to find out how BIM can support decisions on different energy renovation designs for existing buildings (DEMO B.V., 2016). The conceptual model of the P2Endure research is visualized in figure 11 and the original version can be found in Appendix 9.2. For the P2Endure research project, the renovation strategy will be implemented and tested on real cases.
Since the strategy of this graduation research is based on the strategy of the P2Endure project, it will be explained shortly. The strategy consists of three phases: the pre-renovation mapping phase, the renovation design phase and the renovation decision-making phase (Sebastian, 2017).

[Phase 1] Pre-renovation mapping

Phase 1 consists of generating data about the building, such as 3D point clouds, 3D objects, pictures and thermal and acoustic images. This data needs to be translated into a BIM model of the existing building. At the same time, a condition assessment needs to take place, which will result in condition scores. These condition scores and additional information about the technical state needs to be implemented in the BIM model. The result of the pre-renovation mapping phase is a BIM model enriched with information.

[Phase 2] Renovation design

For the renovation design phase there are 'Plug and Play solutions' (PnP) considered as energy conservation measures. These consist of predefined and standard solutions. There are BIM components of these solution available in a catalog. One can select a solution from the catalog and create possible renovation designs (variants).

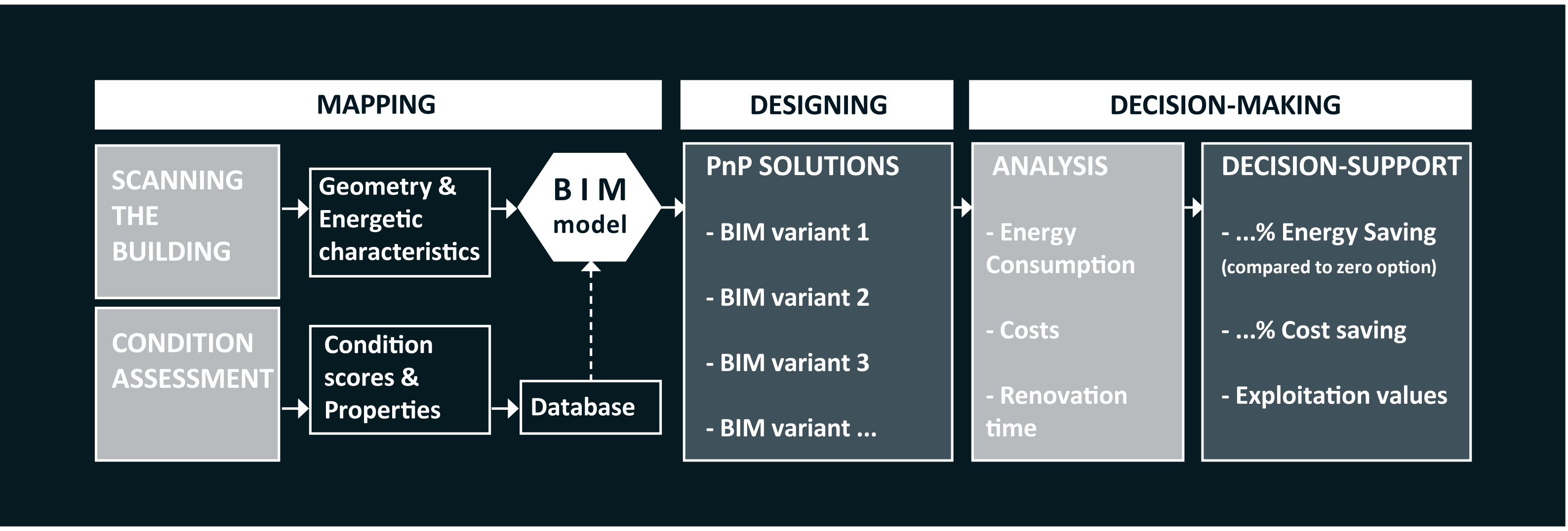
[Phase 3] Renovation decision-making

Each design variant will be calculated on the energy consumption, renovation costs and renovation time as shown in figure 11. Consequently, the results of these analysis are shown in the asset management decision support tool visualized with Key Performance Indicators (KPI's). This tool directly shows the performance of different aspects like costs and energy consumption, on which the decision for the design option can be based (Sebastian, 2017).

1.7.2 Strategy adapted for monuments

The P2Endure strategy is not applicable for monuments, because the cultural values are not taken into account. Therefore, in this research the original pre-renovation mapping phase is complemented with the assessment of the cultural values. The concept is slightly changed in order to make it suitable for monuments. The changes per phase will be explained next. The adapted concept will be tested and optimized in this research, therefore figure 12 is the conceptual model of this research.

Figure 11: Conceptual model of P2Endure research (own illustration).



[Phase 1] Mapping
Next to a condition assessment, a building historic research needs to be performed by an historian. The results of this research need to be implemented in the BIM model.

[Phase 2] Designing
'Plug and play' solutions are often not applicable for monuments. These are general solutions and for monuments often tailor-made solutions are necessary (Nusselder & Dulski, 2008). The Plug and Play solutions will be replaced by 'possible solutions'. Consequently, different renovation designs can be created in the BIM model.

[Phase 3] Renovation decision-making
In the calculation/analysis phase, the impact on the cultural value will be calculated. The addition and the loss of cultural values are added KPI's on which the decision can be based.

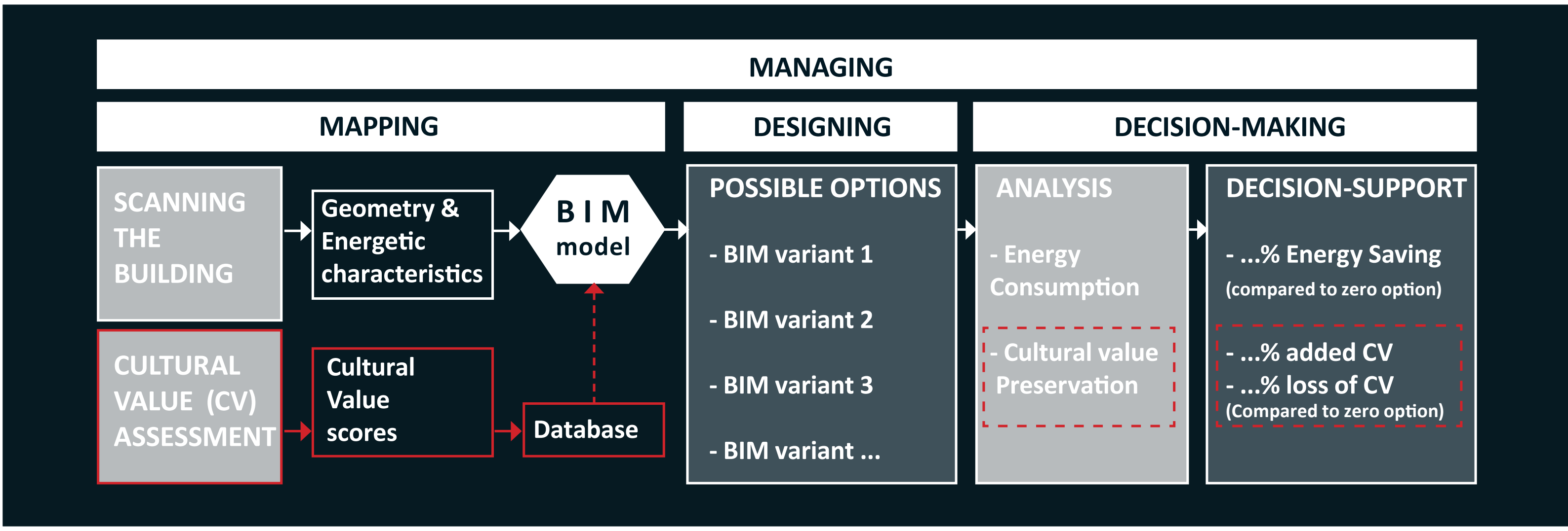
1.8 Relevance

1.8.1 Societal relevance
There is a demand for tools that stimulate the re-use of monuments and monumental conservation in a sustainable way. Citizens, organizations and entrepreneurs who have plans for a monument must be nurtured (Janssen, 2014). Therefore the creation of a new management and decision-support strategy with the use of new technological features can support these stakeholders.

Also, if the cultural values of monuments are being conserved and simultaneously optimized on its usability in terms of energy consumption, monuments can function better in society. They can still attract tourists, or reflect the history of society, yet the use of the building has a less negative impact on the environment. Less negative impact on the environment is more beneficial for the society of today and the society of the future.

1.8.2 Scientific Relevance
The need for decision support tools that stimulate adaptive reuse is also acknowledged in the field of researchers (Franco et al., 2015; Yung & Chan, 2012). This research is about creating a strategy by using BIM to find energy conservation measures that takes the cultural sustainability into account. There is not much research done yet on the application of BIM in the management of and the decision-making in monumental real estate. Therefore, research in this field can lead to the discovery of new opportunities.
Also, the European commission acknowledged the relevance of this topic since it supports research that identifies cultural, social, economic, institutional, legal, regulatory and administrative barriers and bottlenecks for adaptive re-use of cultural heritage monuments, and research that recommends ways to overcome them (European Commission, 2015).

Figure 12: Conceptual model (own illustration).



THEORETICAL FRAMEWORK

2.1 INTRODUCTION

All the phases of the conceptual model, as visualized in figure 12, will be analyzed in the literature. Firstly, the mapping phase, which consists of the creation of the BIM model of a monument and the gathering of information about the energy performance and cultural values. Secondly, the implementation of the gathered information in the renovation design. Thirdly, the decision-making on design options based on the two main aspects: monumentality and energy efficiency.

Figure 13: Westergasfabriek Amsterdam (Source: Westergasfabriek BV)

2.2| HERITAGE BIM

2.2.1 Introduction

The first part of the strategy, as visualized in figure 12, consists of the creation of a BIM model of a monument. There is an increasing amount of techniques available that enhance the process of 3D documentation of buildings in the computer (Yastikli, 2007). First, the creation of the BIM model will be analyzed. Consequently, the analysis of the thermal performance will be explained. The focus of this research is not on the technical aspects of the creation of a digital BIM model of a building but on the practical application. However, a short analysis of the process, limitations and opportunities is required in order to assess whether designing a strategy, where these kind of applications are integrated, is feasible.

2.2.2 Creating the BIM model of a monument

A BIM model can be created by a BIM modeler, who draws the model by hand in the computer. However, this is time-consuming and difficult to realize accurately for an existing building. An innovative technique that can be used to create 3D models from existing buildings is laser scanning, whereby lasers scan the building and the context, and subsequently produces a digital 3D point cloud (Yastikli, 2007). This kind of technique is valuable for the creation of 3D models of monuments because it can process complex and irregular surfaces (Garagnani & Manferdini, 2013; Previtali et al., 2014; Yastikli, 2007). Creating BIM models of monumental and heritage buildings is also called Heritage BIM (H-BIM).
The point clouds resulting from laser scanning are not directly suitable for application, because it represents no kind of information. The point clouds need to be transformed into a vector format file, which is still time-consuming and requires skilled operators. Therefore, there is an increasing interest for automatic modeling, in which this process is automated (Garagnani & Manferdini, 2013; Nan, Sharf, Zhang, Cohen-Or, & Chen, 2010).
When the vector format is made, a 3D model can be created. This 3D model can be integrated in BIM, because it can combine objects, relations and attributes. The use of such a model is relevant for the entire life cycle of the building and has the possibility to integrate other information like time and costs as further dimensions, which may efficiently supports the decision-making process (Previtali et al., 2014).

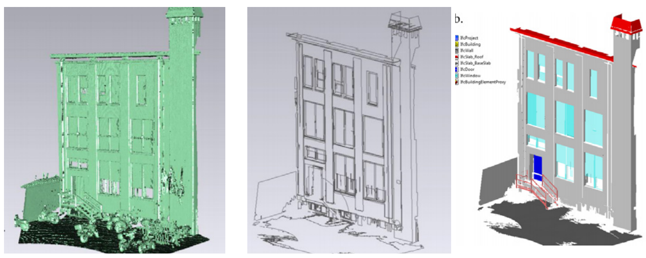
2.2.3 Limitations Heritage BIM

It seems that the innovative techniques make it easy to create a BIM model of a monument, however there are still some limitations.
Monumental buildings often have many ornamental details, damaged components and components which geometry and characteristics are very far from specifications of modern component libraries, which makes automatic feature extraction difficult (Figure 14) (Jalaei & Jrade, 2014).
Next to this, according to Garagnani & Manferdini (2013), the automatic feature extraction software is also not yet effective. As a result, still a large amount of the geometric data has to be implemented by hand (Franco et al., 2015; Jalaei & Jrade, 2014). Because of these limitations, the process of creating the 3D model is still time-consuming and a costly operation (Previtali et al., 2014).

2.2.4 Promising trends in BIM modeling

Apart from the limitations, there are also promising trends. The automation in acquisition and registration of scans is getting more optimized and the costs of the required instruments are reducing.
A lot of research is being performed on optimization and automation of innovative techniques like laser scanning. These trends suggest that it will become a more easy and less expensive process, which will result in more application in the future (Previtali et al., 2014).

Figure 14: From pointcloud into BIM model (Source: Previtali)



2.2.5 Integrating thermal performance in BIM

Once the BIM model is created, information about the energy characteristics of the building has to be integrated in the model. There are many factors that influence the energy efficiency of a building, for example the solar exposition, building orientation, geographic location, neighbor environment, heating and cooling systems, typology of electrical appliances, building materials and size (Previtali et al., 2014). According to Previtali et al. (2014), the composition of the façade and roof is the most crucial for the thermal performance of the building, because of the thermal bridges that are often present in the monumental façade. In order to do an thermal assessment of the façade in the BIM model, a highly detailed model of the current building is required.

When the model is completed and enriched with information about the thermal performance of the building, the accuracy of the model has to be evaluated by simulating the annual energy consumption of the building within the model. The simulations can reproduce the current energy performance of the building if all the technical specifications about the materials and components are included in the model. There are various types of building energy simulations and analysis tools developed (Jalaei & Jrade, 2014). For example, Infrared Thermography (IRT) is a powerful tool to detect the external temperature of the building envelope and can detect thermal bridges and heat losses (Fig. 15). The thermal transmittance (U-Value) can be measured with sensors (Edis, Flores-Colen, & de Brito, 2012; Lagüela, González-Jorge, Armesto, & Arias, 2011).

The outcome of the simulations has to be compared to the reference data of the actual annual energy consumption of one reference year. When the outcome of the simulations of the model does not deviate much from the reference data of the real building, it is possible to work with the model as a reference (Franco et al., 2015). The amount of acceptable deviation between these two outcomes is not available in the literature.

2.2.5 Conclusion

The creation of a BIM model of a monument can be done by hand, however this process is time-consuming. To decrease the creation time, it can be done in a more automated way through the application of laser scanning. The process of creating these automated models still has its limitations but the trends are promising that it will become less expensive and less time consuming in the future.
The BIM model has to be enriched with data of the energy performance of the building and has to become highly detailed in order to be able to run energy simulations and indicate the thermal bridges. This data can be gathered with sensors and infrared thermography. When the outcome of these thermal performance simulations are similar to the real thermal performance of the building, it is possible to work with the model as a simulation model.

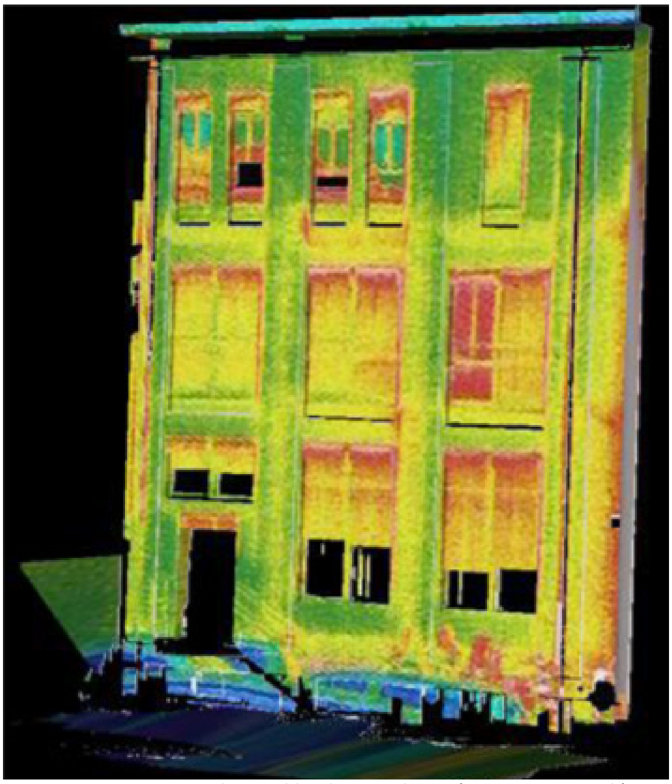


Figure 15: Detect thermal bridges with IRT (Source: Previtali)

2.3| CULTURAL VALUES

2.3.1 Introduction

In addition to the energy performance of the building, the cultural values of the monument need to be integrated in the BIM model according to the designed conceptual model (Fig. 12). Monuments are the tangible remaining of the cultural and societal history and therefore, the cultural values are the core of the conservation interest (Nusselder & Dulski, 2008; Mason, 2008). For that reason, the monumental values are an important influencing factor in the creation of the renovation design and the decision-making on the adaptation of a monument. In order to integrate the cultural values in the design phase and decision-making, they first need to be analyzed by an historian. An historian (Dutch = Bouwhistoricus) is an expert who indicates the cultural values of a monument after an interior and exterior inspection.

2.3.1 (In)tangible Cultural value assessment

When the cultural values of the monument are determined, conservation professionals can understand the social relevance of the project and can take proper care of the building. This can lead to more socially beneficial conservation practice (Mason, 2008).
When a building is listed as a monument, it is protected by the government or municipality. However, this does not automatically mean that every building component of the building is protected. There are often also unprotected building elements present in the building, which create room for adaptation.
These adaptations can be beneficial for the function, (thermal) performance or use of the building (Nusselder & Dulski, 2008).

The protected building components are part of the tangible/material cultural historic values. However, there are also non-material/intangible values that should be taken into account. These values are similar to 'memory values', where people create a link between the real estate and for example a historic event or person. These values are more embodied in peoples minds rather than in inanimate objects. Also the image and visibility are important values for monuments, but are not directly linked to materials (Bouchenaki, 2007; Ruggles & Silverman, 2009; Tomaszewski, 2003). These values can only be identified by those who are in a position to observe and understand (Stephenson, 2008). The historian is specialized in this and needs to analyze these values as well (Hendriks & van der Hoeve, 2009).
This specialist can apply the 'sketch-grid' method, by drawing the building schematically and indicate per component or area the classification of its monumentality (Fig 16-17). The areas or components with an A are of an higher value than the ones with a B value (Nusselder & Dulski, 2008).
These sketches provide insight in the areas of the building with either a high level of protection or with no protection and thus room for adaptations.

Figure 16: Sketch grid with monumental values (Source: Nusselder)

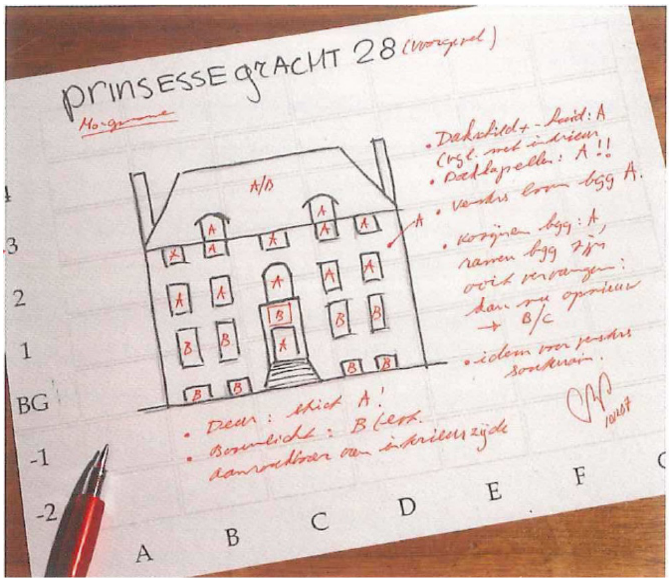
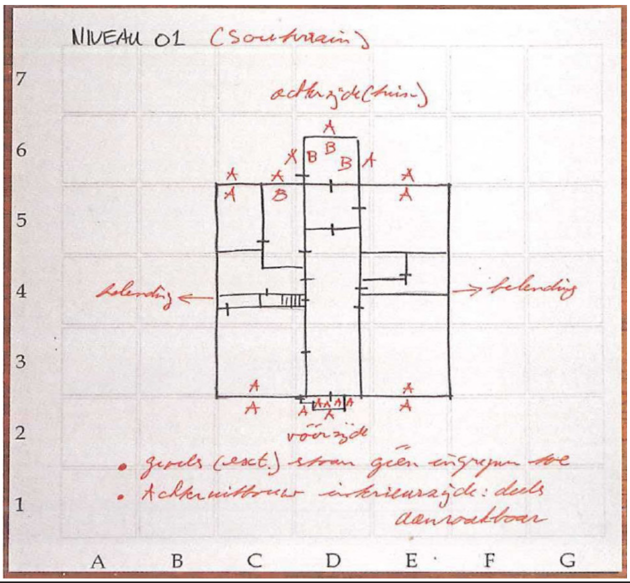


Figure 17: Sketch grid floorplan (Source: Nusselder)



2.3.2: Existing methods for Cultural Value assessment

In order to implement the cultural values in a BIM model and integrate it as a influencing factor in the decision making process on the alteration of a monument, it is necessary to research on which criteria these values can be determined, valuated and taken into account. There are several existing methods to analyze the tangible and intangible cultural values of monuments.
Four methods are analyzed in the following paragraphs:

[1] The SuMo calculation model developed by research institute NIBE (2008);
[2] The Cultural Historical Value measurer (Dutch: Cultuur Historische Waarde meter) developed by Bert Jan Beers (2004) as a graduation assignment at the TU Delft;
[3] The Cultural historic aspects with conservation factor for churches developed by Schrieken (2000) as a graduation assignment at the TU Delft;
[4] The Building archeological research guidelines method, developed by Hendriks & Van der Hoeve (2009).

The analysis will be followed up by a critical reflection of the methods.

<u>2.3.2.1 Method 1: Sustainable Monuments (SuMo) calculation model</u>

During the application of Sustainable Monuments (SuMo) method, an historian indicates the cultural values of a monument after an interior and exterior inspection. The method consists of a calculation model for the cultural values and includes a worksheet that needs to be filled in by the historian. The worksheet consists of four parts. Figure 18 shows the overview of the method whereby the historian has to fill in the form by highlighting the number that represents the score of that criteria.
Part 1 consists of the value assessment of the cultural historic values, architectural historic values and contextual values of the whole monument or parts of the monument. Points can be assigned to the height of these values (as visualized in the overview of the method on the next page). The historian needs to base the choice on the amount of points on reference projects. The total points will be multiplied with a completeness factor, which will leads to a final score that indicates in what category the monument belongs (A,B,C or X).
Part 2 consists of the value assessment of the separate building components. Also the shell, structure and the interior of the building will be assessed in this part.
In part 3, the technical state and the previous conservation activities will be analyzed. The fourth part consists of an analysis of the use of the monument (Dulski, 2017; Nusselder & Dulski, 2008).

Reflection on method 1
- Part 1 consists of the analysis of the intangible values and part 2 is more focused on the tangible values.
- Part 1 focuses on the complete building and part 2 on the individual building components.
- Part 3 indicates where there is room for intervention.
- The completeness influences the total score; it would make more sense if the completeness per criteria influences the score of that criteria.
- Part four is more or less an impact assessment analysis; the impact of the adjustments will be determined by the building history specialist.
- There is no distinction between positive and negative impacts. That is remarkable, since adjustments can also have a positive impact. The positive impacts do not automatically outweigh negative impacts.
- The impact on the monumentality score will be determined by filling in the worksheet again after the (planned) changes and measuring the difference.
- The weighting of the criteria is incorporated in the score ranges.
- The way the intangible values are linked to the building components is still unclear.

→

Figure 18: Overview of the SUMO cultural value assessment method (Own illustration, based on: Nusselder)

METHOD 1: SUMO

Part 1: Monument values (complete building, or building area)

Cultural historic values	(max. 27pt)
o Relation to historic theme	|15| 8 | 5| 0|
o Relation to historic developments	|10| 6 | 4| 0|
o Relation with an historic figure or event	|10| 6 | 5| 0|

Architectural historic values	(max. 60pt)
o Quality of building type	|25| 23| 9| 0|
o Quality of architectural design	|25| 23| 9| 0|
o Quality construction design	|15| 8| 5| 0|
o Quality of craftsmanship	|10| 6| 4| 0|
o Meaning building within the oeuvre of the architect	| 5| 3| 2| 0|
Total points x completeness factor (1, 0.75, 0.5, 0.3) = total points	

Contextual values	(max. 13pt)
o Relation with historical context	| 8| 4| 2| 0|
o Impact on the image of the surroundings	|10| 6| 4| 0|

A: Conserve only (if >95% max score)
B: Adapt in favor of the preservation of the cultural values (if >80% max score)
C: Adaptations for functional reasons possible with respect (if >55% max score)
X: Flexible (if <55% max score)

Part 2: Building components

Changes
- o per building component |Unchanged |Changed pres. Character| Changed| Reconstructed| Not present|

Architectural/cultural/historical/scientific/technical value
- o per building component |(very) high| Fairly high | Moderate to low | Not present|

Historical values
- o Historical value building shell | (very) high| Fairly high| Moderate to low|
- o Spatial structure | (very) high| Fairly high| Moderate to low|
- o Interior | (very) high| Fairly high| Moderate to low|

Part 3: conservation

Technical state
- o per building component | Good |Moderate | Bad | Not present|
- o Previous restorations correct executed? |yes/never restored | no/new restoration not necessary|

Part 4: use

Functional adjustments
- o Degree of adjustments intensity |big | fairly big | moderate | none|
- o Influence on monument value |big | fairly big | moderate | none|

2.3.2.2 Method 2: The Cultural Historic Value Measurer (CHVM)

The Cultural Historic Value Measurer method of Van Beers (2004) analyses the cultural values on 40 criteria divided in landscape criteria, urbanism criteria, architecture criteria, social/cultural criteria and history criteria (Fig. 19). Each criteria will be evaluated by an historian and assigned with a score ranging from 0-4. Each criteria can be weighted with a 1, 2 or 3 to mark the importance of the criteria. The score will be multiplied with a completeness factor and rarity factor. Finally, each building component that is related to this value will receive this score multiplied with the relation factor. The building components that have the most value, will receive the highest score. This provides insight in the most important building components that need to be preserved and the less important ones.
Consequently, the relation factor, strong (9), mediocre (3), weak (1), none (0), between the cultural value and the building component will be determined. The historian needs to determine which building components are related to these values. The result is a relative importance between building components (van Beers, 2004; Van der Voordt, 2007).

Reflection on method 2

- The criteria are selected for recent monuments (between 1850-1940).
- The model tries to identify and visualize the relation between tangible components and intangible values by indicating which components are related to an intangible value.
- The model is very elaborate and has many options, which makes it unclear and thereby decreases the user friendliness.
- There are many criteria per category. Especially the urbanism chapter is very elaborated with overlapping criteria.
- When a monument has a high overall cultural value, and one component scores lowest in the relative valuation matrix, it does not automatically indicate that it is possible to to apply changes to that component.
- The weight that indicates the importance needs to be determined by the one who is filling the form according to Van Beers. However, it is unclear whose weight needs to be implemented when the cultural value assessment starts. (owner?/ the board of mayor and alderman?/historian?)
- This model has not been applied in practice, therefore real user feedback is not available.

2.3.2.3 Method 3: Cultural Historic Aspects and Conservation Factor applicable for churches (CHA&CF)

This method is developed by Schrieken (2000) and is created for the cultural historic value assessment of churches, so not for all sorts of monuments (Fig. 20). The method is created in cooperation with experts of the government department of cultural heritage (RCE). The weighting factor determines the importance of the aspect and has a value of 1, 2 or 3, where 3 indicated the highest importance. These weighting factors are determined in cooperation with the RCE as well (Schrieken, 2000).

Integrality factor
The maximum score is 132 points. The score is multiplied with an 'integrality' factor. The factor has a value of 1 when the object is complete and in a good shape and 0 when there is nothing left of that aspect. The score is 0,5 when a value is partly damaged.

Conservation factor
Various design options for adaptations can be tested on the amount of preserved cultural values by multiplying each aspect with the so called conservation factor. When the aspect will be completely preserved, the factor will be 1, if it will be partly preserved 0,5 and when the aspect fully disappears, the factor will be 0. By multiplying each aspect with the conservation factor, a new score can be assigned to each scenario. By doing this, the different scenarios can be compared on the amount of preserved cultural historic values.

Reflection on method 3

- The visibility is an important factor in this case because the method is focused on churches. This is not important for every monument.
- Part 4, 'details' is specifically focused on church details.
- Different building components (like walls, doors etc.) are not integrated in the approach.
- In the most favourable option the cultural historic value will be 100% conserved, but there is no possibility in this method to indicate that there is added value created in a scenario.
- The weight of different aspects is determined in cooperation with the RCE. Predetermined weighting factors are probably not possible to apply in a generalized approach for all sorts of monuments.
- The criteria are mostly related to intangible cultural values.

Figure 19: Overview of the CHVM cultural value assessment method (Own illustration, based on: van Beers)

METHOD 2: CHVM

<table>
<tr><th>Part 1: Landscape</th><th>Score</th><th>Weight</th><th>Compl.</th><th>Rarity</th><th>Component</th></tr>
<tr><td>1.1 Morphologic underground</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>1.2 Culture landscape</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>1.3 Natural landscape</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>1.4 Architectural landscape</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>1.5 Trade routes, water ways</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>Part 2: Urbanism</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.1 Relation green, water, public space</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.2 Urban concept</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.3 Scale</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.4 Allotment type</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.5 Unity buildings & public space</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.6 Framework of the city</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.7 Urban fabric (stedelijk weefsel)</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.8 Public structure</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.9 Quality public space</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.10 Composition</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>2.11 Transformation Urban fabric</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>Part 3 Architecture</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.1 Typology</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.2 Construction</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.3 Unity use and function</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.4 form and Construction</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.5 Harmony and proportion</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.6 Ornament and details</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.7 Measurement and grids</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.8 Use of material</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.9 Concept</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>3.10 Composition</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>Part 4: Social/Cultural</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4.1 Status by the public</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>4.2 Status of the building</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>4.3 Relation with historic event</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>4.4 Visual recognizability</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>4.5 Social-cultural service</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>4.6 Status architect</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>4.7 Oeuvre Architect/Urban planner</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>4.8 Recognizability</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>Part 5: History</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5.1 Innovative techniques</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>5.2 Innovative materials</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>5.3 Style period</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>5.4 Building period</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>5.5 Age</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
<tr><td>5.6 Lot history</td><td>|0|1|2|3|4|</td><td>|1|2|3|</td><td>|0|1|</td><td>|1|4|8|12|16| …</td><td>|0|1|3|9|</td></tr>
</table>

METHOD 3: CHA&CF

Part 1: General Cultural Historic characteristics

		Weight	Score	Integrality	Conservation
1.1	Status by the public	|3|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
1.2	Rarity of building type within the area	|3|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
1.3	Meaning building within the oeuvre of the architect	|2|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
1.4	Legal status	|2|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
1.5	Relation with historic event	|1|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|

Part 2: Design

2.1 Purity of construction and architecture within the style	|3|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
2.2 Facades as part of the total design	|2|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
2.3 Entrance area as part of the total design	|2|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
2.4 Embedding of the building within the direct outdoor space	|2|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|

Part 3: Building as part of the city

3.1 Visibility of the building	|2|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
3.2 Visibility of the tower or cupola	|2|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
3.3 Importance building in the structure of context	|3|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|

Part 4: Details

4.1 Design Liturgical center	|1|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
4.2 Design of furniture	|1|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
4.3 Design of organ (Dutch: orgel)	|1|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
4.4 Present Art	|1|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|
4.5 Specials elements (e.g. iron work, stained glass, masonry, mosaics..)	|1|	|0|1|2|3|4|	|0|0.5|1|	|0|0.5|1|

Figure 20: Overview of the CHA&CF cultural value assessment method (Own illustration, based on: Schrieken)

2.3.2.4 Method 4: Building archeological research

The Building Archeological Research (BAR) method is most applied in practice and is developed by the RCE. The method consists of guidelines and is based on a qualification of cultural values instead of quantification. First, the intangible values will be determined by an analysis on criteria in different categories. The values will be described in a report instead of assessed by numbers or qualifications (Fig. 21). When these values are determined, it often does not offer enough handles to evaluate restoration plans. Therefore, the historian indicates the monumental value per building component (high, positive or indifferent) and shows them in a sketch of a floor plan with colors (Fig. 22). Indicating immaterial/ intangible values is hard and therefore references are made in the drawings to the text that describes these values (Hendriks & van der Hoeve, 2009).

Reflection on method 4

- The criteria are more focused on intangible values of the whole monument, whereas the next step is mainly focused on tangible values of the different building components.
- The relation between tangible and intangible is made by references from the sketch with tangible values to the text that describes the intangible values. It is not explained what the qualification is based on.
- The descriptions of the criteria are free for interpretation, with a risk that it will be valued differently by other persons.
- It is unclear how integrity and rarity are implemented.
- There are no scores assigned to the criteria or weights.
- The sketch is an example of how the cultural values can be visualized in a BIM model (in 3D).

METHOD 4: BAR

Part 1: General historical values (related to developments in society)
1.1 Relation with cultural, socio-economic and/or spiritual development(s)
1.2 Relation with development(s) in geography, landscape and/or public administration
1.3 Relation with technological and/or typological development(s)
1.4 Importance as a result of its character

Part 2: Ensemble values (interconnection) and urban values
2.1 Relation with (inter)national (historical) structure
2.2 Importance development surrounding area
2.3 Importance of the way it has been parceled out/developed
2.4 Importance for the appearance of a region, town, village or neighborhood
2.5 Relation with the structure of the surrounding area

Part 3: Architectural-historical values
3.1 Importance for the history of architecture
3.2 Importance for the oeuvre of a master builder or architect
3.3 Aesthetic qualities of the design
3.4 Ornamentation
3.5 Interior finish (in connection with the exterior)

Part 4: Building archaeological values
4.1 Importance to the history of building engineering
4.2 Readability of its construction history (historical layering)
4.3 Use of materials

Part 5: Values on the basis of the history of use (related to the object of study)
5.1 Interconnection between appearance and (historical) function
5.2 Importance of a (historical) function, use or production
5.3 Reminder of a historic event or prominent inhabitant/user/client

EACH CRITERIA IS ALSO TESTED ON:

- INTEGRITY
- RARITY

Figure 21: Overview of the BAR cultural value assessment method (Own illustration, based on: Hendriks & van der Hoeve)

HIGH MONUMENTAL VALUES
POSITIVE MONUMENTAL VALUES
INDIFFERENT MONUMENTAL VALUES
VALUES OF CEILING/ROOF
VALUES OF INTERIOR ASPECTS

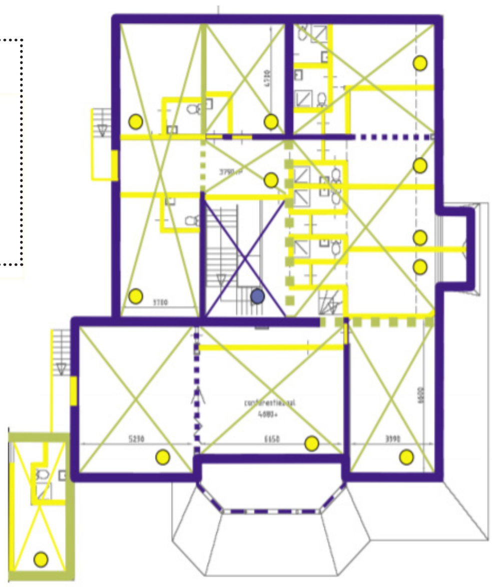


Figure 22: Monument values visualized per building component in a floor plan (Source: RcE)

2.3.3 Overview of the four methods.

The comparison of the four methods led to the following findings (table 4):

- Method 4 is the only exception of being a calculation model.
- Integrity and Rarity are both included in all models.
- Technical state is more or less integrated in all models.
- The division of criteria is more or less the same in each model, yet with different names. It comes down to: Cultural/social values, Historical values, Architectural values, and context values.
- The amount of criteria differs a lot. Especially the amount of criteria in method 2 is high, however that method does not assess the building components separately.

2.3.4 Conclusion

The cultural values of a monument can be divided in tangible and intangible cultural values. The building components that are a tangible remaining of the cultural an societal history represent the tangible cultural values of a monument and the indirect and relational values form the intangible cultural values. There are four theoretical methods for the cultural value assessment of monuments in the Netherlands (SUMO, CHVM, CHA&CF and BAR). Two of them are applied in practice. The main differences between the methods is three of them quantify the cultural values and one method is based on a qualification. The main factors that are included in the value assessment are completeness, rarity and technical state.

Table 4: Comparison of the cultural value assessment methods

	M1 SUMO	M2 CHVM	M3 CHA&CF	M4 BAR
Applied in practice	Yes	No	No	Yes
Quantification of tangible values	Yes	Yes	Yes	No, classification
Quantification of intangible values	Yes, in theory	Yes	Yes	No
Weights	Indirect predetermined weight	Person who fills in the form determines the weight	Predetermined weight	No weight
Integrity/ authenticity	Yes, multiplies total score with 1, 0.75, 0.5, 0.3	Yes, multiplies each score with factor 0-1	Yes, multiplies each score with factor 0, 0.5, 1	Yes, but how is unknown
Rarity	Not separate, integrated	Yes, multiplies each score with 1, 4, 8, 12, 16	No, integrated in criteria	Yes, but how is unknown
Technical state	Yes, per building component	More or less, completeness	More or less, integrity	More or less, integrity
Assessment Building Components (BC)	Yes	BC related to scores of the criteria, relative value	No, only important church components	Yes
Adjustment impact assessment	Yes, fill in again, negative and positive outweigh each other	No	Yes, conservation factor, but only negative impact	No
Themes criteria	Cultural hist. value Arch. hist. value Context value	Landscape Urbanism Architecture Social/cultural Historical	Cultural/historic Design Building as part of the city Details	Historic value Ensemble value Arch. His. value Archaeological History of use
Amount criteria	10	40	17	20
Tested	yes	yes	yes	yes

2.4| IMPLEMENTING CV

2.4.1 Introduction

Once the cultural historic values are assessed, they need to be incorporated in the design of the renovation plan. The cultural values need to be preserved and therefore form the starting point of the design phase. This means that the cultural values determine the adaptability of the monument and the adaptability determines to what extent energy conservation measures can be applied. This is also called: the tolerance for change (Logan & Reeves, 2008; Nusselder & Dulski, 2008; Vieveen, 2013).

2.4.2 Tolerance for change: Touch ability

Nusselder and Dulski developed a theory regarding the determination of the adaptability of a monument as a result of the assessed cultural values (2008). In this theory, the cultural values are translated into 'touch ability' categories, which form an indication of the possible action that can be taken. The theory is based on the analysis of case studies of monuments and the possible interventions in the buildings. The rule of thumb is, the higher and comprehensive the cultural values of the monument, the lower the touch ability. Each touch ability category will be explained, starting with the lowest category.

Category A: Documentary
In this category, the main aim is to preserve the structure and details of the monument. The functionality is inferior to the preservation of the state of the building.
Interventions are only applicable when they are done with the aim of preserving the existing cultural values. Buildings that belong to this category are for example national ruins (Fig. 23).

Category B: Functional museum
For buildings that belong to this category, the preservation of the cultural values comes first, yet adaptations that make the building more functional can be permitted under strict conditions. An example of a building within this category is the Van Nelle Fabriek (Fig. 24).

Category C: Flexible monument
Monuments that belong to this category are not highly important. Often multiple changes are implemented in this type of monuments in order to serve the use of the building. Interventions that increase the functionality of the building with respect to the cultural values of the building are possible. A building that belongs to this category is the Watertower in Bussum (Fig. 25) (Nusselder & Dulski, 2008).
Either an entire monument can be assigned to one of these categories or the building can be divided into different parts, whereby each part is assigned to a category. The latter is common when parts of a monument are built in another time period.

Reflection on theory
The indication of the tolerance for change with categories can be seen as the translation from cultural values towards directive instructions for the renovation plan. This translation makes it more clear how the cultural values can be incorporated in the design.
However, this theory is only applicable for the entire building or building areas and not for building components. Therefore, it can still be an unclear starting point for the design phase. The theory does not indicate directly whether certain walls or windows can be renovated, demolished or replaced.

2.4.3 Conclusion

In order to incorporate the cultural values in the design of a renovation plan for a monument, the assessed cultural values determine the touch ability category. The touch ability category is subsequently directive for the possible interventions. However, the theory is based on a building (area) level and not on a component level, and can be therefore remain vague.

Left: Figure 23: Ruin of Strijen (Source: De Rijksoverheid)
Middle: Figure 24: Van Nelle Fabriek (Source: (Prokopičová)
Right: Figure 25: Water tower Bussum (Source: Vocus)



2.5| DESIGN STRATEGIES

2.5.1 Introduction

Once all the information about the thermal performance and the cultural values of the monument is gathered, the renovation plan can be created. The renovation of a monumental building often comes along with custom made products (Nusselder & Dulski, 2008). In order to adapt a monumental building into a more energy efficient building, one could apply Energy Conservation Measures (ECM), like insulation layers, heat pumps or new ventilation system (Jalaei & Jrade, 2014). Which ECM is most applicable for a monumental building differs per building due to its needs and specifications. However, the functional possibilities and the characteristics of monuments can be so different from new buildings, that the usual energy conservation measures will not automatically work in monuments (Nusselder & Dulski, 2008).

Nonetheless, there may be measures possible which can reduce the energy need of a monumental building. For example, a heat pump can function properly in order to heat the building. Also original elements such as blinds can be reconstructed and applied in order to reduce energy consumption (Van Hal & Dulski, 2011). Even a row of trees in front of a building can protect the building from the sun to make artificial cooling unnecessary. In some cases, wall or window insulation is applicable, yet applying ECM that will impact the indoor climate of a building can bring certain risks in terms of damage. For example, closing chinks in window frames can negatively impact the ventilation of the wooden elements, which can result in wood rot (Nusselder & Dulski, 2008).

In order to deal properly with a monument, there are basic strategies that always need to be the starting point during the design phase. Apart from these basic design strategies there are also design specific strategies, that can be applicable in monuments with the aim of improving the energy performance.

2.5.2 Basic design strategies for monuments

There are five basic design strategies that form the basis of creating a renovation design for a monument.

<u>Strategy 1: traditional performance</u>

Historic buildings often deviate a lot in technical and physical performance compared to buildings designed in the 21th century. The technical and physical characteristics of the building determine which adaptations are suitable and which are not. Contemporary buildings are often closed buildings with internal systems that regulate the climate. However, historic buildings are often built more 'open' with flexible and porous materials that regulate the ventilation in a natural way. These constructions are, compared to contemporary constructions, more 'on the move', like the wooden roof construction of Het Zeepaert building in Dordrecht (Fig. 26). If this construction would be isolated, the movement of the construction will damage the foils and insulation. Therefore, it is important to analyze the traditional performance of the building and design a plan that fits.

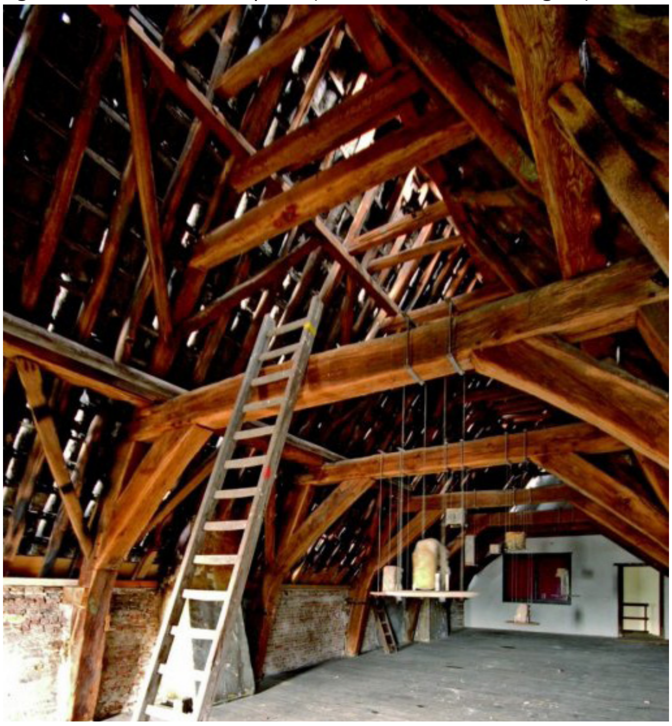
<u>Strategy 2: Minimal interventions</u>

Monuments are not renewable, which means: 'once lost, forever gone'. Applying changes to the cultural valuable elements is only verifiable when it is absolutely needed. Therefore, one has to keep the purpose of the interventions in mind and its necessity.

<u>Strategy 3: Reversibility</u>

One should choose reversible interventions. This prevents irreversible damage to the monument and its cultural values. By doing this, the monument can

Figure 26: Roof of Het Zeepaert (Source: Herbestemming.nu)



remain in the right shape on the long term. If there ought to be a desire for a new function after ten years, previously applied interventions can be undone and removed. Another example is when the effectiveness of installations has improved, they can be replaced with a more efficient one in the future without seeing any marks of the previous installation (Fig. 30).

Strategy 4: Appropriate use
Usually, the original function of the building is the most appropriate one and the least adaptations have to be made when it remains to serve this function. However, when the function needs to be changed, it is desired to choose an appropriate function. So, the function follows the building instead of the other way around. A monument can often not be transformed to a suitable building for all functions. One should avoid implementing unsuitable functions because it will have a negative impact on the conservation of the monument.

Strategy 5: Adapt comfort requirements
The current comfort demands differ from the demands generations ago. However, the indoor climate of a monument (good ventilation, low temperature) adds up to the conservation of the building in its state. Therefore, one should not only take into account the indoor climate preferences of the user but also the indoor climate preferences of the building itself and find a balance between these two (Carbonara, 2015; de Santoli, 2015; Dirlich, 2012; 2008; Nusselder & Dulski, 2008; van Krugten et al., 2016).

2.5.3 Energy renovation strategies for monuments

There are several specific strategies to reduce the required amount of energy for the use of the monument, for example adding adjacent unheated spaces (Dutch = Aangrenzende Onverwarmde Ruimten (AOR)), installing new installations and improving the insulation layer of the building (Nusselder & Dulski, 2008; Van Hal & Dulski, 2011).

Adjacent unheated spaces (AUS)
Heat transmission loss can be reduced in monumental buildings when there is a transition space between the interior and exterior. Well known examples of these kind of spaces are attics, sculleries and conservatories which can all function as a thermal buffer. This concept was already applied in the past and also originally applied in buildings which are currently listed as monuments. Therefore, a reconstruction of those spaces can reduce the energy consumption and add up to the monumental value of the building (Fig. 28) (Nusselder & Dulski, 2008; Van Hal & Dulski, 2011).
Also, the-box-in-a-box system results in a gradual transition from exterior to interior. If the monumental building works as a shell around a box, for example the glass hall in the Beurs of Berlage, all the required installations can be installed in the box, but the transmission loss will be low due to the thermal shell around the box (Fig. 27).

New installations
During the first design and construction period of a lot of monuments, energy efficient installations did not exist yet (Janssen, 2014). Examples of these installations are: heating systems, climate control systems, ventilation

Figure 27: Amvest Hall, Beurs van Berlage (Source: Brabants dagblad)

Figure 28: Reconstructed conservatory Huis Hildebrand (Source: WVAU)

systems, efficient electrical systems like lightning, but also systems that generate energy like solar panels (Nusselder & Dulski, 2008). However, before applying all these new installations in monuments, it is recommendable to research if the ventilation or light ambitions can be targeted by applying natural systems, like natural ventilation and daylight (Van den Berg, 2012; Van Hal & Dulski, 2011). For example, there was originally a patio located in the Promerskazerne in Naarden, yet instead of placing lightning systems, a roof of glass panels was placed to return the original daylight access into the building (Fig. 31).
There are highly efficient installations available on the market, but it is important to realize that the installation of the cabling or pipes needs to be done very carefully. In the most favorable situation, the cabling is installed in a way which is reversible. This means that it can be removed without leaving any traces (Nusselder & Dulski, 2008) (Fig. 29 and 30).


Figure 29: Not reversible cabling (Source: Nusselder)


Figure 30: Reversible cabling (Source: Nusselder)

Improving the insulation layer
One should also be very careful with ambitions to improve the insulation layer of a monument. Extra insulation layers on the inside of the exterior wall increases the risk of internal condensation because of the rising temperature difference between the internal layer and the external layer of the building. Insulating the ground floor is often more effective. It prevents the cold, coming from the ground and crawl space, from penetrating into the interior of the building. However, insulating the ground floor is only possible when the crawl space is well ventilated (preferable naturally) in order to prevent molds and rot (Nusselder & Dulski, 2008).
The windows of monumental buildings are often constructed of single layered glass. This can cause a lot of heat loss. If the window does not consist of historic glass, it can be possible to replace it with isolating glass in order to improve the thermal performance of the monument (Franco et al., 2015; Janssen, 2014; Kuperus, 2016; Previtali et al., 2014).

2.5.4 Conclusion

The basic design strategies for a renovation plan of a monument are: analyze the traditional performance, apply reversible interventions, apply minimal interventions, function follows building and adapt the comfort requirements. There are a lot of possible energy conservation measure available for increasing the energy performance of a monumental building. They can be divided in three categories: adjacent unheated spaces, new installations and extra insulation layers. However, the assessment of the applicability asks for extra attention, since the application of the ECM can bring some risks for the other building components.


Figure 31: Promerskazerne Naarden (Source: Nusselder)

2.6| PERFORMANCE OF DESIGNS

2.6.1 Introduction

Different possible renovation designs for a monument can be applied. A decision has to be made on which design alternative is the most suitable. In order to make a substantiated decision, the thermal performance and the 'cultural performance' of the design options need to be analyzed since the aim is to optimize between these two variables.

2.6.2 Test the thermal performance

Calculating the impact on the thermal performance based on basic index numbers will not be very accurate for monumental buildings. For example, a wall composed of brick 200 years ago does not have the same thermal properties as newly composed brick walls. The thermal performance of the design options can be tested with an energy simulation in BIM software like Autodesk Revit. In order to be able to test the effectiveness of a certain ECM, for example an insulation layer, the technical specifications, which are usually provided by a manufacturer, like the type, size, dimensions and U-values, should be included in the model (Jalaei & Jrade, 2014). Next to this, the measured thermal properties of the existing building should be integrated in the BIM model, as explained in chapter 2.2. The outcomes of the analyses can help the user to decide which measure is the most effective for the building to implement. However, the outcomes of these energy simulations are not very precise. Nevertheless, it can give a good indication about the effectiveness of the design option for the thermal performance of the building.

2.6.3 Test the cultural performance

There are three possible methods for testing the impact on the cultural values. The first method consists of analyzing the impact on the cultural values based on visualizations of the design options. The second and third methods are based on method 1 and 3 of the cultural value assessment methods explained in chapter 2.3.

<u>Testing with visualizations</u>
According to Jeong et al. (2015), decisions upon design options regarding the impact on the cultural values would become more effective if the design options are visualized. Visualizations of the design options directly show the impact on the appearance. The historian can judge whether or not it harms the monumental appearance of the building components or not.
The extent of preservation of the intangible cultural values can also be tested this way, since these values need to be observed and linked, in the mind of the observer, to for example an event or historic figure. If the visualization shows that the fundament for this link is still visible, the intangible values are preserved as well. If there is a BIM model created of the monument and the design options are modeled as well, direct visualizations of these design options will be available.

<u>Testing with the assessment form of method 1</u>
The cultural value assessment form that functions as the input of the cultural value calculation of method 1, SUMO (chapter 2.3.2.1) can be filled in again. The new score can be compared with the original score. The difference between the outcomes can indicate whether the design option affects the cultural values (Nusselder & Dulski, 2008).

<u>Testing with the 'conservation factor' of method 3</u>
Multiple design options can be tested along the amount of preserved cultural values by multiplying each criteria of the cultural value assessment method CHA&CF (chapter 2.3.2.3) with the so called conservation factor. When the aspect will be completely preserved, the factor will be 1, if it will be partly preserved factor 0,5 and when the aspect fully disappears the factor will be 0. By multiplying each original score with the conservation factor, a new score can be assigned to each design option. By doing this, the different design options can be compared on the basis of the amount of preserved cultural historic values (Schrieken, 2000).

2.6.3 Conclusion

The use of the visualization possibilities of the BIM model and the outcomes of the energy analyses will give more insight in the thermal and cultural performance of the design options and can therefore support the decision-making process. Next to that, the impact on the cultural value can be tested as well by filling in again the cultural value assessment forms of methods 1 and 3.
Next page: an example of an energy efficient monument.

EXAMPLE B30

B30 is a Dutch national monument, located in The Hague and dated around 1900. Until 2013, it was used by the Dutch ministry of Economic affairs, Agriculture and Innovation, but the building could not meet the users' demands anymore. Therefore, the government decided to adapt the building into a so-called 'think-tank' (a place to meet, discuss and work) with the aim of transforming it back to the original design of architect Knuttel from around 1900 (B30, 2017). Apart from to the goal of enhancing the monumentality of the building, there was another goal: sustainability. The main focus was on sustainable use and maintenance of the building. The project succeeded in both goals. First, a valuation of the current building was executed by the Rijksgebouwendienst in collaboration with the government department of welfare and monument care. They determined what was possible to change in the building and what not. According to Bas Niese (director of the execution party Facilicom) ,this caused tension between parties and a subtle way of working became required (Facilitair, 2016). Eventually, the building was adapted back to its original status and shape. A lot of innovative design features are applied , such as a mechanic ventilation system with a heat recovery system, a thermal storage system, an energy monitoring system and many other features. This resulted in a BREEAM score 'very good' and energy label A (Facilitair, 2016; Unknown, 2016).

Figure 32: B30 (Source: Root B.V.)

2.7| LEGAL PROCESS

2.7.1 Introduction

Once the possible designs are created, the decision has to be made on which design will be implemented. The client can use for example the most effective design as described in chapter 2.6. However, the client is not the only stakeholder who has a say in the decision-making. A permit needs to be requested before the implementation phase can start.

2.7.2 Requesting the permit

If one wants to make changes to a monument, an environmental permit needs to be requested. This counts for every type of monument. In case of a change, demolishment, or reconstruction of a national monument, the RCE has an advising role. The permit request will also be tested by the municipal monuments committee (MC). This is an independent committee that advises the board of mayor and aldermen (Dutch: college van B&W) on the plans for the monument and indicates whether or not the environmental permit can be granted. This committee has at least 3 members with knowledge of restoration techniques, architecture, building history, historic geography, archeology and urbanism. Through this knowledge they can assess whether the new plans are harming the cultural values of the building or not. They determine what amount of adaptations are acceptable and how they need to be executed. This together forms the advice towards the board of mayor and aldermen. This board will take the final decision, not only based on the advice of the RCE and monuments committee but also on interests of the owner and the municipality (Ankone, 2016; Korthuis, ten Cate, & van ’t Veen, 2009). Figure 33 illustrates the formal process. Therefore, the impact assessment on the cultural values of the design options is important, because it increases the chance that the design can be implemented.

2.7.3 Changes in the Dutch law regarding monuments

Recently some change have been applied to the Dutch laws and regulations regarding monuments. The monuments law that was in force since 1988, is abolished since 2016 and implemented in the heritage law and the environmental law. The core of the regulations did not change but it is more efficient organized.
Most of the environmental aspects of the monuments law are going to be integrated in the environmental law in 2019. From 2019 on, the regulations on housing, environment, infrastructure, nature and water will be combined in one law in order to reach a better result and speed up the decision-making process (Ankone, 2016; RCE, 2016a). Table 5 visualizes how the topics of the monuments law are divided in the environmental law and the heritage law. The most important regulations regarding applying energy conservation measures in monuments is written in the Environmental law.

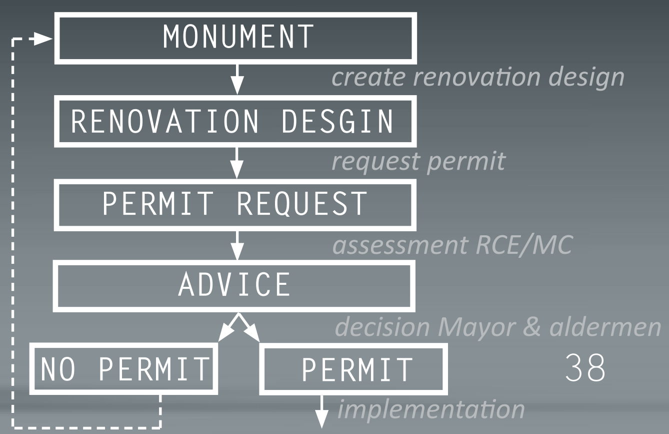
2.7.4 Conclusion:

The most important regulations regarding applying energy conservation measures in monuments have not been changed, but moved from the monuments law to the environmental law. The final decision whether the permit is authorized is taken by the board of mayor and aldermen, advised by the monuments committee or the national service of cultural heritage (RCE) in case of national monuments. The monuments committee tests whether the adaptation does not harm the cultural values of the monument.

Table 5: Division of subject from the monuments law

HERITAGE LAW	ENVIRONMENTAL LAW
Designation national monuments	Authorization of permits National monuments.
Movable cultural heritage	(designation) protected city- and village sites.
	Appointing monuments committee.
	Provincial monuments.
	Municipal monuments.

Figure 33: Legal Process (Own illustration)



2.8| STAKEHOLDERS

2.8.1 Introduction

It can be concluded from the literature that the decision-making on design options will be influenced by multiple stakeholders. In order to manage the decision-making process, it is required to know which stakeholders are involved.
It is possible to distinct contracted stakeholders and not-contracted stakeholders. Contracted stakeholders are most of the time commercial parties, which are profit oriented. So their interest is making profit and delivering a good product to serve the client. These stakeholders are steered by the project manager or client. The non-contracted stakeholders are permit authorization parties, advising parties and interested parties (Dutch: belangengroepen). These parties are less easy to steer because they have their own interests (Schunselaar, 2009). However, they can influence the decision-making in the project. Every stakeholder will be discussed in the following paragraphs.

2.8.2 Stakeholder analysis

Client
There are many different types of clients with different levels of ambitions. The client can be the owner of the building, a developer, a financier, the government, a housing association or a group of individuals together (Wamelink et al., 2009). Also the profiles can differ a lot: commercial or not commercial, experienced or not, with a private interest or with a collective interest (Roos & Frösch, 2007). In this report, the clients with the ambition to reduce the energy use of a monument are targeted. It can be the case that the client tries to save money on the long term by investing in the monument and lower the monthly energy bill but this is not necessarily the case. The client is the paying and decision-making party and therefore has a lot of power in the process.

Building user(s)
The building users are the people who use the building and their preferences depend on the type of function of the building. Monuments often do not meet the current indoor climate preferences like the amount of daylight, fresh air and the level of control the indoor climate (Silva & Henriques, 2016; Mishra & Ramgopal, 2013). The level of power of the user in the process is dependent on the client (Schunselaar, 2009).

Contracted stakeholders
Project manager
The project manager is contracted by the client and is responsible for the management of the project. He/she has to make sure that all the ambitions will be realized within time and budget. The manager also acts as an objective consultant for the client, to support the client in making the decisions (Wamelink et al., 2009).

Historian
The historian is contracted by the client. The municipality can oblige the client to hire an historian to perform an archaeological research, since the new Environmental law of 2016 (van Bommel, 2017). This expert will report the cultural values in an archeological research report, that needs to indicate which building areas or building components are of high value and which of low value (Dulski, 2017; Hendriks & van der Hoeve, 2009; Nusselder & Dulski, 2008; van Bommel, 2017).

(restoration) Architect
The architect is also contracted by the client. This stakeholder creates a new design for the building based on the demands and restrictions of the client. The architect can have different positions within the project, for example as a leader of the process, as a designer or as an advisor (Wamelink et al., 2009). The position determines the level of influence on the project. A restoration architect is specialized in creating designs for existing buildings and can perform a building archeological research as well (Vromen, 2012).

Sustainability consultant
In order to increase the energy performance of a monument, a client can ask a sustainability consultant for advice. The consultant will do research on the possible interventions that will enhance the energy performance. There are specialized sustainability consultants for monuments. They take the results of the archeological research into account (Dulski, 2017; Nusselder & Dulski, 2008).

BIM specialist
The BIM specialist can also be contracted by the client. There are many types of BIM specialists, each with different tasks. For example, a BIM modeler is responsible for the creation of the BIM model, while a BIM analyst

performs analyses and simulations (Barison & Santos, 2010; Kymmell, 2008). The specialist works on behalf of the client and delivers a model or advice based on the results of the simulations.

Executor/contractor
For the execution of restoration projects of monuments, there are specialized contractors. These contractors have more experience with historic building techniques and monument procedures. The influence of the contractor differs per project. In case of complex restoration project they are often involved in an early phase of the project. Their aim is to realize the ambitions of the client (Schunselaar, 2009).

ECM supplier
In case of a custom made product, the ECM supplier can be contracted. When there is a contract between the contractor and the supplier, the supplier is subcontracted. But it can also be an independent firm that just wants to sell their products. The role of the supplier can differ per project.

Non-contracted stakeholders
National service of cultural heritage (RCE)
The national service of cultural heritage is not contracted by the client but is involved in the project as an advising party. In case of an alteration of a national monument, the RCE will analyze the plan and give an advice to the board of Mayor and aldermen who is authorized to grant the permit. The responsibility of the RCE is to preserve the cultural values that are of national importance (Ankone, 2016; RCE, 2016a; Schunselaar, 2009).

Municipal Monuments committee
The municipal monuments committee is also not contracted by the client and is like the RCE an advising party. The committee analyzes the restoration plans for the monuments and advises the board of Mayor and aldermen who is authorized to grant the permit (Ankone, 2016; CWM, 2017; Korthuis et al., 2009; Schunselaar, 2009; van Bommel, 2017).

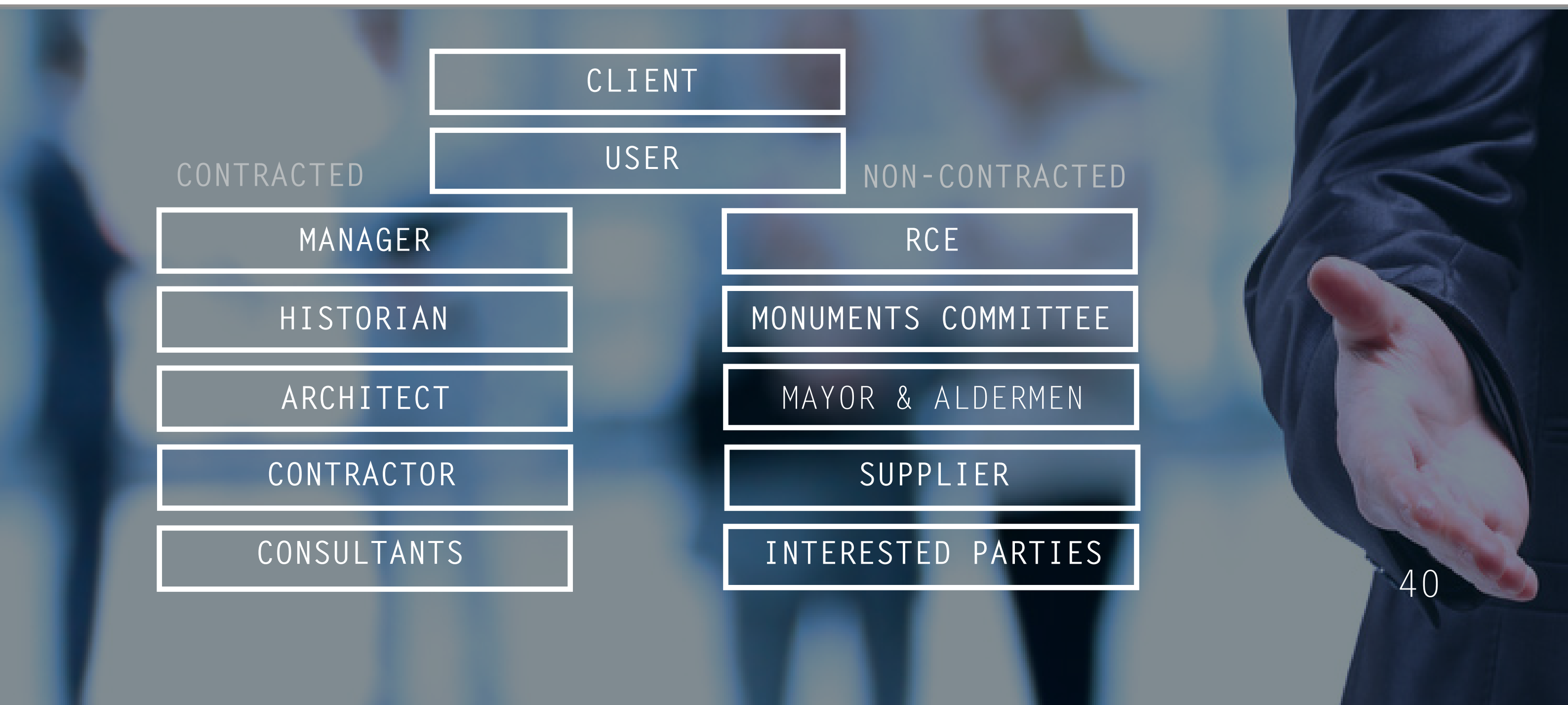
Board of Mayor and aldermen
The board of Mayor and aldermen are eventually the deciding party on the approval of the project, so they can have a high influence on the project. The decision can be based on political grounds or based on grounds of the advise they received (Ankone, 2016; Dulski, 2017; Schunselaar, 2009).

Interested parties (Dutch: belangengroepen)
Some projects have to deal with interested parties that consist of people who are directly or indirectly involved in the project. Examples of these kind of parties are residents that live nearby and associations with interests in the building. They can influence and delay the process by making objections (Roos & Frösch, 2007; Schunselaar, 2009).

2.8.3 Conclusion

Table 6 provides an overview of the involved stakeholders and their power and interest. Many stakeholders have a high power and interest in restoration projects of monuments. Therefore, proper management will be essential. Most of the stakeholders are involved during the decision-making phase. Therefore, it is important to integrate their interest in the project from the beginning in order to diminish risks in the end.

Figure 34: Involved stakeholders (Own illustration)



STAKEHOLDER	INTEREST	POWER	PHASE
BUILDING OWNER/CLIENT	HIGH, reducing energy costs, expand life cycle building	HIGH, makes decisions	Decision-making
BUILDING USER	MEDIUM/HIGH, comfortable use (temperature, climate, light)	MEDIUM, influences building requirements	Decision-making
PROJECT MANAGER	MEDIUM/HIGH, good project, include interests of stakeholders	MEDIUM, steers the process	Mapping, Designing and Decision-making
RCE	HIGH, preserve cultural values	HIGH, evaluate the renovation plan, advices the board on the permit	Decision-making
HISTORIAN	LOW, independent consultant	MEDIUM, determines the cultural values, set design restrictions	Mapping
MONUMENTS COMMITTEE	HIGH, preserve cultural values	HIGH, evaluate the renovation plan, advices the board on the permit	Mapping and Decision-making
MAYOR AND ALDERMEN	~ variable	HIGH, decides on the permit	Decision-making
INTERESTED PARTIES	~ variable	MEDIUM, can negatively influence the legal process	Decision-making
SUPPLIER	MEDIUM, sell products	LOW, just offering	Designing
RESTORATION ARCHITECT	MEDIUM, clear design specifications	MEDIUM, creates arguments for the design (amendments)	Decision-making
SUSTAINABILITY CONSULTANT	LOW, independent consultant	LOW, independent advice	Designing and Decision-making
BIM CONSULTANT	LOW, independent consultant	LOW, independent advice	Mapping, Designing and Decision-making

Table 6: Stakeholder analysis: the involved stakeholders and their power and interest in the project

2.9| CONCLUSION THEORY

The conceptual model of this research consists of four phases (Fig. 12): mapping, designing, decision-making and managing. Based on the literature the following conclusions can be drawn for each phase:

Mapping

New techniques such as laser scanning are an opportunity for the creation of BIM models of monuments. There are still some limitations in the development of a BIM model of a monument, however there are promising trends. A lot of research is being conducted in order to make the creation of these models less expensive and time-consuming.

Information about the thermal performance can be integrated in the BIM model. The simulated thermal performance of the digital model should be more or less the same as the real thermal performance of the building in order to work with it as a reference model.

The cultural values of a monument can be divided in tangible and intangible cultural values. There are four theoretical methods for the cultural value assessment of monuments in the Netherlands. The main difference between the methods is that three of them quantify the cultural values and one of these methods bases the valuation on a qualification. The main criteria themes are cultural values, architectural historic values and context values. The main factors that are included in the value assessment are completeness, rarity and technical state.

Designing

In order to base the renovation design on the outcome of the thermal analysis and cultural value analysis, thermal leaks can be highlighted and touch abilities can be defined. This creates the possibility to upgrade the weak thermal spots and to touch only the least cultural valuable elements of the monument.

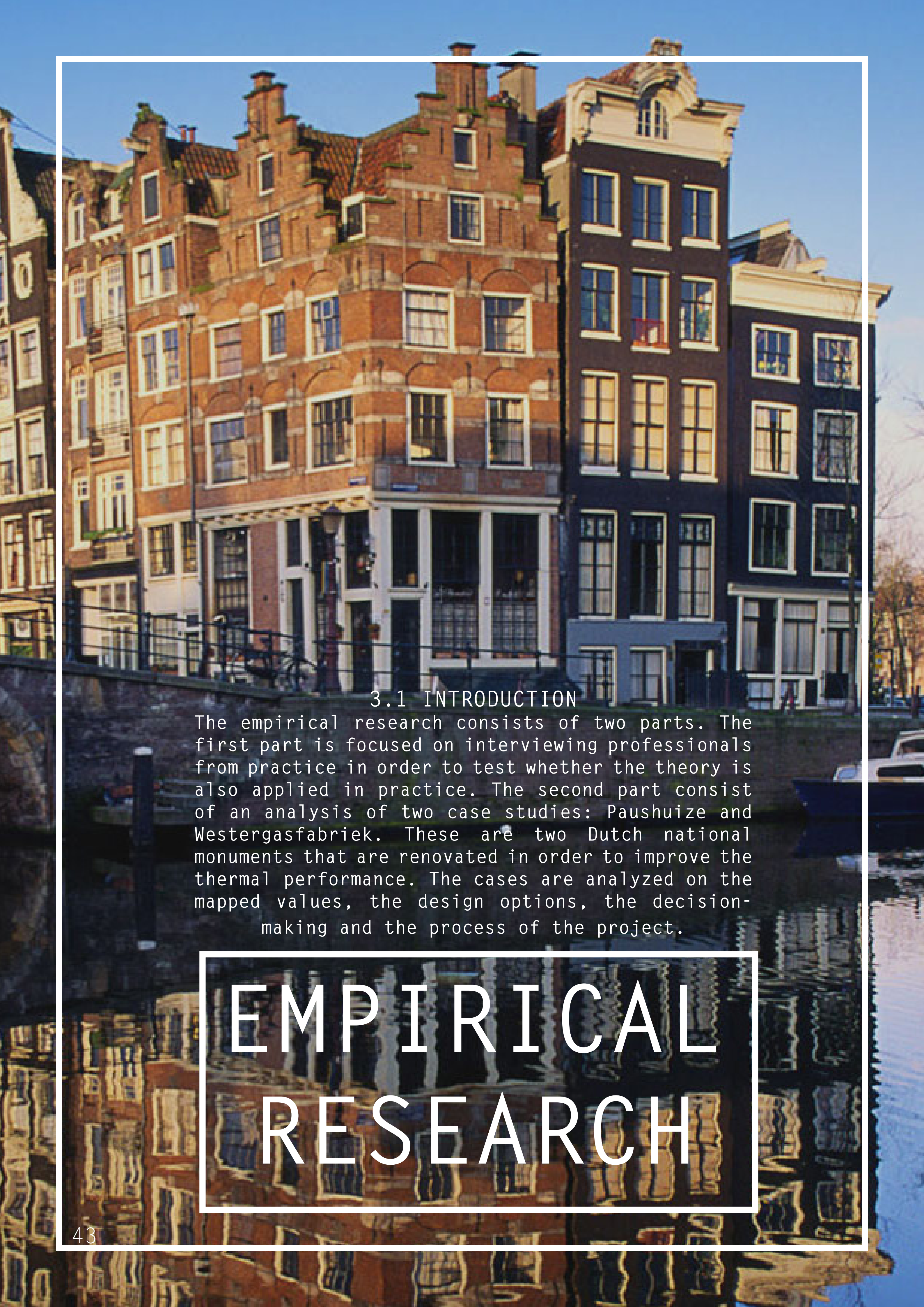
The basic strategies for designing a renovation plan for a monument without harming the monumental characteristics are: analyze the traditional performance, apply reversible interventions, apply minimal interventions, function follows building and adapt the comfort requirements. The possibilities for increasing the energy performance of a monumental building can be divided in three categories: adjacent unheated spaces, new installations and improving the insulation layer. However, the assessment of the applicability of these measures requires extra attention. The application of the ECM might bring some risks for the other building components.

Decision-making

After creating the different renovation designs for a monument, one of these design options has to be chosen. BIM can be used to create good arguments for the decision because of the visualization possibilities and the energy simulation possibilities. The visualizations and simulations will give more insight in the thermal and cultural performance of the design options and can therefore support the decision-making process. Next to that, the impact on the cultural values can be tested by two of the theoretical cultural value asessment methods. The worksheets of the SUMO method and the CHA&CF method can be filled in for the design options and the result can be compared with the result of the zero option.

Managing

Since multiple stakeholders can have influence on the decision-making process, proper management in these kind of projects is essential. Multiple stakeholders have a high power and interest and are mostly involved in the decision-making phase. Therefore, it is important to integrate their interest in the project from the beginning in order to diminish risks in the end.



3.1 INTRODUCTION

The empirical research consists of two parts. The first part is focused on interviewing professionals from practice in order to test whether the theory is also applied in practice. The second part consist of an analysis of two case studies: Paushuize and Westergasfabriek. These are two Dutch national monuments that are renovated in order to improve the thermal performance. The cases are analyzed on the mapped values, the design options, the decision-making and the process of the project.

EMPIRICAL RESEARCH

3.2| EXPERT INTERVIEWS

3.2.1 Introduction

In order to base this research not only on theory, but also on information from practice, professionals are interviewed. These professionals are specialized in the field of monument conservation aimed at improving the energy performance. The aim of these interviews is to create insight in the practical experiences from different perspectives on the mapping phase, design phase, decision-making phase and the management of these kind of projects. Next to that, the interviews are performed in order to validate whether the analyzed theory is applicable in practice. First, the interviewees will be introduced and subsequently the main conclusions from the interviews will be explained.

3.2.2 The interviewed Experts

Birgit Dulski is a researcher and consultant specialized in sustainable monument conservation. She is currently employed by NIBE and is one of the creators of the SuMo method. Next to that, she gives advice on sustainability measures for monumental buildings.
Bert van Bommel is the advisor of the Chief Government Architect (Dutch: Rijksbouwmeester) in the field of monument conservation. He was also a member of the municipal monuments committee of Vlaardingen and teaches students at the TU Delft in the field of building archeological research and how to implement it in a renovation design.
Peter Rutten is an architect and founder of pr-architecten in Haarlem. He is specialized in creating designs for private clients who own a monument. Currently, he is also performing a research in the field of sustainable monument conservation.
Vera Franken is a restoration architect and currently employed at TAK architecten in Delft. She gives advice and creates designs for alterations on monumental buildings.
Jan van der Voort is an architect and founder of attika architekten. He is also a teacher at the TU Delft and a former member of the monuments committee of Rijswijk and Dordrecht.

3.2.3 Mapping information
The interviewees are first questioned on their methods for gathering information about the thermal performance and the cultural values of a monument in practice. The following is a summary of the expert interviews.

<u>Cultural value assessment:</u>
Four theoretical models are analyzed in this research, whereby method 1, 2 and 3 quantified the cultural values and method four qualified the cultural values. The interviewees are asked which method is preferred in practice.

Quantification of monumental values (method 1, 2 & 3)
The process of quantification of monumental values like in the described theoretical methods 1, 2 and 3 is very appreciated by the stakeholders who need to give the advice on sustainability measures. However, historians do not like to work with this method because they believe that these cultural values are not quantifiable.
Next to this, the calculation model of the SuMo method (Method 1) does not work out in practice. The numerical outcome of the calculation mostly does not correspond with the 'feeling' the historian has and therefore, the calculation is not applied in practice. However, the Mo-coefficient is applied in practice, although the coefficient is not calculated with the calculation model but based on a feeling, after filling in the table with criteria. Determining a Mo-coefficient based upon a feeling is a method that is more appreciated by historians. Thereafter, this coefficient can function as useful a nd concrete information for other stakeholders, like the sustainability consultants. Thus, the score is not calculated as described in the theory (Dulski, 2017).

Qualification of monumental values (method 4)
Method 4 consists of guidelines that need to support the historian to assess the cultural values of a monument. However, these guidelines are outdated according to Bert van Bommel. The method is created in 2009. The municipal monuments committees evaluate the renovation plans on the basis of the cultural valuation supplemented with the image of the colored floor plan including the integrated cultural values divided in classes (high monumental value, monumental value, indifferent monumental value). If there are any alterations designed

←
Figure 35: Source: Duurzame Monumenten Coalitie

on components that are highlighted as (high) monumental components, the plan will simply be rejected by the monuments committee. This is not what is desired in practice. The designer became dependent on the drawings of the historian and subsequently there is no room for design arguments or perspectives of the designer to motivate the design. The designer can have an idea and a clear motivation to amend a monumental building element and not directly negatively impact the cultural values (van Bommel, 2017). So, the qualification is applied in practice and is supportive, however the application can be too short sighted. The classes of monumental values need to be used more to feed the discussion instead of sharp restrictions.
Additionally, in the past, elements that were harassing the cultural values were also highlighted. Van Bommel believes it is a good idea to reintroduce this in the method in order to be able to debate about what is monumental and what is not. It can also indicate what needs to be removed out of the building in order to renovate the monument more into the original state. So, next to the classes monumental and high monumental, the classes disturbing and highly disturbing should be added. The classes can function as arguments for the interventions. However, he argues that other experts in the field of monuments conservation disagree with him regarding reintroducing the disturbing classes into the method and therefore, the guidelines are not updated yet (van Bommel, 2017).

Further practical issues on cultural value assessment
The theory described in chapter 2.3 about using sketch matrices in order to indicate the cultural values in an overview is not always applied in practice. It depends on the person who executes the research, but most of the time it is more easier to indicate the cultural values on pictures with arrows (Dulski, 2017).
The practical method used to determine the cultural values differs per historian. Next to this, the outcome can differ as well. Since the cultural value assessments are prone to subjectivism, NIBE (the research company of Dulski) always works with a second opinion. However, Dulski claims that the second opinion often does not deviate much from the original cultural value assessment (Dulski, 2017).

<u>Thermal performance assessment:</u>
The thermal performance of a monument will be assessed by an inspection, whereby often the technical specifications and the technical state of the building components are determined as a basis for the advice of the energy conservation measures. For example, if the windows consist of single glass or if the window frames are in a bad technical condition, secondary windows will be advised.
Next to these inspections, the yearly gas and electricity use of the building will be compared with reference buildings in order to assess whether the energy use is very high or not and if measures are necessary. Sometimes, thermal scans are executed in order to determine thermal leaks of the building as well (Dulski, 2017).
The analysis of the cultural values and the possible energy conservation measures, takes a lot of time and is therefore a costly operation. These analyses are therefore only executed for top monuments, which are most of the time owned by the government (Dulski, 2017).

Implementing information in BIM
None of the interviewees has actually worked with BIM. However, Van Bommel had a vision on how cultural values should be integrated in BIM. According to Van Bommel, it is desired that if one clicks on an element in the digital BIM model, the user will see relevant information of the cultural values of the element as described in the archaeological research report. However, this report is most of the time not organized in a way to be directly implementable in such an information model. Not every element is evaluated and the valuation is often more on a more global scale. However, what sometimes happens in practice, is the creation of a spacebook (Dutch: ruimteboek). This has been done in the more important projects for the most significant rooms. The cultural value assessment is for these rooms more detailed on the component scale. These spacebooks have more potential to be implemented in a BIM model (van Bommel, 2017).

3.2.4 Designing the renovation plan

Next to the information mapping, the interviewees are questioned about the creation of a renovation design for a monument.

From cultural values to design restrictions
The level of monumentality determines the level of possibilities to amend the monument (Dulski, 2017). So, the theory of the touch ability categories, described in chapter 2.4 is confirmed. However, Dulski indicated that other factors also influences the touch ability of the monument. For example, if a wall is considered as an very valuable building component, but is about to collapse, something has to be done in order to remain

the functionality and safety of the building. So, the technical state of an element can influence its 'touch ability'.

Design requirements
Next to the design restrictions, there are also design requirements. Initially, the client determines the program of requirements, however for a monument it is better to see this as a program of requirements and wishes. The requirements are set and can be tested in the law, while the wishes are negotiable. This room for negotiation is needed in order to prevent irreversible damage of the building for serving the temporary wishes of users or owners (van Bommel, 2017; J. Van der Voordt, 2017). This is in line with the theory on the basic design strategies described in chapter 2.5.

Further practical issues on designing renovation plans for monuments
A difficult aspect of making alterations in a monument is that the building components are strongly interrelated. If an architect wants to replace a window, it will impact the window frames. If the window frames needs to be adjusted, it will have impact on the wall. If for example an extra insulation layer needs to be placed on a wall, it will have impact on the ceiling, floor and construction as well. Therefore, it is important not to isolate the building components (Rutten, 2017).
Vera Franken agrees with Rutten on this aspect. Building concept, function, installation and many other factors are interrelated. So, if one changes one aspect, it will influence all the other aspects (Franken, 2017).
Another aspect that should not be forgotten is the environment of the building. The environment of the building has an important influence on the possible energy conservation measures. When the building is always in the shadow, solar panels are of no use. Another possibility is that the soil is not suited for implementation of a heat pump (Rutten, 2017).

3.2.5 Deciding on the implementation of the design

The theory indicated that multiple stakeholders could influence the decision-making phase. The interviewees are asked how the decision on the final design is made in practice and if they have experienced difficulties with receiving a permit to implement the designs.

Choosing a design option
The final design that will be implemented is strongly interrelated with the costs according to all interviewees. However, this is a factor that is excluded from the scope of this research. In practice, the decision upon the design option is not only taken on the two variables energy performance and cultural value.
Working with different scenarios for amending a monument is a way of working that proved to be very beneficial. It provides more insight on the impact of different alterations and creates more support for the final decision upon the chosen design option (Dulski, 2017).

Granting the permit
Theoretically, the decision to grant the permit or not is made by the board of mayor and aldermen, who can ignore the advice of the monuments committee or the RCE. This is what happens sometimes in practice. Just before the elections, the decisions can become more political and strategic (Dulski, 2017). So, the theory of the RCE and the monuments committee advising the board of Mayor and aldermen is confirmed, however the decision is in practice not always in line with the advice.

3.2.6 Managing the process

All interviewees confirmed that performing a cultural value assessment at the beginning of the project is very beneficial, because it shows what the stakeholders will have to deal with.
During the design process, it is often not the case that a complete design is made and consequently submitted to the monuments committee. This can be seen more as an iterative approach between the municipal monuments committee, the sustainability advisor and the architect. Collaboration in this phase will result in optimal solutions and saving of time. However, this is not always possible (Dulski, 2017; Rutten, 2017).

3.2.7 Conclusion

Differences are discovered between theory and practice, yet also alignments are found between theory and practice. The most important discovery in the expert interviews is that in theory, the quantification of monumental values works, but it does not work out in practice and historians do not want to work with it. Next to this, the possible update of method 4 is interesting information to include in this research. If the disturbing values are integrated in this research already, the strategy will remain applicable after the adjustment of the cultural value assessment.

| Case studie 1

Paushuize

3.3.1 Introduction

The first case study consist of an analysis of the renovation project of the national monument Paushuize located in Utrecht. The aim of the project, its characteristics and the involved stakeholders will be analyzed first. Consequently, the project is analyzed on the aspects of importance for this research, the mapping phase (determining the cultural values and the current thermal performance), the designing phase (determining the possible interventions), the decision-making (which design option is implemented) and the process (management).

3.3.2 General information Paushuize

The building is built in 1517 for the Dutch pope Adrianus VI and is one of the oldest buildings in the historic city centre of Utrecht. The pope never lived in the building, but diverse sovereigns and the commissioner of the queen did so. Currently, the building is used for representative occasions, meetings and weddings. The building is built in the renaissance style with gothic influences. Especially the stepped gable (Dutch: trapgevel) consisting of red bricks and natural stone is iconic. Parts of the interior are well preserved (fig. 38 & 39) (Bezoek Utrecht, 2017; Provincie Utrecht, 2015).

3.3.3 Aim of the renovation project

The province of Utrecht is the owner of Paushuize and decided in 2008 to manage and exploit their real estate in a sustainable way. The province wanted to show that a sustainable renovation is also possible for monuments. By doing this project, they strived to become a source of inspiration for other provinces and municipalities and stimulation to start similar projects (NIBE, 2008).
The aim of the Paushuize project was to perform a renovation that reduced the energy consumption of the building, preserved the cultural historic values, made the building suitable for the office functions, made the building future proof, met the fire safety requirements and increased accessibility for people in wheelchairs (Provincie Utrecht, 2015).

3.3.4 Project Characteristics

Duration: 1 year 2010-2011 (van Limpt, 2010)
Budget: 4.2 million (van Limpt, 2010)
New energy label: A (Provincie Utrecht, 2015)
Monument status: National Monument
Location: Utrecht, Kromme Nieuwegracht

3.3.5 Involved stakeholders

Owner & Client: Province of Utrecht
Project manager: Henk te Brake on behalf of the Province of Utrecht (van Limpt, 2010)
Consultant Sustainable Monuments: NIBE consulting b.v. Birgit Dulski employee of NIBE gives advice on sustainable renovations of monuments
Historian: Hylkema architects, Evert Jan Nusselder
Municipal Monuments Committee Utrecht: Richard Rodenburg and Jan van der Hoeve
Architect: Hylkema architects (NIBE, 2008)

3.3.6 Mapping information and designing possibilities
In the following analysis, each building area is analyzed on the following aspects:

1 Functional (F): the use of the building areas.
2 Monumental (M): the cultural values of the building components/areas.
3 Thermal (T): the energy characteristics/thermal performance of the components/areas.

The functional aspect is included in this analysis since it determines the thermal demands of the room. Next to the monumental aspects, the Mo-coefficient is visualized per building area. This coefficient has a range from 1-3, where 1 is the lowest cultural value score and 3 the highest.

Consequently, the possibilities and advice given by NIBE on the possible energy conservation measures to improve the thermal performance of each building area without harming the cultural values are analyzed.

←
Figure 36: Paushuize entrance (Bramer)

STARTING POINT CELLAR

1 HALLWAY

F| Into kitchen
M| Floor, door tiles no cultural value

2 STORAGE

F| Into reception room
M| Concrete floor on historic floor
M| Wall covered with mangaan tiles (18th century)
T| Window low thermal performance

3 RECEPTION ROOM

F| Into meeting room
M| Floor high cultural value
M| Remainder of original stairs
M| Original closet
T| Window low thermal performance

4 KITCHEN

F| Into reception room
M| Original hearth
M| Original canal window
M| Original shutters lost
T| Windows low thermal performance

5 CRAWL SPACE

F| Into installation room
M| Sensitive monumental floor above
T| Mechanical ventilation system

6 GATEHOUSE

F| Into wardrobe & sanitary room
M| Vault of the 16th century
M| Maastrichtse floor tiles
T| Shutters do not close
T| High accumulating brick

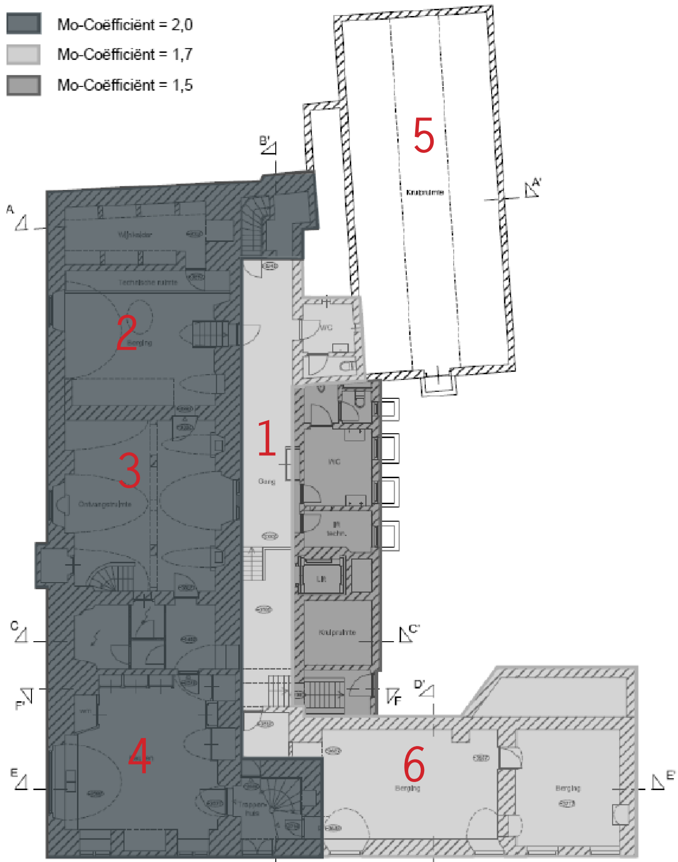


Figure 37: Floor plan cellar (Source: NIBE, 2008)


Figure 38: Reception room Paushuize (Source: Bramer)


Figure 39: Kitchen Paushuize (Source: Paushuize)

POSSIBLE MEASURES CELLAR

1 HALLWAY

| New floor with insulation
| New ventilation system in the kitchen
| Close ventilation openings in the frames of the windows
| Replace glass with double glazing
| Place thin wall insulation
| Replace door, with an insulated one

2 STORAGE

| Repair windows and place an insulating curtain
| Or replace windows with double glazing or vacuum glass

3 RECEPTION ROOM

| Repair the window, or place double glazing/vacuum glass
| Place a heavy insulating curtain in front of the window
(improve acoustics and isolation)
| Place a limited permanent heating system

4 KITCHEN

| In case of Adjacent Unheated Space:
  | Repair windows
  | Place a heavy curtain
| In case of heated space:
  | Restore the window to the canal
  | Place a secondary window
  | Repair window + place secondary window
  | Replace window with vacuum/ double glazing

5 CRAWL SPACE

| Let it function as an Adjacent unheated space

6 GATEHOUSE

| Use as adjacent unheated S. (do not insulate the floor)
| Repair the indoor shutters and window frames
| Place reversible weather stripping (Dutch: tochtstrips)
| Keep shutters closed during winter time
| Remove finish of the brickwork, repair brickwork with damp regulating plaster
| Apply mechanical ventilation in the room on the right, dry brick masonry will have a better insulating performance

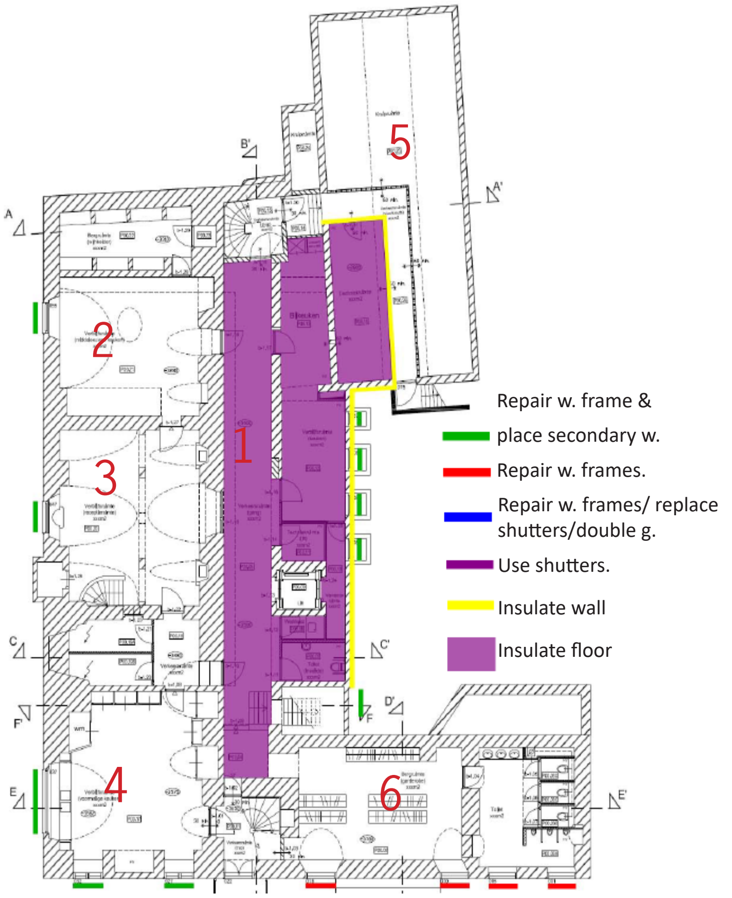


Figure 40: Cellar, possible interventions (Source: NIBE, 2008)

Figure 41: Floor plan cellar, heated zones (Source: NIBE, 2008)

STARTING POINT GROUND FLOOR

1 ENTRANCE

T| Enclosed porch of glass
T| Heating system present

2 HALL

T| Single glass
M| Radiators present
M|T| Covered with wooden panels (20th c.)

3 SALOONS

F| Keep function
M| Windows not monumental
M| Wall cover not monumental
M| Monumental shutters, floors & fireplaces
M| Monumental cast iron radiators
M|T| Covered with wooden panels (20th c.)

4 MIRROR ROOM

M| Doors part of monumental image
M| Original shutters lost
M| Monumental skylights above doors
M| Monumental floor
M| Monumental ceiling

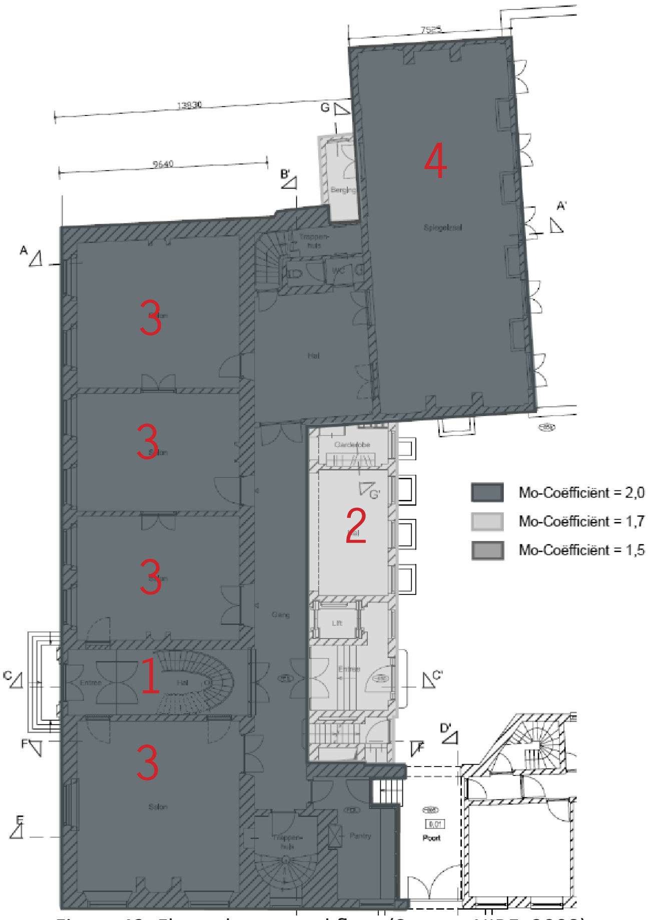


Figure 42: Floor plan ground floor (Source: NIBE, 2008)

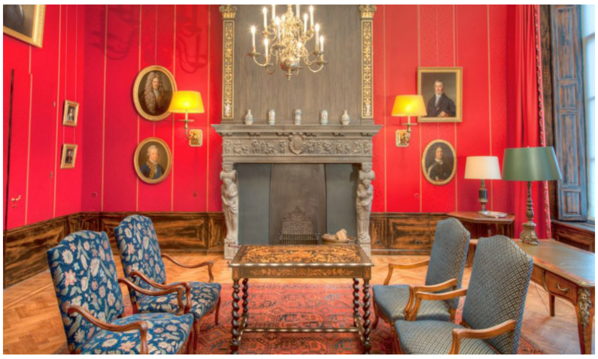
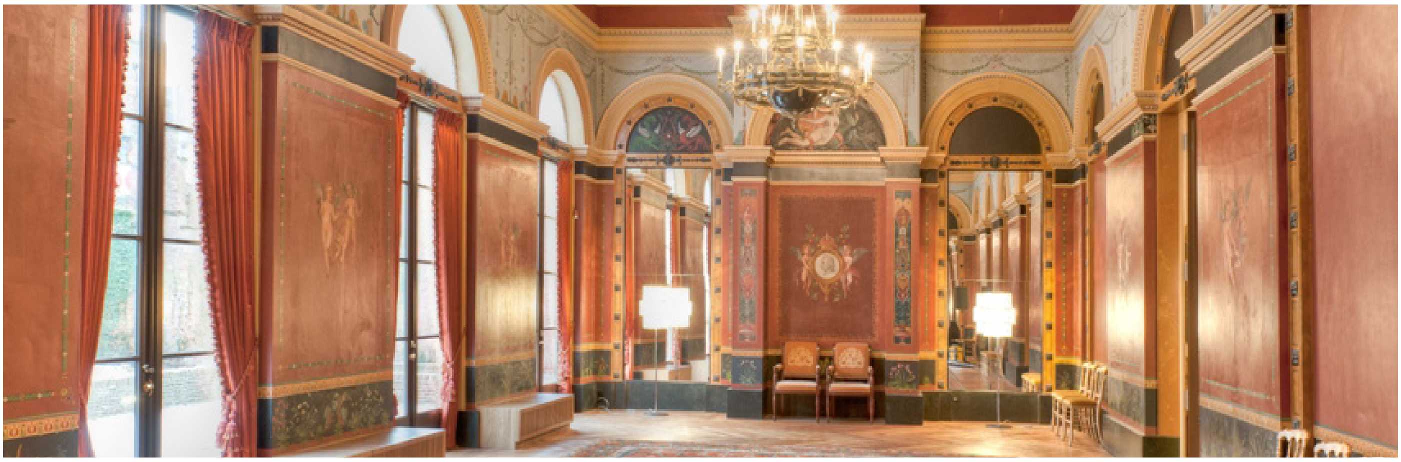


Figure 43: Saloon (Source: Paushuize)

Figure 44: Mirror room (Source: Bramer)



POSSIBLE MEASURES GROUND FLOOR

1 ENTRANCE

| Remove the radiator, entrance will become an AUS
| Make sure the enclosed porch of glass closes well

2 HALL

| Replace windows with double glazing or layered glass
| Remove the wooden panels around the radiator
| Improve radiator performance with a foil or a mechanical air trim

3 SALOONS

| Use the shutters again (Monumental: looks, Energy: insulation, Use: burglar-proof)
| Remove the wooden panels (Monumental: looks, Energy: increasing heat release)
| Place insulation and a foil behind the radiator

4 MIRROR ROOM

| Reconstruct the shutters (with insulating performance)
| If rejected, place door with double layered glass
| Place a secondary window in front of the skylights
| Insulate the floor

Repair w. frame & place secondary windows

Repair widow frames.

Repair window frames/ replace shutters / place double glazed windows

Use shutters.

Insulate floor

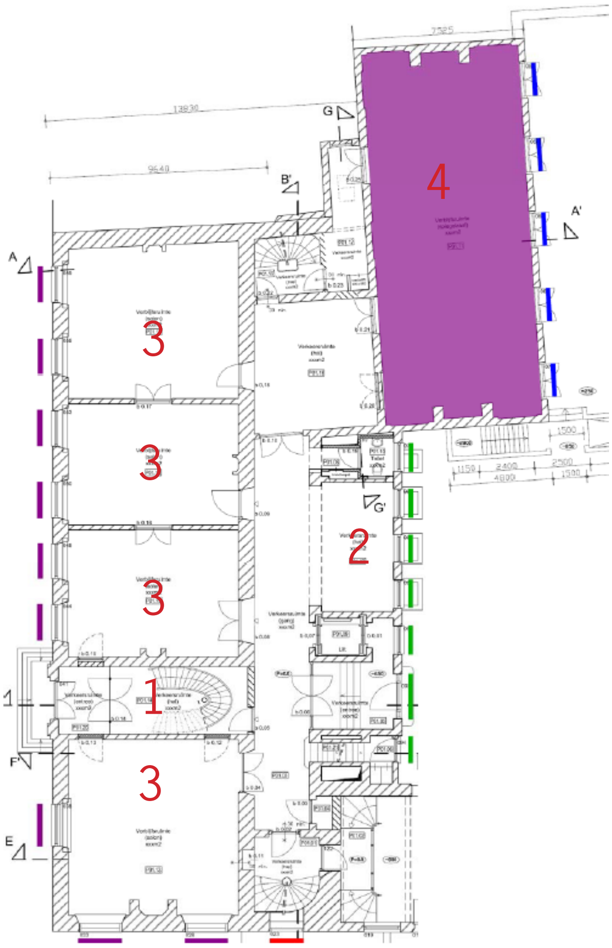


Figure 45: Ground floor with measures (Source: NIBE, 2008)

Figure 46: Ground floor, heated zones (Source: NIBE, 2008)

STARTING POINT FIRST FLOOR

1 LADIES ROOM

F | Into office
M | Window frames monumental
M | Windows not monumental, part of image
T | Windows low thermal performance

2 OFFICES

F | Keep as office
M | Monumental and not monumental windows
T | All windows single glass

3 MEETING AREA

F | Into sanitary rooms
M | Windows not monumental
T | Not enough ventilation

4 MEETING ROOMS

F | Keep function
M | Monumental window frames
M | High ceilings, part of monumental image
M | Original shutters lost
M | Balcony doors not monumental, part of image
T | All windows single glass

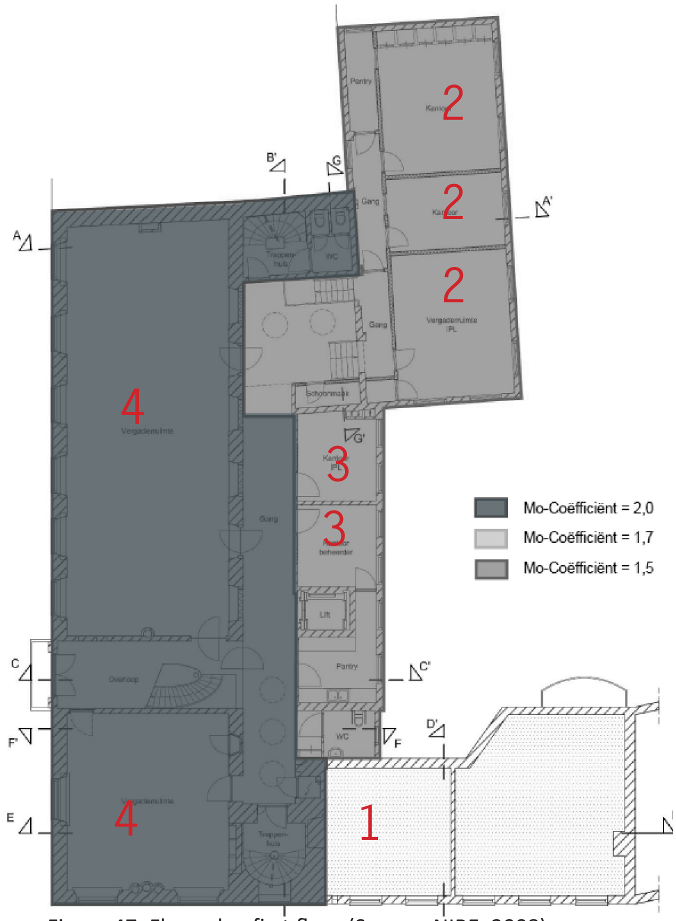


Figure 47: Floor plan first floor (Source: NIBE, 2008)


Figure 48: Offices (Source: Paushuize)

Figure 49: Meeting room (Source: Bramer)

POSSIBLE MEASURES FIRST FLOOR

1 LADIES ROOM

| Replace the windows with sliding windows and place a secondary window
| Or repair the windows and place thin double glazing with pulled glass (Historic way of manufacturing glass)

2 OFFICES

| Provide every window with double glazing
| Or place a secondary window in front of the windows (possible because they rotate towards the exterior)

3 MEETING AREA

| Replace windows with double glazing
| Possible to place double layered squared cupola’s
| Apply mechanical ventilation

4 MEETING ROOMS

| Replace windows with thin double glazing
| Or place secondary windows
| Place secondary windows in front of the skylights

Repair w. frame & place secondary windows

Repair widow frames.

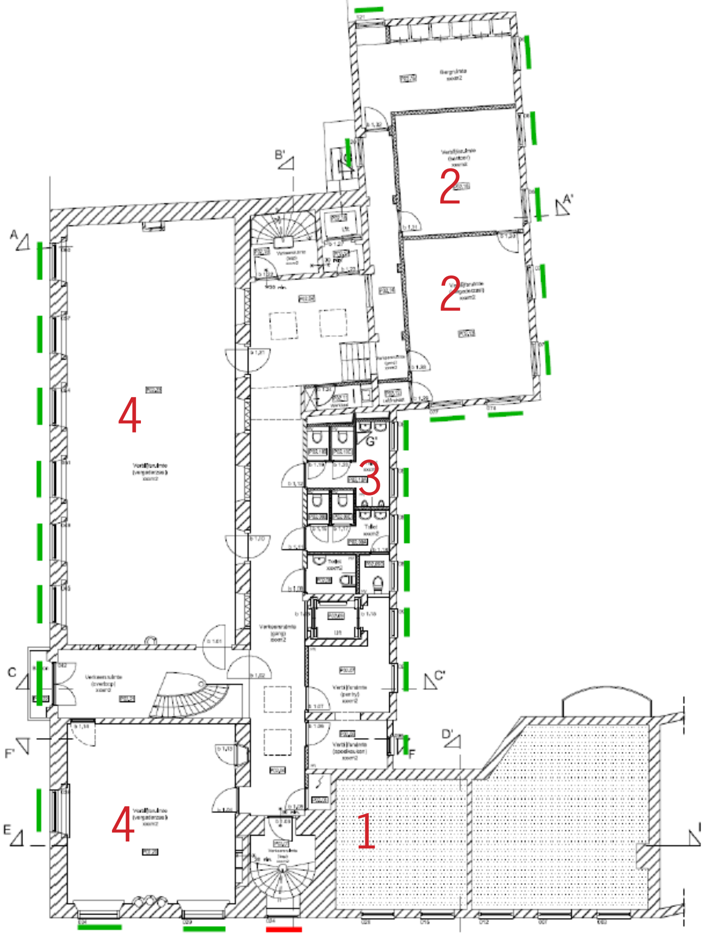


Figure 50: Floor plan first floor with measures (Source: NIBE, 2008)

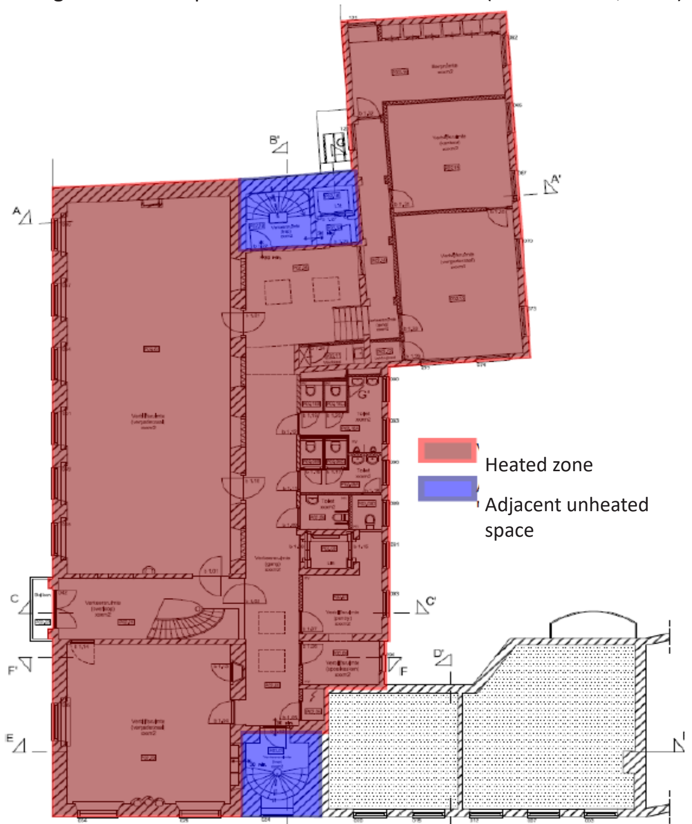


Figure 51: Floor plan first floor, heated zones (Source: NIBE, 2008)

STARTING POINT ATTIC

1 STORAGE ROOMS

F| Into archives
M| Monumental roof construction (19th century)
T| Secondary windows present

2 OFFICES (RIGHT)

F| Keep as office
M| Roofs and windows not monumental

3 OFFICES (LEFT)

F| Into 2 big meeting rooms
M| Monumental beams covered by a ceiling
M| Windows not monumental
T| Insulated floor
T| Not enough ventilation

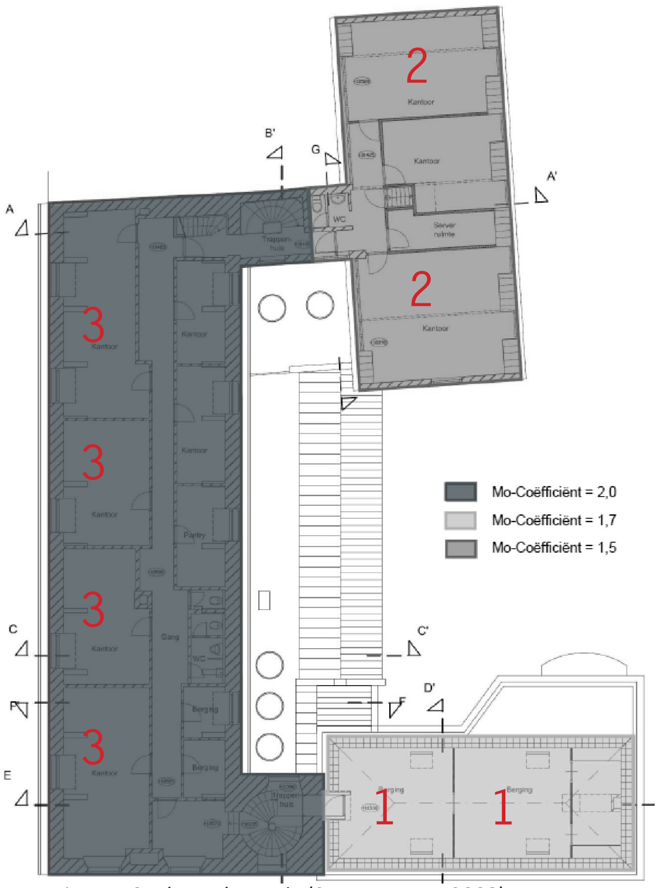


Figure 52: Floor plan attic (Source: NIBE, 2008)

Figure 53: Office (right) (Source: Paushuize)

Figure 54: Office (left) (Source: Bramer)

POSSIBLE MEASURES ATTIC

1 STORAGE ROOMS

| Depending on the comfort demands:
| AUS: Insulate the floor
| Heated space: Insulate roof on the outside

2 OFFICES (RIGHT)

| Insulation on the outside of the roof
| Replace the windows with insulating ones
| Or insulate the floor and a Box-in-box meeting room

3 OFFICES (LEFT)

| The vestibule and staircase can become an AUS, the window needs to be repaired and a insulating curtain is advisable
| Or place a reversible secondary window
| Insulation of the roof is only possible on the outside, max 5 cm, and de imperfections needs to remain visible. Also the historic roof tiles need to be replaced after installing the insulation on top of it.
| Removing the floor adds up on monumental values
| The current secondary windows are not aesthetically preferred. The windows can be replaced to improve the appearance, if the size en position are taken into account.
| Every room will receive an own ventilation system with C02 sensors

THE WHOLE BUILDING

Next to adjustment focused on specific building components and areas, there are also adjustments possible focused on the whole building.

| Replace all lights with LED lights and place a smart system with movement detectors
| Place a heath pump (Dutch: luchtwarmtepomp) and connect with the city heating network
| Replace all sanitaria with water saving ones (NIBE, 2009)

Repair window frame & place secondary windows

Repair widow frames.

Insulate roof.

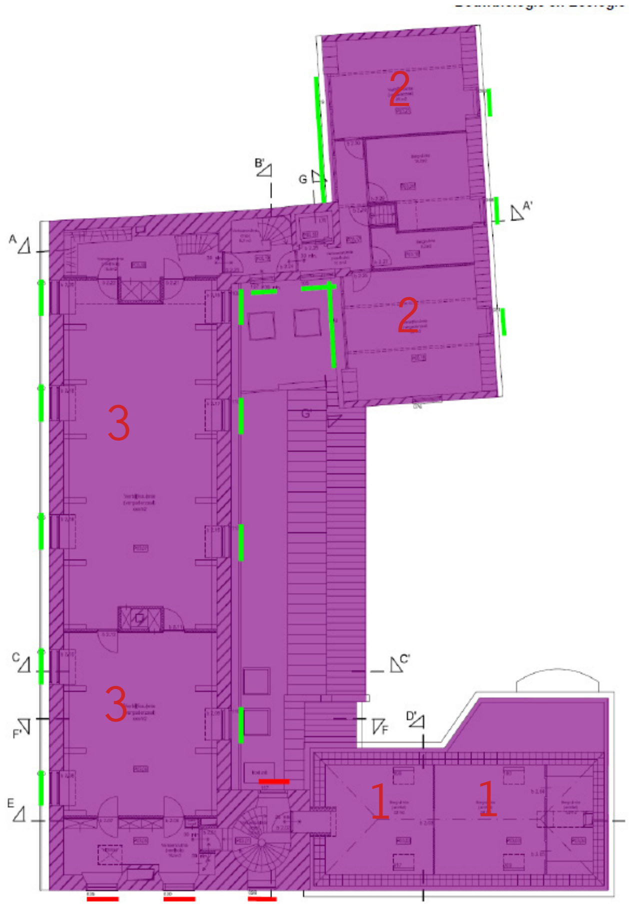


Figure 55: Floor plan attic with measures (Source: NIBE, 2008)

Figure 56: Floor plan attic, heated zones (Source: NIBE, 2008)

3.3.7 Deciding on the implementation

In the case of Paushuize, the decision-making process was based on the outcome of the energy calculations of the design options. The greencalc+ calculation method was used to execute the calculations. The results are added in appendix 9.3.
The intervention with the highest positive impact on the thermal performance appeared to be the implementation of the secondary windows. Therefore, the decision was made to apply this measure on every suitable window. Nearly every possible measure that was indicated is implemented. An extra insulation layer has been placed on the roof and the wall and the secondary windows are installed. An exception is made for one window that consisted of stained glass. The initial plan was to place a secondary window on this stained glass window as well. Some samples were ordered in order to test which kind of secondary window was the most suitable one. After running the tests, it was decided to cancel this measure because the amount of energy that would be saved, did not outweigh the negative impact on the appearance of the monumental window (Bisschop, 2017). Marco Bisschop (2017), who is the building coordinator of Paushuize, mentioned that a visualization of the samples that are projected on the window of Paushuize, could have prevented such a situation: "*A visualization of the possibilities could have prevented the order of the secondary window frames. However, you can not know everything in advance*".
In the decision-making process, there was one element of disagreement between the project team and the municipal monuments committee. This disagreement was about the wooden panels that covered the radiators. The monument committee had the opinion that also 'ugly' interventions of the 20th century needed to be preserved. Bisschop disagreed on this aspect and made the proposition to move the radiators to another room and install new and high efficient radiators underneath the wooden panels. According to Bisschop, this was a win-win solution because the wooden panels would have been preserved, the monumental radiator would have become visible again and the thermal performance would have been improved. However, this proposition was rejected by the monuments committee, because the monumental radiators were not allowed to move.

3.3.8 management of the process

Several steps have been taken in order to create a suitable energy renovation plan for Paushuize:
1: Identification of desired functional changes per room.
2: Archaeological (desk) research by Hylkema architects.
3: Building visit of Evert Jan Nusselder (NIBE) together with Richard Rodenburg and Jan van der Hoeve (Monuments committee) to map the cultural values, 'touch abilities' and the thermal performance.
4: Independent second opinion on the cultural values and 'touch abilities' of the building components.
5: NIBE researched the possible ECM (advice report).
6: Decisions on what to apply by the Project manager.
7: Designing the renovation plan.
8: Execution of the renovation (Dulski, 2017; NIBE, 2008).

There were no further disagreements between the project team and the monuments committee. There were also no difficulties in the legal process. This was the result of considering the cultural values and touch abilities as the starting point of the project, according to Bisschop (2017). Evert Jan Nusselder, who performed the cultural value assessment, was working for a consultancy firm that was specialized for monuments and was simultaneously a member of the monuments committee. Since the possible interventions were the result of the cultural value assessment, the implementation of these interventions could start almost right away. Bisschop also pointed out that even after the decisions were made upon the renovation plan, the plan could change a lot during the implementation phase. According to Bisschop (2017): "*A monument asks for a flexible attitude*. *During the implementation of the renovation plan, we found all kinds of surprises. Elements that are discovered during the execution can be of high cultural value as well. This needs to be assessed first and can subsequently impact the original plan. Several times, the plan had to be adapted and the architect had to create a new design. Therefore, flexibility in the strategy is very important*".

3.3.9 Conclusion

The theory of assessing the cultural values first, and then translate it into design restrictions and consulting a specialist on the possible energy conservations measures was implemented in this project and worked out very well. The main three strategies of reducing the energy need in the monumental building as described in the literature, AUS, insulation and new installations, were also the applicable design strategies in this case.
Regarding the decision-making process, the use of visualizations of the interventions could have been helpful. However, the greencalc+ calculations supported the decision-making process. These conclusions confirm the outcome of the analyzed theory. An additional conclusion that can be taken from this case study is that the renovation design and the whole process requires flexibility.

Westergas-fabriek

| Case studie 2

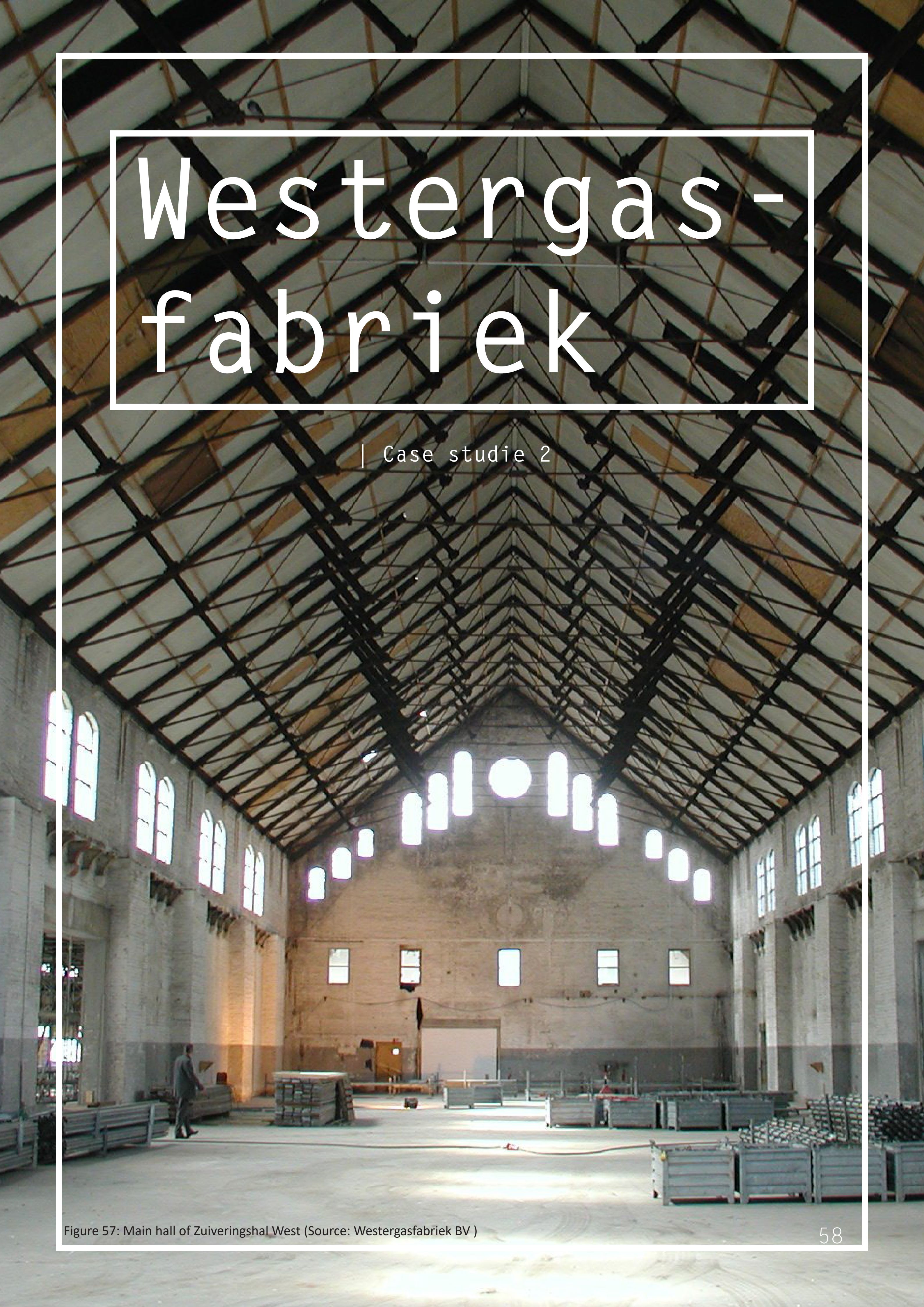


Figure 57: Main hall of Zuiveringshal West (Source: Westergasfabriek BV)

3.4.1 Introduction

The second case study consists of an analysis of the renovation project of the national monument 'Zuiveringshal West, Westergasfabriek' located in Amsterdam (Fig. 57 & 58). The aim of the project, its characteristics and the stakeholders will be analyzed first. Consequently, the project is analyzed on the aspects of importance for this research, the mapping phase (determining the cultural values and the current thermal performance), the designing phase (determining the possible interventions), the decision-making (which design option is implemented) and the process (management).

3.4.2 General information Zuiveringshal West

The Zuiveringshal West is part of the entire zuiveringshal. The building is very recognizable and one of the biggest buildings on the site of the Westergasfabriek. The building is currently used for big events, meetings, dinners, presentations and catwalk shows.

3.4.3 Aim of the renovation project

The greater aim of the Westergasfabriek BV and the municipality of Amsterdam is to create a $C0_2$ neutral terrain of the Westergasfabriek area. They want to reduce the energy need of the buildings, attract clients that want to organize events in a sustainable way and improve the image towards the clients and citizens. Six buildings on the Westergasfabriek area will be renovated. For this research, one building is selected: Zuiveringshal West. This building is chosen because it has the best match with the case study criteria of this research.

3.4.4 Project characteristics

Time frame: 2008 - 2013
Budget: Unknown
New energy label: Unknown
Monument status: National Monument
Location: Amsterdam

3.4.5 Involved stakeholders

Historian: Clemens Temmink (bureau monumenten en archeology)
Sustainability consultant: Birgit Dulski & Kamiel Jansen (NIBE)
Owner/ maintenance advisor: Martijn Bleichrodt (Stichting Westergasfabriek)
Owner/ building coordinator: Ingo Ruijterman (Stichting Westergasfabriek)

3.4.6 Mapping information and designing possibilities

In the following analysis, each building area is analyzed on the following aspects:

1 Functional (F): the use of the building areas.
2 Monumental (M): the cultural values of the building components/areas.
3 Thermal (T): the energy characteristics/thermal performance of the components/areas.

After mapping the information, the possibilities and advises given by NIBE on the possible energy conservation measures that for improving the thermal performance of the building without harming the cultural values are analyzed. For the previous case (Paushuize), the possibilities were analyzed per room or building area. Because this case consists of one room, the possibilities are analyzed per building component. The concept remains the same, but due to the smaller scale of this case, it was possible to zoom in.

Figure 58: Facade of Zuiveringshal West (Source: DuurzameStudent.nl)

STARTING POINT ZUIVERINGSHAL

F| Different events, different users, changing demands
F| Demand for fast adaptation of indoor temperatures
M| Monumental roof construction: 'Plofdak' will reduce damage by an internal explosion (Fig. 61)
M| The construction of the roof consists of monumental iron 'polonceau' trusses
M| Exterior roof layer not monumental
M| Halogen lightning emphasizes industrial character
M| Walls add up to the industrial character
T| Air heating system present
T| The boiler that is connected with the heating system is quite new and has a good performance
T| Changing installations (lights, heaters, coolers) due to changing use
T| No cooling system present, but ventilating
T| Insulation not optimal due to steel construction
T| Insulating secondary windows present (noise/heat)
T| Floor not insulated

Figure 59: Floorplan of Zuiveringshal West (Source: NIBE, 2013)

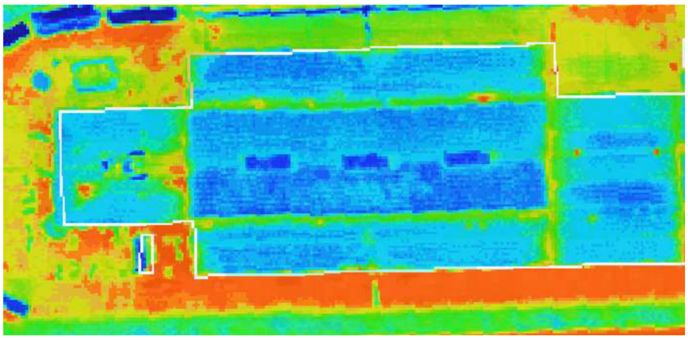


Figure 60: Thermal scan of Zuiveringshal West (Source: NIBE, 2013)

POSSIBILITIES ZUIVERINGSHAL

WALL

Insulate wall (Remark: It is possible but it will have a negative impact on the industrial character and it will not increase the thermal performance distinctively because there are already (un)heated spaces around the main hall (Fig. 59).

FLOOR

Place a thin extra insulation layer on top of the floor.

LIGHTS

Replace the halogen lightning by led lights (negative impact on the industrial character). Next to that, daylight sensors can regulate the required illumination. Movement detectors can control when the lights need to be on or off.

WINDOWS

It is possible to replace the secondary windows with better insulating ones. However, the windows are in a good technical state and therefore the replacement is only recommendable when the window is damaged.

ROOF

The new roof layer scores mediocre on the insulating performance (Fig. 60). It is not possible to insulate the interior side of the roof, because of the monumental construction and the industrial appearance that is protected. An extra insulation layer can be added on the exterior side of the roof by removing the tiles, placing an extra insulation layer and replace the tiles.

HEATING

A Nivolar indoor climate system can be installed in order to heat up the hall more quickly, so that the pre-heating becomes unnecessary and the indoor climate can be controlled.

GENERATING

Possible to install 50 m^2 PV panels.

Figure 61: Roof construction of Zuiveringshal West (Source: NIBE, 2013)

3.4.7 Deciding on the implementation

After the inventory of the cultural values and the current thermal performance of the Zuiveringshal, the decision has been made to implement the energy conservation measure with the highest impact on the thermal performance of the building. The analyzed possible measures have been calculated on their impact on the thermal performance of the building with the use of the greencalc+ calculation tool. The outcome of these calculations are inserted in appendix 9.4.
In this case, the measure with the highest impact appeared to be the indoor climate installation. The insulating measures that were analyzed as a possible intervention, had a negative impact on the appearance of the building according to the municipal monuments committee. Subsequently, it took too much time to come into an agreement with the committee about the insulating measures.

In order to come into an agreement with the monuments committee, each decision was supported with technical drawings and a many sketches of the architect. Next to that, one of the other monumental buildings on the Westergasfabriek terrain was already renovated. This created the opportunity to see the effect of certain measures on the appearance of a building in real life.

3.4.8 Management of the process

Several steps have been taken in order to create a suitable energy renovation plan for the Zuiveringshal:

1: Identification of the functional demands.
2: Visit of Birgit Dulski and Kamiel Jansen (NIBE) together with Martijn Bleichrodt, Ingo Ruijterman (Westergasfabriek BV) and Clemens Temmink (Monuments Committee) to assess the thermal performance, the cultural historic values and map the touch ability factors of the building components for the purpose of applying ECM.
3: Independent second opinion on the cultural values and 'touch abilities' of the building components.
4: Thermal scan performd (Fig. 60).
4: NIBE researched the possible ECM and wrote an advice report.
5: Designing the renovation plan.
6: Negotiation about the design of the renovation plan.
7: Decisions on what to apply by the Project manager.
8: Execution of the renovation (Dulski, 2017; NIBE, 2008).

The process as described took a lot of time. It consisted of at least half a year of researching the possibilities, designing the renovation plan and negotiate it with the monuments committee every month (step 4, 5 & 6). The latter two steps were an iterative process.
The analyzed cultural values of the Zuiveringshal were mostly intangible and therefore prone to subjectivism. This caused the fact that the negotiation phase took a long time. The monuments committee had different ideas about the renovation design than the project team. According to Ruijterman, (the building coordinator of the Westergasfabriek) it was the monuments committee very important to have the feeling of being involved in the project (2017).

3.4.9 Conclusion

The outcome of the cultural value assessment was incorporated in the analysis of the possible interventions. The main three strategies of reducing the energy need in monumental building as described in the literature, creating an AUS, applying extra insulation and implementing new installations, were applicable interventions in this case.
However, the monumental values were less straightforward and more prone to subjectivism in this case. This resulted in a need for more research, time, meetings, design options, calculations and visualizations. The visualizations were technical drawings, sketches and reference projects in this case. It was an intensive process whereby the early involvement of the monuments committee was of key importance in order to receive a permit.
For the decision-making process, the visualizations and the outcome of the calculations on the effectiveness of the measures were of essential support. Eventually, the intervention with the biggest impact on the thermal performance has been chosen. Flexibility was required because the monuments committee was difficult to persuade in the negotiation phase en therefore the renovation plan needed to be reshaped multiple times.

3.5| COMPARING CASES

3.5.1 Introduction

The two case studies, Paushuize and Westergasfabriek, are analyzed on the same aspects. The next step in a comparative research design, is comparing the analyzed results of the two cases on similarities and differences.

3.5.2 Comparison of Paushuize and Westergasfabriek

Similarities

- The cultural value assessment and the determination of the causes of the bad thermal performance were the first activities in both projects. The outcomes of these analyses were in both cases directive in the design phase.
- Early involvement of the monuments committee appeared to be important for the process in both cases.
- Flexibility in the design was required in both cases.
- In both the case of Paushuize and the case of the Westergasfabriek, there was a need for visualizations of the designs to check whether the intervention had an impact on the appearance and the cultural value of the building. For the Westergasfabiek, the visualizations were used as a communication medium and as a ground for the decisions. Since the legal process was less strict for Paushuize, visualizations were not used, but afterwards it could have prevented some mistakes in the process.
- The calculated impact of the design options on the thermal performance of the building was of great support for the decisions that had to be made in both cases.

Differences

- The thermal performance of Paushuize is analyzed by visiting the building and observing the materials. In the case of the Westergasfabriek, there was an additional thermal scan performed in order the assess the thermal performance of the building and detect thermal leaks.
- In the case of Paushuize, it was more clear which elements were of high monumental value. This resulted into clear design restrictions, such as: '*Do not adjust*'. In the case of the Westergasfabriek, the cultural values were not of the highest range, less defined and more prone to subjectivism. This resulted in disagreements in the decision-making phase between the project team and the monuments committee.
- In comparison with the Paushuize case, the process of creating a suitable renovation plan for the Westergasfabriek required more time, research, design options and visualizations.
- Nearly every analyzed possible intervention was implemented in the final renovation design of Paushuize. This was not the case in the project of the Westergasfabriek. The monuments committee disagreed with some of the analyzed possible interventions. This emphasizes the need for checking the advised possible interventions on their applicability.

3.5.3 Conclusion

The two cases show both similarities and differences.
The cultural value assessment and the thermal analysis were in both cases the starting point for creating a suitable renovation design. The assessed cultural values resulted in the case of Paushuize in clear 'touch abilities' and were consequently directive in the design phase. Since the cultural values were less straightforward in the case of the Westergasfabriek, it was less clear which interventions were suitable.
The advised energy conservation measures were in both cases adjacent unheated spaces, new installations and extra insulation.
Supportive elements in the decision-making process for the renovation design were in both cases the thermal impact calculations and the visualizations. Visualizations were dual used: to improve the communication and to see the impact on the appearance.
Both cases showed that flexibility is required in the renovation design and that early involvement of the monuments committee is of key importance for a smooth process.

3.6 | CONCLUSION EMPIRICAL RESEARCH

The aim of interviewing experts and performing case studies was to check whether the analyzed theory is applicable in practice. Based on practical information from experts, the practical applicability of the strategy can be optimized. The strategy that is explained in the conceptual model in figure 12 includes four different phases: mapping, designing, decision-making and managing. The conclusions of the empirical research will be elaborated per phase.

Mapping
The cultural value assessment and the thermal analysis are both in theory and practice a good starting point for creating a suitable renovation design for a monument.
In theory, there are cultural value assessment methods available to calculate the cultural values. However, this is not in line with the cultural value assessment in practice. Additionally, according to the theory, there are only positive or indifferent cultural values, however in practice it is also possible to identify negative cultural values.
Theoretically, the thermal performance of a monument can be measured with sensors and thermal scans. However, these measurement methods are not always applied in practice. In the case studies, the thermal performance was estimated trough a survey and the values were calculated with the use of key figures.

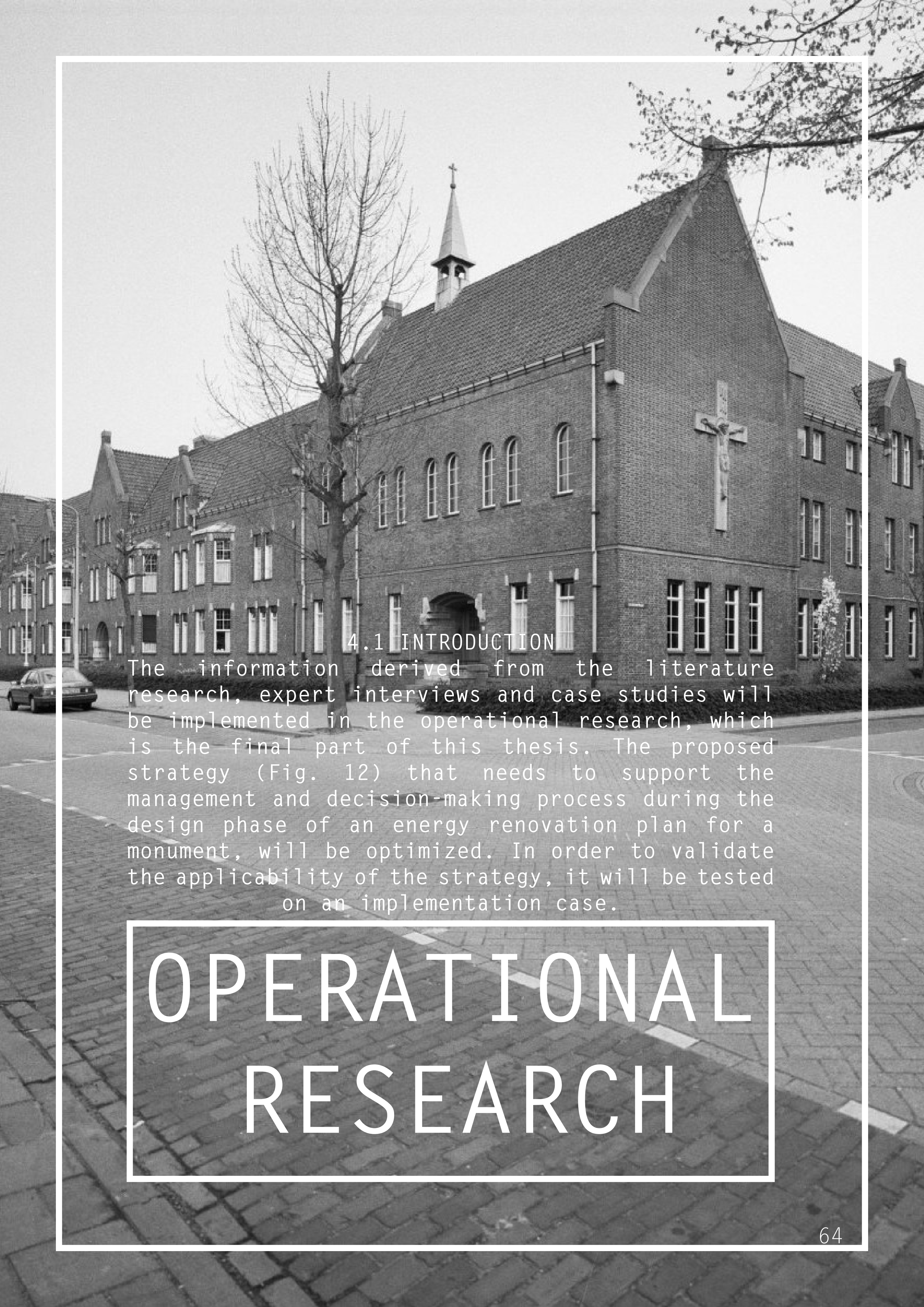
Designing
The assessed cultural values can theoretically be translated into ‘touch abilities’, which are consequently directive in the design phase. This is also the case in practice when the cultural values are more straightforward; very high or no cultural value. When there are elements present in the monument that are valued with a more ambiguous cultural value, the touch ability is also less clear.
The theoretical strategies for improving the energy performance of a monument namely, adjacent unheated spaces, new installations and extra insulation, are the applied strategies in practice as well.

Decision-making
Supportive elements in the decision-making process upon the renovation design are in theory and practice the thermal impact calculations and the visualizations. Visualizations can be used in two ways; to improve the communication and to see the impact on the appearance. In theory, the conservation factor of method 3 (CHA&CF) and filling in the cultural value assessment forms of method 1 (SUMO) and 2 (CHVM) are not applied in practice.

Managing
When there are cultural values assessed that are not of the highest range, less defined or more prone to subjectivism, disagreement in the decision-making phase can arise. Consequently, the process can require more time and the design of the renovation plan can require more preparatory research, design options and visualizations.
The empirical research showed that flexibility is required in the renovation design and that early involvement of the monuments committee is of key importance for a smooth process.

These conclusions will be integrated in the following paragraphs, which consist of the operational part of this research, whereby the design of the strategy will be optimized.

→
Figure 62: Ludwina Monastery (Source: Rijksmonumenten.nl)



4.1 INTRODUCTION

The information derived from the literature research, expert interviews and case studies will be implemented in the operational research, which is the final part of this thesis. The proposed strategy (Fig. 12) that needs to support the management and decision-making process during the design phase of an energy renovation plan for a monument, will be optimized. In order to validate the applicability of the strategy, it will be tested on an implementation case.

OPERATIONAL RESEARCH

4.2| TEST CASE

4.2.1 Introduction

The main aim of this research is to design a BIM-based strategy that supports the creation of a renovation plan for a monument. The concept of the strategy is derived from the P2Endure research and is explained in the research proposal. This concept needs to be tested and the new information that is obtained through the literature study and empirical research needs to be incorporated. A test case is selected in order to be able to test the strategy.

4.2.2 Selecting the test case

The selected test case is the Lidwina Monastery in Tilburg. This case is selected because it is also a case in the P2Endure project, so a deep renovation is planned for this building. Next to this, the monastery is a national monument and there is a BIM model of this building available (Fig. 63). The main idea is to integrate the cultural values into the BIM model in order to make the P2Endure concept, as described in chapter 1.7, also applicable for monuments.
In the case of the Lidwina Monastery, a new renovation plan needs to be created in order to improve the energy performance of the building. The original plan was to work according to the scheme visualized in figure 12 and create a BIM model by laser scanning and enriching the model with information about the technical state and the thermal performance. However, this model is made by hand by an architectural firm and the thermal data acquisition and cultural value assessment are not started yet.

Figure 63: The BIM model of Ludwina Monastery (Own illustration)

4.2.3 The Lidwina Monastery

The Lidwina Monastery is built in 1935 and was devoted to Saint Lidwina of Schiedam. The building is designed by architect M. van Beek and F. Vervest. The building has characteristics of the traditionalism and elements of the Delftse School. The interior of the building is slightly changed in 1949 (RCE, 2015). No extensive cultural value assessment has been performed but the exterior façade is of high monumental value and therefore protected by the RCE (Gralka, 2017).

4.2.4 Conclusion: Testing the strategy

In the following paragraphs, every step of the conceptual model visualized in figure 12 will be tested. The BIM model of the Ludwina Monastery will be used for these tests.
Because of the lack of information about the thermal performance and the cultural values of the Lidwina Monastery, the data derived from the case studies (Paushuize and Westergasfabriek) will be used.

4.3| CULTURAL VALUES IN BIM

4.3.1 Introduction

The mapping of the cultural values is analyzed in the literature study, questioned in the interviews with professionals from practice and analyzed in the case studies. This chapter reflects on the actual implementation of the cultural values in a BIM model. The advantage of inserting these values in the BIM model of the monument, is that all the information about the building is stored in one integral system. Currently, information about the objects, the energy performance of building components, size and many more properties are stored in such a BIM model. If the cultural values are integrated as well, they can be incorporated more easily during the design of a renovation plan for the building. Since this is never done before, the conclusions of the former theoretical and empirical research will be directive for the implementation. The goal of the implementation is to find out whether or not the outcome of the cultural value assessment is compatible in BIM or not.

4.3.2 Choosing a cultural value assessment method

With the aim of increasing the energy performance of a monument, the assessment of the cultural values of the separate building components results in useful information for the creation of the renovation design (Hendriks & van der Hoeve, 2009). The concrete valuations of the cultural values of building components lead to direct restrictions of actions. Intangible cultural values like the industrial appearance in the main hall of the Westergasfabriek led also to concrete restrictions for the building components. The components became of more value because of their contribution to the industrial appearance. This appearance was the main thing that needed to be preserved, which led to specific restrictions such as, '*Do not change the material*'. Thus, it matters whether special care on the element is required and in what way. Therefore, the assigned cultural value and the description together needs to be implemented in BIM. There are four different theoretical methods available to assess the cultural values of a monument (Fig. 64). The question rises: which one is the most suitable to use and has an output that is implementable in BIM?

Method 3 does not include an assessment of building components separately. Next to this, the empirical research showed that the exact quantification of the cultural values and calculating cultural value scores is not applied in practice. Methods 1, 2 and 3 include an quantification of cultural values. Therefore, method 4 (Building Archeological research) is the most suitable method to implement in the strategy. This method is based on a qualification of cultural values in three classes: high monumental, monumental and indifferent monumental values.
As concluded from the interviews, building components of a monument can also affect the cultural values of the building. The case studies confirmed this conclusion. For example in the case of Paushuize, a new concrete floor has been placed on top of the original historic floor. This new floor can be seen as an disturbing element with a negative cultural value. If the concrete floor will be removed and the original floor becomes visible again, it will positively influence the monumental appearance of the room. Another example is that in the attic of Paushuize, the visibility of the beams of the roof construction dating from the 16th century was blocked by a ceiling. The demolishment of the ceiling resulted in a room with more height and a different appearance.
Whether the disturbing values are going to be integrated in cultural value assessment method or not is not clear yet. Since there were also building components present in the case studies that had a negative impact on the cultural values, two monumental classes will be added: disturbing value and highly disturbing value.
When the RCE decides to implement these negative values in their method, this research is still up to date. If these disturbing values will not be integrated in the method, one can discard these classes. The following classes are distinguished, each with its meaning:

Class	Meaning
A	High monumental value
B	Monumental value
C	No monumental values
D	Disturbing the monumentality
E	Highly disturbing the monumentality

Table 7: Cultural value classes and the corresponding meaning ▲

Figure 64: The BIM model of Ludwina Monastery (Own illustration) ▼

M1 SUMO | M2 CHVM | M3 CHA&CF | M4 BAR

4.3.3 Enrich the BIM model with cultural values

One of the aims is to add information to the building components of the BIM model. For example, if a door is valued as 'high monumental', the digital building component of the door in the BIM model needs to have the following property: *Cultural value: High monumental*. Therefore, an extra property needs to be created for the building components in the BIM model, where the assigned cultural value class can be defined.
A class that defines whether the building has monumental value or not, informs the user of the BIM model only on an abstract level. According to method 4, a reference has to be made from the valuation towards the written text about what this value includes and what it is based on. This textual explanation needs to be integrated in the BIM model as well. Therefore, another property set is needed that includes the description of the assigned cultural value, for example if the door is cultural valuable due to its paintings. The dsecription will give more direction on on ways for preserving this door.

4.3.4 Implementing cultural values in the test case

In order to implement the cultural values of the Lidwina Monastery in the BIM model, the values need to be assessed first. Through an interview with Anna Gralka, a researcher who is involved in this case study for the P2Endure project, information about the cultural values of the Lidwina Monastery was retrieved:

- The exterior façade and the roof are fully protected, because these building components are part of a protected city site (Class A: High monumental value).
- The exterior façade on the back is not incorporated in the protected site, but has monumental value (Class B: monumental value).
- The internal structure has no monumental value (Class C: no monumental value).

The information about the cultural values is implemented in the BIM model for the walls. Two parameters are created, one for the monumentality class and one for the complementing textual description. In appendix 9.5 an explanation can be found in a step-by-step approach for inserting these parameters and values in a BIM model by using Autodesk Revit software.

4.3.5 Evaluation of the implementation

The implementation is effective and not labor intensive. The outcome of the cultural value assessment is compatible in BIM.

Easy information sharing
If a user of the BIM model clicks on a building component like the façade, he or she can directly read the assessed class of monumentality and the corresponding description in the properties dialog. This means that a stakeholder does not have to read the full report of the historian anymore and that he or she is able to see the information instantly when he or she needs it. The information is shared with all the stakeholders in the project more easily, once the stakeholders have access to the model.

Visualization of information will improve communication
Another beneficial aspect of integrating the values in the BIM model, is that when there is a project meeting with different stakeholders, all the information is stored in one integral model. Instead of being limited to the stakeholders' own report, the information can now be visualized with color schemes in the 3D model of the building instantly and shared with everybody (appendix 9.6). This can improve the communication. The historian can directly show which parts of the building are protected and which parts are not. In Figure 65 it is visualized what this will look like for the monastery and the protected walls. A visualization with colors provides directly an indication for the architect where there is room for adjustments. In this case, there is room for adjustments on the interior structure of the building, visualized in green (no monumental value).

4.3.6 Conclusion

It is possible to add information to a BIM model about the monumental value classes of the building components and a complementing textual description. It will ease the sharing of information between stakeholders.
Since the information about the cultural values is integrated in the BIM model, 3D visualizations can be created instantly of the building with the information about the monumental classes per building components visualized with color schemes, which can improve the communication between stakeholders.

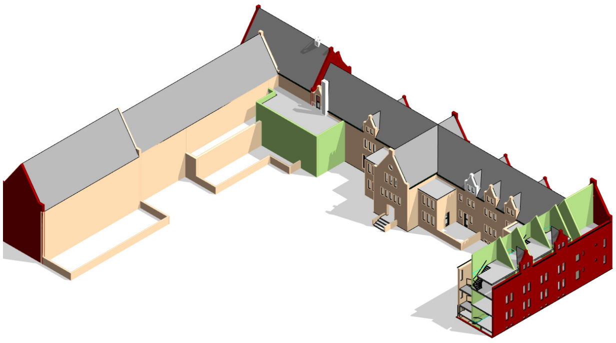


Figure 65: Cultural values visualized with color schemes (Own ill.)

4.4| BIM DESIGN SUPPORT

4.4.1 Introduction

When the BIM model is enriched with data (the cultural values, the technical condition, U-values, R-values etc.), it is possible to perform smart analyses. For example, an analysis of components that have no monumental value and a low thermal performance can be performed. The outcomes of the analysis can support the design of the renovation plan for the monument. First, it will be explained how these analyses can be generated and subsequently a test analysis will be performed on the test case.

4.4.2 Filtering of information

In order to perform an analysis as described in the introduction, the inserted data about the thermal performance and cultural values of the building components have to be filtered. There is a filtering tool available in Autodesk Revit. By using the filtering tool, it is possible to filter for example all the walls that have a low thermal performance, so that the renovation plan targets the weak spots of the building. If the filter is applied, the building components with a low thermal performance are highlighted in the model. However, when working with a monument, the cultural values need to be taken into account as well. This can be done by adding another filter. It is possible to filter all the walls that have no monumental value and have a U-value (heat transfer coefficient) above a to be defined value. In this way, the user of the model can identify where renovations are directly applicable and suitable.

4.4.3 Creating design/renovation arguments

The filters of Autodesk Revit can be used to perform many analyses on multiple parameters, such as technical state or fire rating. The outcome of these analyses will give more insight in the most urgent or effective spots for renovation. Since the cultural values are integrated in the BIM model, they can incorporated in the analyses and consequently during the creation of the renovation plan and its corresponding design arguments. If an element is monumental (class B) yet has a very low thermal performance, there may be a reasonable argument to make adaptations on even protected elements.

4.4.4 Performing an analysis in the test case

An analysis is performed in the BIM model of the test case. All the walls with monumentality class C, D, E (no or disturbing cultural value) and a U-value above 2.45 are filtered. The higher the U-value, the worse the thermal performance. The result of this analysis is a schedule with an overview of all the elements with these characteristics. Next to the schedule, the result is also visible in the floor plan or in 3D. Figure 67 shows the result in the floor plan, the highlighted components match with the filtered characteristics. The step-by-step implementation of the filters is demonstrated in appendix 9.7.

4.4.5 Conclusion

When information about the thermal performance and the cultural values of the building components is implemented in the BIM model, it is possible to generate analyses. The information can be filtered and the outcome of these analysis can support the creation of the design arguments. It can also help to identify the building areas where renovations are directly applicable and where this is not the case.

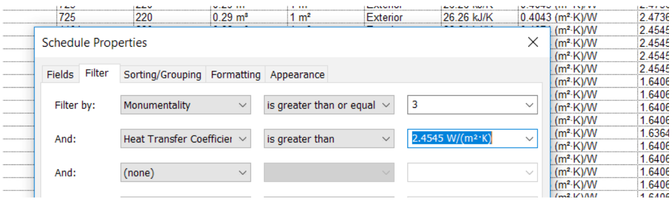


Figure 66: Filtering on cultural value & thermal performance (Own ill.)

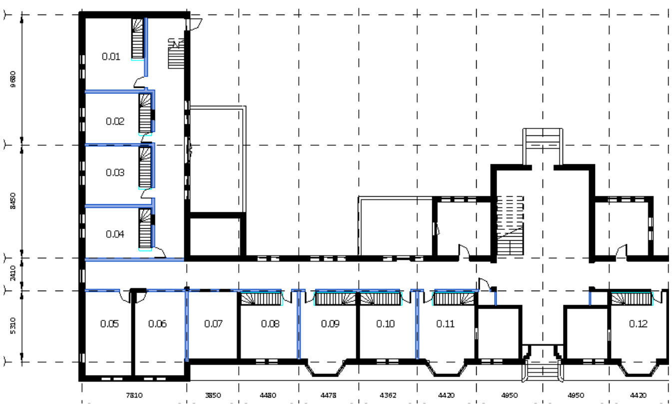


Figure 67: The filtered building components (Own ill.)

4.5 | MANAGING THE DESIGN PHASE

4.5.1 Introduction

The BIM model of a monument can be enriched with information about its monumentality and thermal performance. Performing analyses with the use of filters can support the designer to locate the areas of the building where easy adaptations are possible and the onces where more attention is needed. The next step is to respond appropriately to the outcome of the analysis and design interventions that enhance the energy performance of the building and conserve the cultural values.

4.5.2 Desired action per monumentality class

In order to safeguard the cultural values, the project manager and the architect have to respond carefully to the outcome of the cultural value assessment. It was concluded in the literature study and case studies that the level of monumentality determines the consequent 'touch-ability' of the building component, which means the possible level of intervention.
Per monumentality class, the desired action can be defined to which the manager can steer the architect on (table 8).

High monumental (class A) = Preserve, do not touch this.
The most valuable elements of the building cannot be touched and need to be preserved.

Monumental (class B) = Conserve, adaptations are only possible with respect to the cultural values.
The building components in monumentality class B need to be conserved but may sometimes be renovated. For example, repairing a monumental window frame will enlarge the lifecycle of the frame and will improve the thermal performance of the element. Therefore, some win-win situations can arise in this category. However, depending on the strictness of the monuments committee, disagreements can arise between stakeholders because this class is not clearly bounded.

Not monumental (class C) = Flexible, suitable for adaptation.
Components in class C do not have monumental value and are therefore suitable for adjustments. In this category there is more flexibility. However, it needs to be checked whether the adaptation does not indirectly influences a monumental component.

Disturbing (class D) = Remove, conserving possible in case of addition to thermal performance.
Disturbing elements in the building need to be removed if this is possible and results in additional cultural historic value. However, since an optimum is searched between monumentality and thermal performance, conservation of this component can be considered if the component positively influences the thermal performance of the building. Because this class is not clearly bounded personal, it is prone to subjectivism.

Highly Disturbing (class E) = Remove.
Highly disturbing elements in the building need to be removed if this is possible.

Table 8: Cultural value classes, the meaning and suited action

Class	**Meaning**	**Action**
A	High monumental value	Preserve, do not amend
B	Monumental value	Amend with respect to the cultural values only
C	No monumental value	Free of action
D	Disturbing the monumentality	Remove if its favorable for the project
E	Highly disturbing the monumentality	Remove

4.5.3 Managing uncertainties

Because the level of allowed interventions on building components in class B and D is not clearly bound and prone to subjectivism, disagreements between stakeholders can arise. As derived from the literature, interviews and case studies, the following issues need to be taken into account by the project manager when there are a lot of building components classified in class B and D:

- The project can require more historical research and thermal advice (extra use of consultants).
- The design phase can take more time (implement this in the project planning).
- The project can become more expensive, due to the extra time and research.
- More chance on disagreements between stakeholders, (involve the monuments committee in an early stage).
- Need for a flexible design (multiple design options).
- Need of clear communication (use of visualizations).

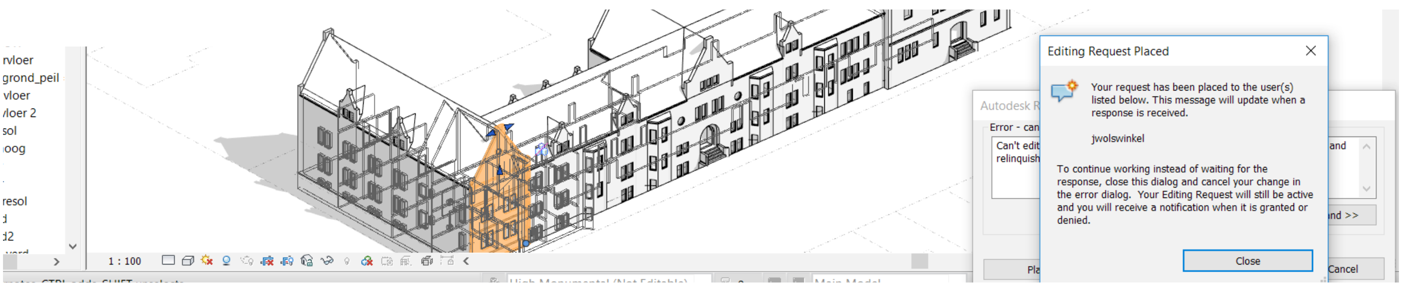
4.5.4 Managing stakeholders in the BIM environment

The cultural value classes are linked to an action that should be implemented in the design of the renovation plan. However, the process of creating a feasible renovation plan for a monument comes along with the involvement of many stakeholders, as described in chapter 2.8. During the design phase of the renovation plan, these stakeholders can work together in the BIM model from their own office via the network. Their workflow in the BIM environment can be managed digitally by creating worksets. A workset is a part of a BIM model (for example all the building components of the ground floor). By assigning stakeholders as a host of a workset, responsibilities can be divided.
Next to this, the manager can steer on the defined actions (table 6) through the implementation of the worksets. For example, in order to make sure that there will be no changes applied to components labeled with the monumentality class A, all the components can be inserted in a workset. The manager can become the owner of this workset. If another stakeholder, such as the architect wants to make changes to one of these components, he will receive an error. This will result in a warning that he can not edit this part of the model and he can request permission by the owner of the workset (in this example the manager). He can send the request and the manager will receive it (Fig. 68). The manager is consequently responsible for making contact and organizing a meeting with the architect and the historian, to discuss the problem and see if the permission can be granted.
The B workset (workset with all the components valued with a monumentality class B) can for example be owned by the restoration architect who is an expert in creating design for monumental buildings. He should have the knowledge and experience to make an estimation whether or not the change to the building component will harm the cultural value. Changes to elements with no value can become a disturbing element on the cultural values after changing it in an improper way and therefore, the restoration architect can be in charge of the C workset as well.

4.5.5 Implementing worksets in the test case

In order to test whether the management of the actions on the monumental building components in the BIM environment through worksets is possible, it is implemented in the BIM model of the test case. The step-by-step plan of the implementation is explained and illustrated in appendix 9.8. The exterior walls at the front of the building are inserted in workset A, the exterior walls at the back of the building in workset B and the interior walls in workset C are owned by user jwolswinkel. The test consisted of placing an extra window in the exterior facade at the front. The test showed that it was not possible to place the window but permission could be requested (Fig. 68). The test confirms that the actions of the stakeholders during the design phase can be regulated and steered trough worksets in the BIM environment.

Figure 68: Preserving cultural values with worksets (Own ill.)



Limitation

It is left out of the scope of this research whether or not stakeholders, such as the restoration architect and project managers, are willing to work in an interactive BIM environment. Research that has been done on this topic concludes that the amount of firms who are working with this method is increasing (Azhar, 2011; Ghaffarianhoseini et al., 2016). Therefore, it can be concluded that working in the interactive BIM environment can be beneficial for the management of the design phase of a renovation plan for a monument.

4.5.6 Conclusion

By creating worksets and dividing responsibilities in the digital BIM environment, the project manager can steer the stakeholders upon the desired action as a consequence of the cultural value assessment. The restoration architect will remain in charge of the design, and the risk that other stakeholders will negatively impact the cultural values of the building will be diminished.

4.6| DECISION-SUPPORT

4.6.1 Introduction

The cultural values can be implemented in the BIM model and the design space can be set with boundaries trough worksets. However, not all the boundaries are clear lines; as for example the bounded action for building components assigned with monumentality class B.
In the analyzed case studies, a consultant was hired to perform a research and give advice on the energy conservation measures that are appropriate based on the outcome of the cultural value assessment and the thermal performance of the building. In this paragraph it will be researched how the use of BIM can support the finding of an appropriate and effective energy conservation measure.

4.6.2 Create design options in BIM

In order to identify the most suitable intervention, multiple design options have to be created in the BIM model.
In the Autodesk Revit software, there is a possibility to create design options. The software duplicates the BIM model and in the duplicated model, the intervention can be designed. In this way, the designer can easily create multiple alternatives. The required flexibility of the design, as described in chapter 3.2, can be facilitated in this way because the design can easily be adapted.

4.6.3 The energy performance of the design options

To be able to analyze the design alternative that has the most positive effect on the thermal performance of the building, the energy characteristics of the building before the renovation have to be modeled as described in chapter 2.2. In order to run an energy analysis in Autodesk Revit software, an energy model has to be created out of the BIM model. The outcome of the energy analysis has to be compared with the measured thermal performance of the building. If the modeled energy performance does not deviate much from the real performance, the model can be used as a reference model.
In order to analyze the energy performance of the design options, energy models of the design options have to be created and the energy analyses can be performed.
The outcome of the energy analysis is a document with the calculated values for the thermal performance.
The simulations are dynamic and not static, which means that the time aspect is included in the calculation. However, it should be taken into account that these calculations have a range of uncertainty. After comparing the calculated performance of the design options it can be concluded which measure is the most effective.

Energy modeling vs greencalc+ calculations
In the case studies, the thermal performances of the design options are calculated with the greencalc+ software. This is more a static calculation tool which calculates the thermal performance based on key figures (for example standard U-values of materials) (Agentschap NL, 2010; DGMR, 2011). However, the U-value of an insulation layer of a monument has probably changed after 100 years. Therefore, the method of measuring the energy characteristics of the building and simulating dynamic energy models is more applicable for monuments.

4.6.4 The cultural performance of the design options

Next to the thermal performance of the design options, the impact on the cultural values is a factor that influences applicability of the design option. A distinction can be made between tangible and intangible cultural values as described in chapter 2.3.
For the impact assessment of the design option on the tangible cultural values, the instant visualization of the digital model in 3D can be used (or even in virtual reality and augmented reality). The design option can be viewed from different perspectives and within the context (if the context is modeled).
The intangible values are more relational values or linked values which can only be observed by the ones who understand the relation. Therefore, instant visualization of the changes can serve as the basis for the observation by the historian. Not all the intangible values can be registered in 3D such as a smell in the room that forms the link to an event. However, a lot of criteria such as the concept of the original architect, connection between appearance and historical function, or readability of construction history, are easier to read when visualized.
Therefore, it can be concluded that not every cultural value can be observed in a digital 3D model, however it can support the visual links that have to be made in order to analyze the impact on the tangible and intangible cultural values.

4.6.5 Monumental & thermal performance

In order to analyze the most suitable design option optimized on the cultural performance and thermal performance, the performances of the design options can be measured with energy simulations and observed by the use of visualizations. In this way, a measurable aspect and an immeasurable aspect can be combined and the decision on the most suitable design option can be made.

4.6.6 Implementing design options in the test case

The applicability of the design options in the BIM model will be tested in the BIM model of the test case. In the case studies, multiple possible energy conservation measures are proposed in order to increase the thermal performance of the building without harming its cultural values. The next step in this research is to test these measures in the test case and analyze whether or not BIM can support the decision making upon the most suitable design option.
The model of the Ludwina Monastery is cropped in order to have a more simplified test model and to reduce the required time for the implementation of the design options. The following measures are proposed in the cases and will be implemented in the BIM model of the monastery.

Design options:

Windows:
- Leave the windows and window frames as it is. (zero option).
- Repair window frames.
- Repair window frames + replacing with double layered glass.

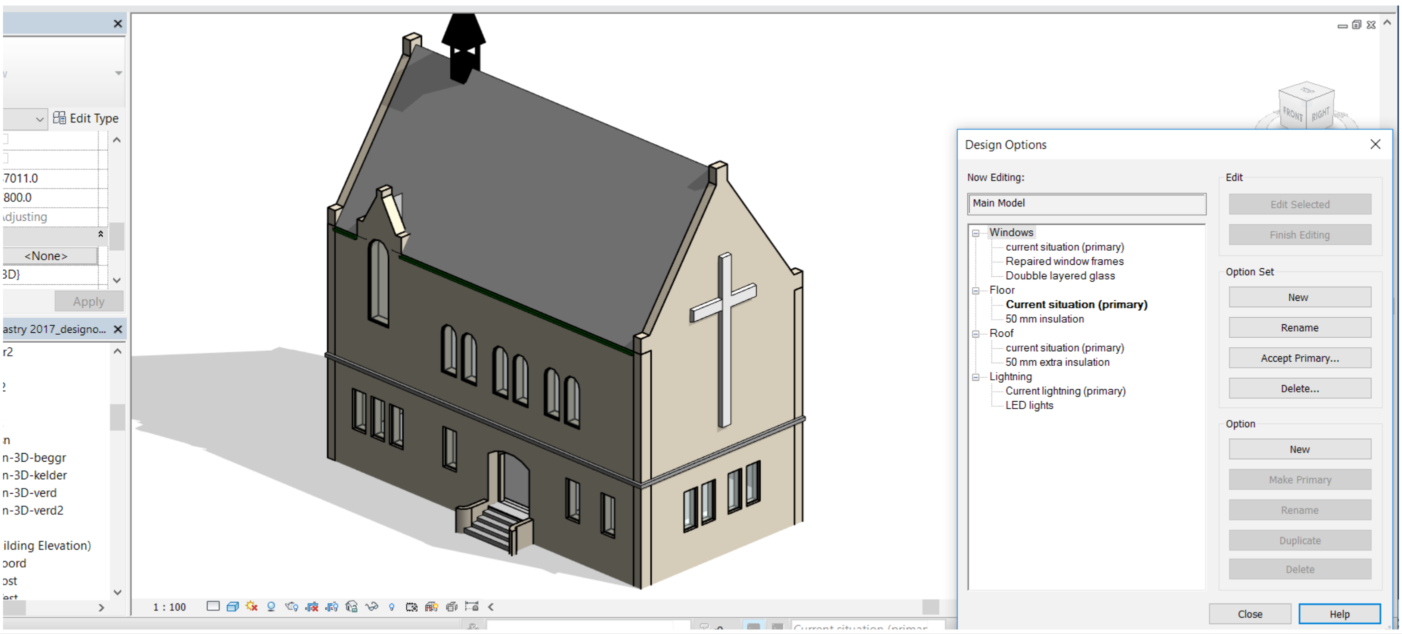
Floor:
- Leave the floor as it is (zero option).
- Insulate floor (50mm).

Roof:
- Leave the roof as it is (zero option).
- Extra insulation layer on the roof (50 mm).

Heating system:
- Keep the current heating system (zero option).
- Replace the heating system with a more efficient one.
- Install a heat pump.

Figure 69 shows the visualization of the cropped BIM model and the implemented design options. After implementing the design options, an energy model of every design option is made (Fig. 72) Consequently, an energy analysis is performed for each design option.

Figure 69: Cropped BIM model of Ludwina Monastery with design options (Own ill.)



performance. The results are visualized in figure 71. The energy analysis settings were set on an office function, which is open 5 days a week. The analysis simulates the building performance during an entire year, so every season is integrated. The results are benchmarked with the thermal performance of small offices. The average Energy Utilization Index (EUI = kWh/m2/yr) for small office buildings is 260 (BCA, 2015). In the test case, an EUI of 260 is reached after applying all the measures. This means that there is something wrong with the energy model. There is a hole in the roof of the energy model that negatively influences the results. However, it is possible to analyze the impact of the different measures on the thermal performance of the building.

Limitations

- A small defect in the model can have a large influence on the results. The defect of the hole in the roof was not easily corrected.
- There is no secondary window element available in the data base. This emphasizes the fact that BIM is not commonly used for monuments. However, a family of such a building component is easily created. The modeling aspect is not of key importance in this research. Therefore, the secondary window is not tested in the test case.
- There was also no window frame component available with imperfections or a bad technical condition. In order to simulate more or less the same effect, a window frame with a bad thermal performance is selected. However, when the building is scanned with laser scanners, a component will be made from the three dimensional data and energy characteristics will be retrieved from the sensors. In that case, it is possible to work with a component that is similar to the real situation.
- The energy analysis is in the Autodesk Revit software only gives an indication of the thermal performance and is not very precise.
- The model is not detailed enough to see whether the appearance of the design option harms the cultural value.

4.6.7 Conclusion

By implementing the possible interventions as design options in BIM, the design is flexible, easily cchanged, and able to be analysed on its energy performance and cultural performance, which can support the decision-making process. To be able to be able to analyze the impact on the cultural values trough visualizations, a highly detailed BIM model is required.

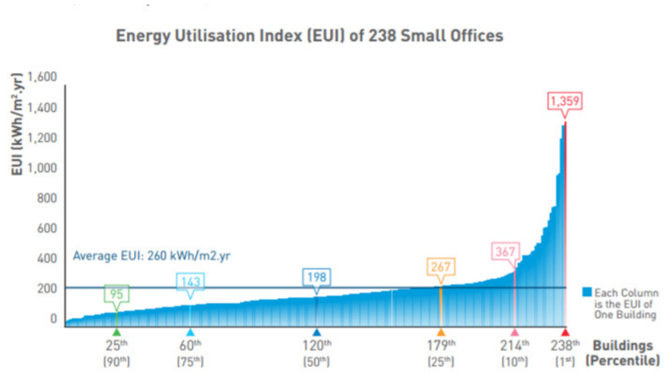


Figure 70: EUI of small offices for benchmarking (Source: BCA)

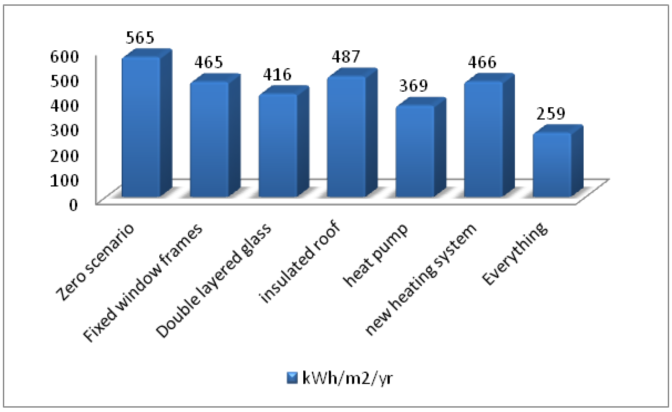


Figure 71: Outcome energy analyses of design options (Own ill.)

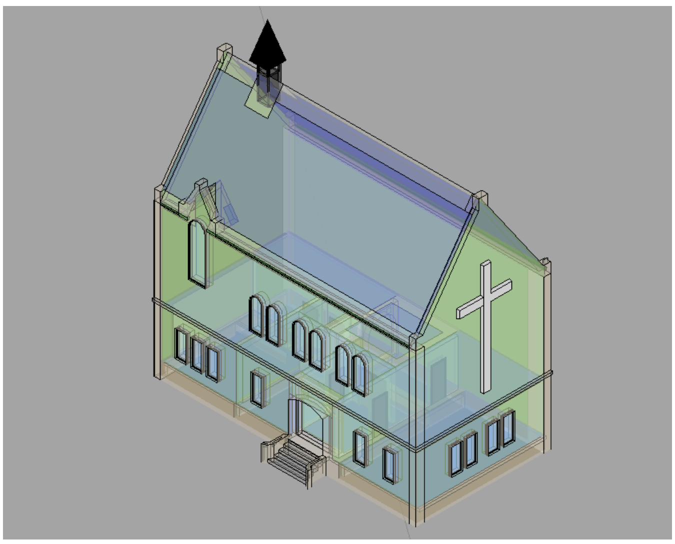


Figure 72: Energy model of Ludwina Monastery (Own ill.)

4.7| OPTIMIZING STRATEGY

4.7.1 Introduction

After performing the literature, empirical and operational research, the design of the first concept of the strategy can be optimized (Fig. 73).

4.7.2 Optimizing the strategy

The strategy will be optimized per phase (mapping, designing and decision-making).

Mapping
It is concluded in this research that the cultural value assessment is based on a classification of cultural value categories (A - E) and a complementary description. In the first concept (Fig 12), the cultural values are implemented as scores. Instead of scores (numbers), the information about the cultural values will be inserted in the BIM model as classes (A-E) and descriptions (text). The test results described in chapter 4.3 confirmed that the outcome of the cultural value assessment can be implemented in BIM.

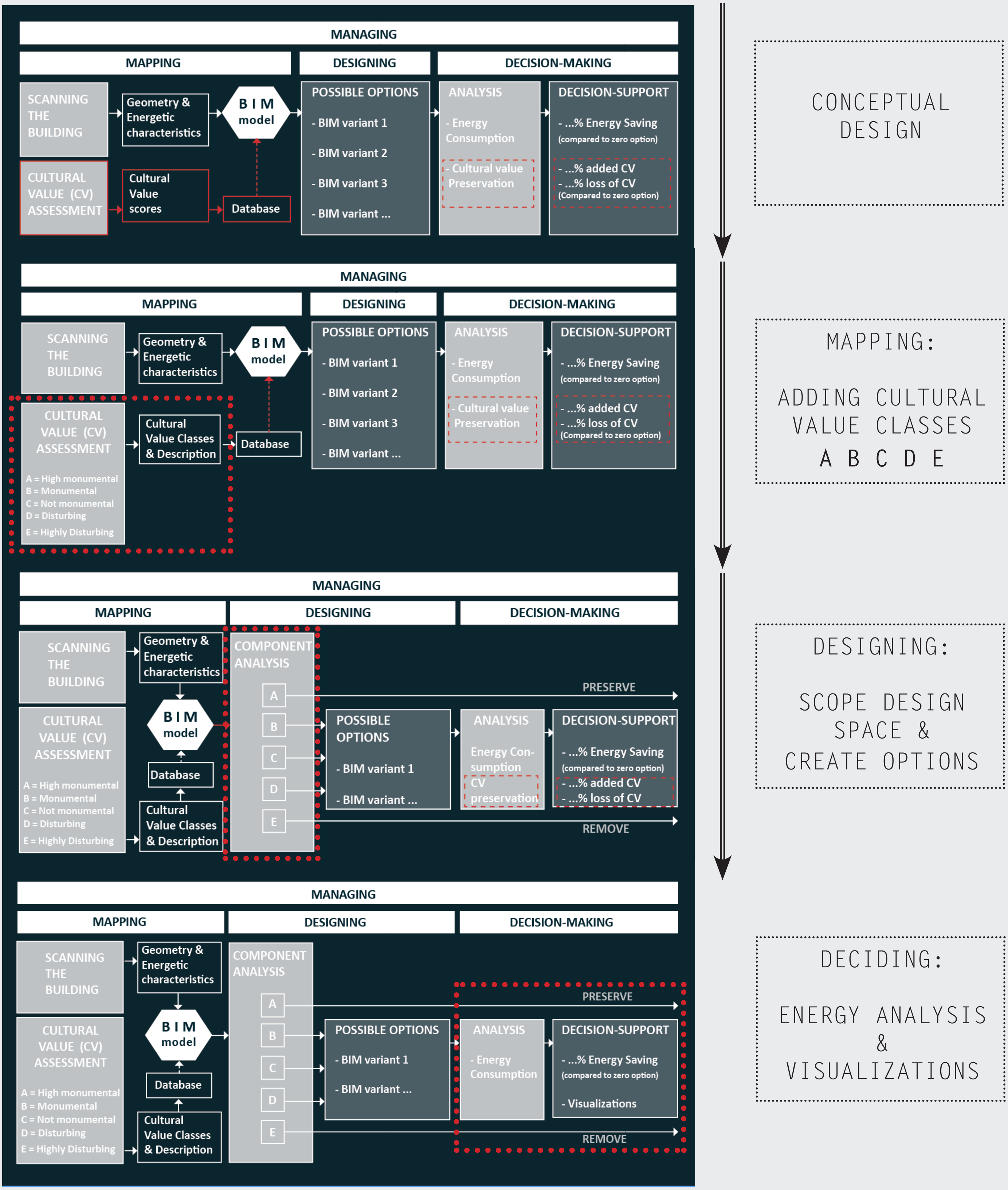
Designing
The outcome of the cultural value assessment can function as the directive starting point of the design phase. Building components classified as '*high monumental (A*)' need to be preserved and components classified as *'highly disturbing (E)*' need to be removed. As a result, the design space is more defined and scoped. During the design phase, design options can be created for the building components classified in classes: B, C and D.

Decision-making
Since the decision on the suitability of alterations on components classified in classes B, C, and D needs more support, different design options can be analyzed on the thermal performance through energy simulations and the impact on the cultural values by the use of visualizations. Indicating the added cultural value or loss of cultural value with percentages is not applicable because calculating these values based on scores appeared to make no sense.

The final strategy is visualized in figure 74, whereby all optimization steps are implemented.

Figure 73: Steps of optimization of the strategy (Own ill.)

OPTIMIZING STRATEGY



5| CONCLUSION

Improving the energy performance of a monument during conservation without harming its cultural values is a complex process. The objective of this research is to design a BIM-based strategy that supports the creation of a renovation plan for a monument, which increases the energy performance of the building and conserves the cultural values. In the previous chapters, the strategy has been designed and all the research sub-questions have been answered. This chapter concludes the research with a concise answer to the main research question.

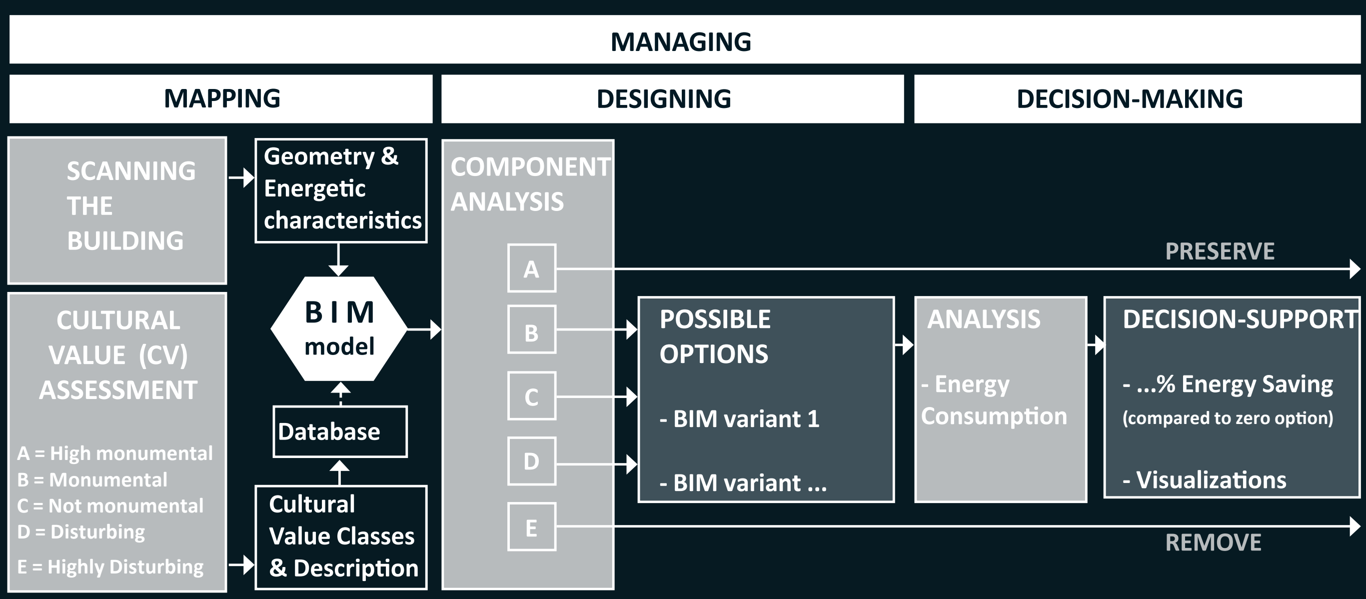
5.1 Answering the main research question

In this paragraph, an answer will be provided to the main research question: *How can the use of BIM support decisions on the optimization of energy performance and cultural value in Dutch national monuments?*

Based upon research findings, it is concluded that the use of BIM can support decisions on the optimization of energy performance and cultural value in Dutch (national) monuments if the following actions of the designed strategy are taken;

(1) Create a BIM model of the monument;
(2) Asses the energy characteristics and cultural values of the building components;
(3) Implement the assessed values in the BIM model;
(4) Preserve highly cultural valuable components and remove highly disturbing components;
(5) Create worksets in the BIM model and make sure that the most cultural valuable components will become unable to change;
(6) Perform analyses on the assessed values by using filters in Revit (or other BIM software) and indicate the most suitable and effective building areas to apply energy conservation measures;
(7) Create design options in BIM by creating unheated adjacent spaces, placing new installations or improving the insulation performance;
(8) Create an energy model of every design option, perform energy analyses and compare the results;
(9) Observe the impact on the cultural values by using the visualizations of the BIM model;
(10) Make a decision upon a design option supported with visualizations and the outcomes of the energy analyses.
The final strategy including these actions is visualized in figure 74.

Figure 74: Final strategy to create a suitable energy renovation plan for a monument (Own ill.)



Mapping information

The results of the theoretical and empirical research showed that the most suitable method to assess the cultural values, is the Building Archeological Research method, whereby the output consists of classified cultural values and a complementary textual motivation. The empirical research concludes that building components can also have a negative impact on the cultural values of a monument and therefore, two classes are added to the assessment method: disturbing and highly disturbing. With the aim of optimizing on cultural values, these building components need to be removed if possible.

Next to the specific requirements of the cultural value assessment method, it can be concluded that there is also a special method required for the assessment of the energetic characteristics of the building components. In order to receive the most reliable information, these characteristics have to be measured instead of determined with key figures. Key figures are not applicable for monuments due to the ageing of the building materials.

Designing an energy renovation plan

Since the data about the two variables can be inserted in the BIM model, analyses can be performed to detect building areas where energy renovations are effective and applicable. For example, building components with a high heat transfer coefficient (U-value) and low cultural value can be filtered. The result of these analyses can support the design process.

Managing the process

Next to supporting the design process, the enriched BIM model with information about the energy performance and cultural values can support the process management of creating a suitable energy renovation design in which many stakeholders are involved. Storing information in one model improves the accessibility of information for all stakeholders. A stakeholder can effortlessly find information about the building component of interest by clicking on the digital BIM component instead of searching for the information in different reports. Additionally, visualizing the data with color schemes in a 3D model can improve the communication between stakeholders.

In order to make sure that the most valuable components will be conserved, these components can be 'locked' in the BIM model trough inserting them in a workset, whereby none of the stakeholders can amend this component without permission.

Decision-making on the implementation

Multiple design options can be created in BIM by duplicating the model. Each design option can be tested along the impact on the energy performance by performing energy analyses and the impact on the cultural values can be analyzed by observing the visualizations of the de designs. In this way, the decision upon the implementation of a renovation design variant can be supported.

Concluding, analyzing the cultural values and thermal performance of the building components of a monument and inserting them in a BIM model, creates the opportunity to use BIM for the support of the managing, designing and decision-making in the design process of a suitable energy renovation plan for a monument.

6| RECOMMENDATIONS

Based upon research findings, the following recommendations can be made for the practical implementation of the outcomes of this research. Subsequently, recommendations for further research are given.

9.2 Recommendations for further research

It is recommendable to perform further empirical research, whereby an energy renovation design process will be managed according to the created strategy. Subsequently, the strategy could be further optimized based on the findings of its applicability.
Additionally, this research is based on two criteria: cultural values and energy performance. However, there are additional criteria that will influence the decision-making upon a renovation design such as cost, time, safety, technical condition, et cetera. For example, interviewees mentioned that if a building component is assessed as '*high cultural valuable'* yet in a bad technical state, the condition can be a good argument to amend this component. This is interrelated with the safety aspect. A building can be cultural valuable, however when it is close to collapsing, it is not safe for use anymore in combination with a potential risk of losing the entire monument. Next to this, the budget can be a limiting factor for possible interventions. Research needs to be performed on how these additional variables can be incorporated in the strategy.

Two different ways of visualizing information are discussed in this research. Data such as the cultural values can be visualized with color schemes in the BIM model. These visualizations can support the analysis phase that precedes the creation of the design options. Next to this, the appearance of the design options can be visualized realistically, in order to support the impact assessment on the cultural values. Software is available that combines the visualization of data and appearance. It takes the BIM model into a virtual-reality environment and the user can observe the appearance of the building by navigating through the model and simultaneously access valuable data by clicking on the components. This can improve the communication and collaboration between stakeholders because ideas can be visualized and the arguments can be supported with the data (Architosh, 2015; Autodesk Inc, 2017; Ghaffarianhoseini et al., 2016). Further research can be performed in order to find out whether this combination of information supports the creation of a suitable energy renovation design for a monument.

9.1 Recommendations for practical implementation (utilization potential)

The designed strategy could be applied in practice and has many advantages. However, the process of the creation of the 3D model with laser scanning and automatic feature extraction is not effective yet. It still costs a lot of time and money. Though, the trends are promising and automation in acquisition and registration of 3D models is getting more optimized. Next to this, the costs of the required instruments are reducing. Therefore, the creation of a BIM model of existing buildings (monuments) by the use of innovative techniques would become more applicable in a few years.
Since the proposed strategy is based on the strategy of an unfinished research project (P2Endure), it is recommendable to wait with its implementation until the P2Endure research is completed as well (2020). The created strategy for monuments as described in this report is optimized on the outcomes of expert interviews, case studies and a test case, however it is never practically implemented in a real case. The P2Endure research includes testing the strategy with other variables (time, costs and technical state) in real renovation projects. Therefore, the outcome of this research could be valuable for further optimizing the proposed strategy for monuments.
To conclude, the strategy is promising, future-proof and implementable in a few years.

7| REFLECTION

7.1 Research methods and validity of findings

The applied research methods are literature research, empirical research and operational research. The empirical research consists of two parts: the expert interviews and the case studies. The operational research consists of the design of the strategy. In this paragraph, a reflection will be provided on each research method and the validity of the findings.

7.1.1 Literature research

The concept of inserting cultural values of a monument in a BIM model for the support of decisions on renovation designs is new. However, it is based upon existing theory. Cultural value assessment of monuments is a practice that is already applied for years and integrating information in a BIM model is the main intention of building information modeling. Therefore, the analysis of the six defined themes in the literature, formed the starting point of this research and resulted in the opportunity to combine the theory and create new ideas. In order to validate the practical applicability of the theory, it is tested within the empirical research. Theories are confirmed such as the theory on the possibility to define the tolerance for change (touch abilities) of monumental building components. However, theories are also rejected, such as the quantification of cultural values.
There was no recent literature available about the Dutch methods to assess cultural values. The most recent source that described new theory for this dated from 2008. The interviewees agreed upon the fact that the theory on this subject is outdated and should be revised and updated. Therefore, the literature about the cultural value assessment only was not sufficient.
There is an abundance of literature about BIM technologies and energy renovations of existing buildings. This resulted in the opportunity to base and validate the theoretical findings of these themes on different sources.

7.1.2 Empirical research

Expert interviews
The interviews are performed with a semi-structured interview approach. This appeared to be the right approach, because it provided the flexibility to zoom in on the field of expertise of the interviewees by asking follow-up questions that one cannot prepare in advance. The aim of the semi-structured interviews was to test the practical applicability of the theory, which was crucial for the design of a practical applicable strategy.

Case studies
In this research, two case studies are performed with the comparative research design. Both cases are analyzed on the cultural values and thermal performance aspects, which functioned as the starting point for the creation of a renovation design. For both cases, the possible energy conservation measures, the process and the decision-making are analyzed and compared. The conclusions are based upon these analyses, however the outcome cannot be generalized. In order to validate the outcomes of comparative case studies, many more case studies are required. Therefore, these case studies can also be seen as explorative case studies. The aim of this research is to design a strategy and therefore the focus was not on the analysis part of the research but more on the operational part. However, the empirical case studies were needed in order to confirm the theory, have a starting point for the operational research part and have data to implement in the test case.

10.1.3 Operational research: Design of the strategy

The operational research part consists of the design of the strategy. An operational research design consists of several steps: define the problem, design a concept, test and evaluate the conceptual design and optimize the design towards a final design (Dym & Little, 2004). All these steps have been taken in this research in order to reach the final design of the strategy. The conceptual design of the strategy as explained in chapter 1.7, is optimized based on the outcomes of the theoretical and empirical research towards the final design (chapter 4.8). The actions that have to be taken in order to implement the strategy, such as the implementation of the cultural values in BIM, the creation of multiple design options in BIM and the calculation of the energy performance of these options, are tested in the test-case Lidwina Monastery and validated. However, testing the strategy on one case is not enough to generalize the result. Next to this, the validation of the strategy would be more reliable when it is implemented in real renovation projects of monuments.

10.2 Reflection on societal relevance

The aim of creating the strategy was to support the creation of an energy renovation plan for a monument that does not harm the cultural values and increases the energy performance. Also, according to the literature, citizens, organizations and entrepreneurs who have plans for a monument must be nurtured and supported (Janssen, 2014). The strategy can support the management of the design phase of a renovation plan, the creation of a suitable design and the decision upon the design option. This emphasizes the societal relevance of this research.
Furthermore, due to this support, monuments can be conserved and improved on their thermal performance and through this, better function in society. The buildings can reflect the history of society, without having a negative impact on the environment. Less negative impact on the environment is more beneficial for the society of today and the society of the future.

10.3 Reflection on scientific relevance

The need for decision support tools that stimulate adaptive reuse is also acknowledged in the field of research (Franco, Magrini, Cartesegna, & Guerrini, 2015; Yung & Chan, 2012). This research answers this need. Next to this, research is conducted about implementing cultural values in a BIM model of a monument for educational purposes or for museums to show the history of buildings in virtual reality (Bonsma et al., 2016). However, implementing cultural values in the way this research suggests with the aim of including them in analyses and in the design of a renovation plan, is never done before. This new perspective opens multiple further research possibilities as described in the scientific recommendations.

10.4 Refection on the process

The research design, as presented in the research proposal in figure 10, represents the executed process and planning quite well. I started with the literature research, although from P2 until P4, the literature research, empirical research and operational research were performed simultaneously in an iterative process.

On beforehand, I did not plan to perform the expert interviews. During the literature research I noticed that a research institute (NIBE) also performed research on sustainable monument conservation and therefore, I decided to contact this institute to discuss the literature. The interview/discussion gave me many new practical insights and via Birgit I got in contact with the other interviewees. Since I had the time to dive into the subject, I was able to perform these additional interviews. In retrospect, the outcomes of these interviews had a large impact on the outcome of the research. Having contact with experts in the field of interest resulted also in the possibility to retrieve very specific case study data. Finding a case study that met all the case study criteria was difficult. Trough NIBE, I received all the data and contacts that I needed for the case studies. Therefore, a lesson learned is that contacting people in the field of interest will help more than searching for information available on the internet. Next to this, I also enjoyed to speak with these people. They inspired me in a way that I would have never experienced if I stayed behind my desk.

The design of the strategy started with the idea to implement cultural values in a BIM model, however it took a while before I found out what the final design of the strategy should look like. I needed the time to process the information and ideas in my mind. During this 'processing time', I produced nothing on paper which felt really frustrating. However, when it suddenly all came together in my mind, I was able to document it properly. I think it is important to realize that I need the time to process information in my mind and cannot produce the same amount of output every day. I appreciate that the graduation project provides time to properly process information and the opportunity to dive into a subject of personal interest.

8| LITERATURE

Ackoff, R. L. S., & Maurice, W. (1968). *Fundamentals of operations research.*

Agentschap NL. (2010). *Centraal stellen van duurzame energieambities in het gebiedsontwikkelings-procesGreencalc+* (p. 3). Agentschap NL Ministerie van Binnenlandse Zaken en Koninkrijksre-laties. Retrieved from https://www.rvo.nl/sites/default/files/bijlagen/Greencalc+.pdf

Ankone, J. (2016). *Niets mag meer en je krijgt er niets voor terug - Een onderzoek naar de effecten van de gemeenschappelijke monumentenstatus op de herbestemming van kerken* (pp. 10–23). Rijksdienst voor Cultureel Erfgoed.

Autodesk Inc. (2017). Color Schemes | Revit Products | Autodesk Knowledge Network. Retrieved April 24, 2017, from https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/Revit-DocumentPresent/files/GUID-4809E31D-8385-4EB9-89C2-B58D7FB25B00-htm.html

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering, 11*(3), 241–252.

B30. (2017). B30. Retrieved January 5, 2017, from http://www.b30.nl/home

Barison, M. B., & Santos, E. T. (2010). An overview of BIM specialists (p. 141). Presented at the international conference on computing in civil and building engineering.

BCA. (2015). *Building Energy Benchmarking Report 2015* (p. 15). Singapore: Green Building Policy Department.

Bezoek Utrecht. (2017). Paushuize. Retrieved March 20, 2017, from http://www.bezoek-utrecht.nl/locaties/2651384832/paushuize

Bilardie, E. (2011). Milieubewust Herbestemmen: Nieuw leven voor monumentaal industrieel erfgoed.

Bonsma, P., Bonsma, I., Ziri, A. E., Parenti, S., Lerones, P. M., Hernández, J. L., … Iadanza, E. (2016). INCEPTION Standard for Heritage BIM Models (pp. 590–599). Presented at the Euro-Mediterranean Conference, Springer.

Bouchenaki, M. (2007). A major advance towards a holistic approach to heritage conservation: the 2003 Intangible Heritage Convention. *International Journal of Intangible Heritage, 2*, 106–109.

Bramer, D. (n.d.). *Fotograaf Paushuize, Pauhuize: een (klimaar) kanjer!* Retrieved from http://www.com-plan.nl/nieuws/nieuwsbrieven/archief-nieuwsbrieven/september-2012/paushuize-een-klimaat-kanjer.html

Bryman, A. (2015). *Social research methods*. Oxford university press.

Carbonara, G. (2015). Energy efficiency as a protection tool. *Energy and Buildings, 95*, 9–12.

CWM. (2017). Commissie Welstand en Monumenten Gemeente Utrecht. Retrieved March 22, 2017, from http://www.welstandutrecht.nl/Default.aspx

De Rijksoverheid. (2014, December 18). Rijk draagt 31 monumenten over | Nieuwsbericht | Rijks-overheid.nl. Retrieved June 12, 2017, from htt-ps://www.rijksoverheid.nl/actueel/nieuws/2014/12/18/rijk-draagt-31-monumenten-over

de Santoli, L. (2015). Guidelines on energy efficiency of cultural heritage. *Energy and Buildings, 86*, 534–540.

DEMO B.V. (2016). *P2Endure.* Retrieved from http://www.p2endure-project.eu/Main.aspx?uri=1,2,3

DGMR. (2011). GreenCalc+. Retrieved June 20, 2017, from https://dgmrsoftware.nl/gcplus.php

Dirlich, S. (2012). The building stock and traditional building principles: sustainability assessment for historic buildings (pp. 31–38). Presented at the Proceedings of the 1st International Conference on Building Sustainability Assessment, Porto, Citeseer.

Dulski, B. (2017, February 14). Interview.

Duurzame Monumenten Coalitie. (2017). Quickscan. Retrieved June 28, 2017, from http://duurzamemonumentencoalitie.nl/services/

DuurzameStudent.nl. (2016). PuurFair - DuurzameStudent. Retrieved June 27, 2017, from http://www.duurzamestudent.nl/agendaitem/puurfair/

Dym, C. L., & Little, P. (2004). *Engineering Design, a Project-based introduction.* New York: Wiley.

Edis, E., Flores-Colen, I., & de Brito, J. (2012). Passive thermographic inspection of adhered ceramic claddings: limitation and conditioning factors. *Journal of Performance of Constructed Facilities, 27*(6), 737–747.

English Heritage. (2008). Energy conservation in traditional buildings. *English Heritage Program*, 1–11.

Facilitair. (2016). B30: van statig ministerie naar denktank. Retrieved January 5, 2017, from http://tinyurl.com/n3v2g43

Franco, G., Magrini, A., Cartesegna, M., & Guerrini, M. (2015). Towards a systematic approach for energy refurbishment of historical buildings. The case study of Albergo dei Poveri in Genoa, Italy. *Special Issue: Historic, Historical and Existing Buildings: Designing the Retrofit. An Over-view from Energy Performances to Indoor Air Quality, 95,* 153–159. https://doi.org/10.1016/j.enbuild.2014.10.051

Franken, V. (2017). Meeting think-thank sustainable monuments preservation.

Garagnani, S., & Manferdini, A. M. (2013). Parametric accuracy: Building Information Modeling process applied to the cultural heritage preservation. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.,* XL-5 W, 1, 87–92.

Georges, L., Haase, M., Houlihan Wiberg, A., Kristjansdottir, T., & Risholt, B. (2015). Life cycle emissions analysis of two nZEB concepts. *Building Research & Information, 43*(1), 82–93.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2016). Building Information Modelling (BIM) uptake: Clear benefits, under-standing its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews.*

Gralka, A. (2017, April 18). Interview with Anna Gralka on the cultural values of the Lidwina Monastery.

Hendriks, L., & van der Hoeve, J. (2009). *Guidelines for building archaeological research - The inter-pretation and analysis of cultural-historical heritage.* The Hague. Retrieved from https://cultureelerfgoed.nl/sites/default/files/publications/guidelines-for-building-archaeological-research.pdf

Herbestemming.nu. (2017). Het Zeepaert, Dordrecht | Herbestemming.nu. Retrieved June 27, 2017, from https://www.herbestemming.nu/projecten/het-zeepaert-dordrecht

Hoppe, T. (2009). *CO2 reductie in de bestaande woningbouw: een beleidswetenschappelijk onderzoek naar ambitie en realisatie*. University of Twente.

Jalaei, F., & Jrade, A. (2014). Integrating Building Information Modeling (BIM) and Energy Analysis Tools with Green Building Certification System to Conceptually Design Sustainable Buildings.

Jansen, J., Storck, M., & Van der Weijden, J. (2012). *Build up skills - The Netherlands - Analysis of the status quo* (pp. 2–5). Harderwijk: Intelligent Energy Europe.

Janssen, J. (2014). Modernising Dutch Heritage Conservation: Current Progress and Ongoing Challenges for Heritage-Based Planning and Management. *Tijdschrift Voor Economische En Sociale Geografie, 105*(5), 622–629.

Jeong, W., Kim, J. B., Clayton, M. J., Haberl, J. S., & Yan, W. (2015). A framework to integrate object-oriented physical modelling with building information modelling for building thermal simula-tion. *Journal of Building Performance Simulation*, 1–20.

Korthuis, S. E., ten Cate, F., & van 't Veen, C. (2009). *Handreiking gemeentelijke monumentencom-missies* (pp. 11–22). Vereniging van Nederlandse gemeenten. Retrieved from https://vng.nl/files/vng/2009-vng-handr-monumentencies.pdf

Kuperus, J. (2016). Duurzaam herbestemmen van grote fabriekscomplexen in Nederland.

Kymmell, W. (2008). *Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations.* New York: Mc Graw Hill.

Lagüela, S., González-Jorge, H., Armesto, J., & Arias, P. (2011). Calibration and verification of thermographic cameras for geometric measurements. *Infrared Physics & Technology, 54*(2), 92–99.

Lashley, M. (2016, February 16). Actuele subsidies en regelingen voor duurzaam renoveren. Retrieved June 1, 2017, from http://www.bouwenaanketensamenwerking.nl/actuele-subsidies-en-regelingen-voor-duurzaam-renoveren-en-energiebesparing/

Logan, W., & Reeves, K. (2008). *Places of pain and shame: dealing with'difficult heritage'.* Routledge.

Lysen, E. H. (1996). The Trias Energica: solar energy strategies for developing countries. Presented at the Proceedings of the EUROSUN Conference.

Mason, R. (2008). Be interested and beware: joining economic valuation and heritage conservation. *International Journal of Heritage Studies, 14*(4), 303–318.

Mishra, A. K., & Ramgopal, M. (2013). Field studies on human thermal comfort—an overview. *Building and Environment, 64*, 94–106.

Monumentenregister. (2016). Aantal gebouwde provinciale monument per gemeente 2016. Retrieved February 21, 2017, from https://erfgoed.databank.nl/jive/?presel_code=ps_geb_rm_antl_act

Monumentenregister. (2017). *Aantal rijksmonumenten - actuele stand.* Rijksdienst voor Cultureel Erfgoed. Retrieved from https://erfgoed.databank.nl/jive/?presel_code=ps_geb_rm_antl_act

Nan, L., Sharf, A., Zhang, H., Cohen-Or, D., & Chen, B. (2010). SmartBoxes for interactive urban recon-struction (Vol. 29, p. 93). Presented at the ACM Transactions on Graphics (TOG), ACM.

Nelissen, N., Smits, J., Bogie, M., & Voorzee, J. (1999). Herbestemming van grote monumenten, een uitdaging. *Stichting Pandenbank Noord-Brabant,'s-Hertogenbosch*.

NIBE. (2008). NIBE | Nederlands Instituut voor Bouwbiologie en Ecologie. Retrieved January 11, 2017, from http://www.nibe.org/nl

NIBE. (2009). *Duurzame monumentenzorg - Paushuize Utrecht* (pp. 1–57). Bussum: Nederlands Instituut voor Bouwbiologie en Ecologie, NIBE Consulting bv.

NIBE. (2013). *Duurzame monumentenzorg Westergasfabriek Amsterdam -Verduurzamingsmogelijkheden Westergasfabriek op basis van zes casestudies* (pp. 14–119). Bussum: Nederlands Instituut voor Bouwbiologie en Ecologie, NIBE bv.

Nusselder, E.-J., & Dulski, B. (2008). Handboek duurzame monumentenzorg: Theorie en praktijk van duurzaam monumentenbeheer.

Paushuize. (2017). Paushuize - Utrechts' mooiste locatie voor bijeenkomsten in besloten kring. Re-trieved June 27, 2017, from https://paushuize.nl/over-paushuize.html

Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and Buildings, 40*(3), 394–398.

Previtali, M., Barazzetti, L., Brumana, R., Cuca, B., Oreni, D., Roncoroni, F., & Scaioni, M. (2014). Au-tomatic façade modelling using point cloud data for energy-efficient retrofitting. *Applied Geomatics, 6*(2), 95–113.

Prokopičová, J. (2015). Funkcionalistická továrna Van Nellefabriek v Rotterdamu a její proměna | EARCH. Retrieved June 12, 2017, from http://www.earch.cz/cs/revue/funkcionalisticka-tovarna-van-nellefabriek-v-rotterdamu-jeji-promena

Provincie Utrecht. (2015). Paushuize - Provincie Utrecht. Retrieved March 15, 2017, from https://www.provincie-utrecht.nl/organisatie/paushuize/

RCE. (2015, April 18). Kerkelijk gebouw in Tilburg. Retrieved June 19, 2017, from http://rijksmonumenten.nl/monument/521194/kerkelijk-gebouw/tilburg/

RCE. (2016a). Overgangsrecht Monumentenwet 1988 naar Omgevingswet | Rijksdienst voor het Cultureel Erfgoed. Retrieved January 9, 2017, from http://cultureelerfgoed.nl/dossiers/erfgoedwet/overgangsrecht-monumentenwet-1988-naar-omgevingswet

RCE. (2016b, August 8). Gemeentelijke monumenten - (voorlopige) telling RCE. Retrieved February 21, 2017, from https://erfgoedmonitor.nl/indicatoren/gemeentelijke-monumenten-voorlopige-telling-rce

RCE. (2017a). Monumenten. Retrieved February 21, 2017, from https://cultureelerfgoed.nl/erfgoed/monumenten/monumenten

RCE. (2017b, September 2). Rijksbeschermde stads- en dorpsgezichten - regionale spreiding. Retrieved February 21, 2017, from https://erfgoedmonitor.nl/indicatoren/rijksbeschermde-stads-en-dorpsgezichten-regionale-spreiding

Rijksmonumenten.nl. (2015). kerkelijk gebouw in Tilburg | Monument - Rijksmonumenten.nl. Retrieved June 28, 2017, from http://rijksmonumenten.nl/monument/521194/kerkelijk-gebouw/tilburg/

Roos, J., & Frösch, M. I. (2007). *De ontdekking van de opgave: herontwikkeling in de praktijk.* VSSD.

Root B.V. (2017). 14013 advisering RVB B30. Retrieved June 27, 2017, from http://www.root-bv.nl/portfolio_page/b30/

Ruggles, D. F., & Silverman, H. (2009). From tangible to intangible heritage. In *Intangible heritage embodied* (pp. 1–14). Springer.

Rutten, P. (2017, March 28). Interview Peter Rutten.

Schrieken, B. J. (2000). *Geloof in transformatie - Een keuze- haalbaarheidsmodel voor de functie na de transformatie van kerken uit de wederopbouw* (M.Sc. thesis). Delft: Technische Universiteit Delft.

Schunselaar, T. (2009). Transformatie van beschermde monumenten.

Sebastian, R. (2017, June 3). Meeting with the project coordinator of the EU-funded research project P2Endure.

Silva, H., & Henriques, F. M. A. (2016). Hygrothermal analysis of historic buildings: Statistical meth-odologies and their applicability in temperate climates. *Structural Survey, 34*(1), 12–23. https://doi.org/10.1108/SS-07-2015-0030

Stephenson, J. (2008). The cultural values model: an integrated approach to values in landscapes. *Landscape and Urban Planning, 84*(2), 127–139.

Tomaszewski, A. (2003). Tangible and intangible values of cultural property in Western tradition and science.

Unknown. (2016, January 7). Den Haag | Gebouw B30. Retrieved January 5, 2017, from http://www.bouwenaanmonumenten.nl/den-haag-gebouw-b30/

van Beers, B. J. (2004). *Herbestemming industrieel erfgoed: Nieuw licht in Eindhoven.* Delft: Technische Universiteit Delft.

van Bommel, B. (2017, July 3). Interview with Bert van Bommel.

Van der Voordt, J. (2017). Meeting thinktank sustainable monument conservation.

Van der Voordt, T. (2007). *Transformatie van kantoorgebouwen: thema's, actoren, instrumenten en projecten.* Rotterdam: 010 Publishers.

Van Hal, A., & Dulski, B. (2011). Niet in dogma's denken: Duurzaamheidsambitie en monumentenzorg. *Building Business,(juni/juli)*, 2011.

van Krugten, L., van Krugten, L., Hermans, L., Hermans, L., Havinga, L., Havinga, L., … Schellen, H. (2016). Raising the energy performance of historical dwellings. *Management of Environmental Quality: An International Journal, 27(*6), 740–755.

van Limpt, C. (2010, February 4). Historisch zuinig, p. 1.

van Oorschot, J. A., Hofman, E., & Halman, J. I. (2016). Upscaling Large Scale Deep Renovation in the Dutch Residential Sector: A Case Study. *Energy Procedia, 96,* 386–403.

Vieveen, M. (2013). Energiek restaureren - Adaptive energy efficiency in historic buildings, (1), 106–119.

Visscher, H., Meijer, F., Majcen, D., & Itard, L. (2016). Improved governance for energy efficiency in housing. *Building Research & Information, 44*(5–6), 552–561.

Vocus. (2010). *Watertoren Bussum.* Retrieved from http://www.vocus.nl/project/herbestemming/watertoren-bussum.html

Vromen, J. (2012). Restaureren op Rijksadvies. PJH Cuypers en de restauratie van de Grote-of St. Michaëlskerk in Zwolle 1875-1898.

Wamelink, J. W. F., Wamelink, J., Geraedts, R., Hobma, F., Lousberg, L., & De Jong, P. (2009). *Inleiding bouwmanagement.* VSSD.
YALDIZ, E. (2010). Reuse of Monumental Buildings as a Sustainability Component (pp. 643–646). Pre-sented at the Central Europe Towards Sustainable Building Conference, CESB, Prague2010.

Yang, T., & Liao, L. (2016). Research on Building Information Model (BIM) Technology. *World Construction, 5*(1), 1–7.

w-dog.net. (2017). amsterdam venetian canal house construction town HD wallpaper. Retrieved June 28, 2017, from https://w-dog.net/wallpaper/amsterdam-venetian-canal-house-construction-town/id/224445/

Westergasfabriek BV. (2017). Westergasfabriek | Evenementen locaties Amsterdam. Retrieved June 28, 2017, from http://www.westergasfabriek.nl/organiseer/locaties/

Yastikli, N. (2007). Documentation of cultural heritage using digital photogrammetry and laser scanning. *Journal of Cultural Heritage, 8*(4), 423–427.

Yung, E. H., & Chan, E. H. (2012). Implementation challenges to the adaptive reuse of heritage build-ings: Towards the goals of sustainable, low carbon cities. *Habitat International, 36*(3), 352–361.

APPENDICES

9.1| GLOSSARY

Adjacent unheated spaces (AUS)
a transition space between the interior and exterior.

BIM
Building Information Modeling.

BIM model
a virtual model of a building, which is digitally constructed and contains precise geometry and relevant data.

Cultural sustainability
The alteration of a building with respect to the necessities of the present era without losing its identity and characteristics.

Energy conservation measures (ECM)
Measures that can improve the energy performance of a building.

Environmental sustainability
Energy efficient building performance which leads to low emission.

EUI
Energy Utilization Index (EUI = kWh/m2/yr).

Greencalc+
A calculation model, that calculates the thermal performance of buildings, based on key figures.

Historian
An expert who indicates the cultural values of a monument after an interior and exterior inspection.

Infrared Thermography (IRT)
A powerful tool to detect the external temperature of the building envelope and can detect thermal bridges and heat losses.

Intangible cultural values
Indirect and relational values of a monument that are the intangible remaining of the cultural and societal history.

Laser scanning
A technique whereby a laser scans the geometry of the building whereby the output of the scan is a digital 3D point-cloud, which can be transformed into a BIM model.

Monument
An historic building that is built in the past and considered important to conserve and keep in shape. Monuments are considered to be the tangible remaining of the cultural and societal history.

municipal monuments committee (MC)
This is an independent committee that advises the board of mayor and aldermen (Dutch: college van B&W) on the plans for the monument and indicates whether or not the environmental permit can be granted.

P2Endure
Research project with the aim of research to what extent BIM can support decisions on different energy renovation designs for existing buildings.

Tangible cultural values Values
Values that are represented by the building components of a monument that are the tangible remaining of the cultural and societal history.

Tolerance for change/Touch ability
The adaptability of the monument, which determines to what extent amendments can be applied.

U-value
Heat transfer coefficient.

Workset
A workset consists of a collection of components a part of a BIM model.

Figure 74: Westergasfabriek surroundings Source: DuurzameStudent

9.2| P2ENDURE CONCEPT

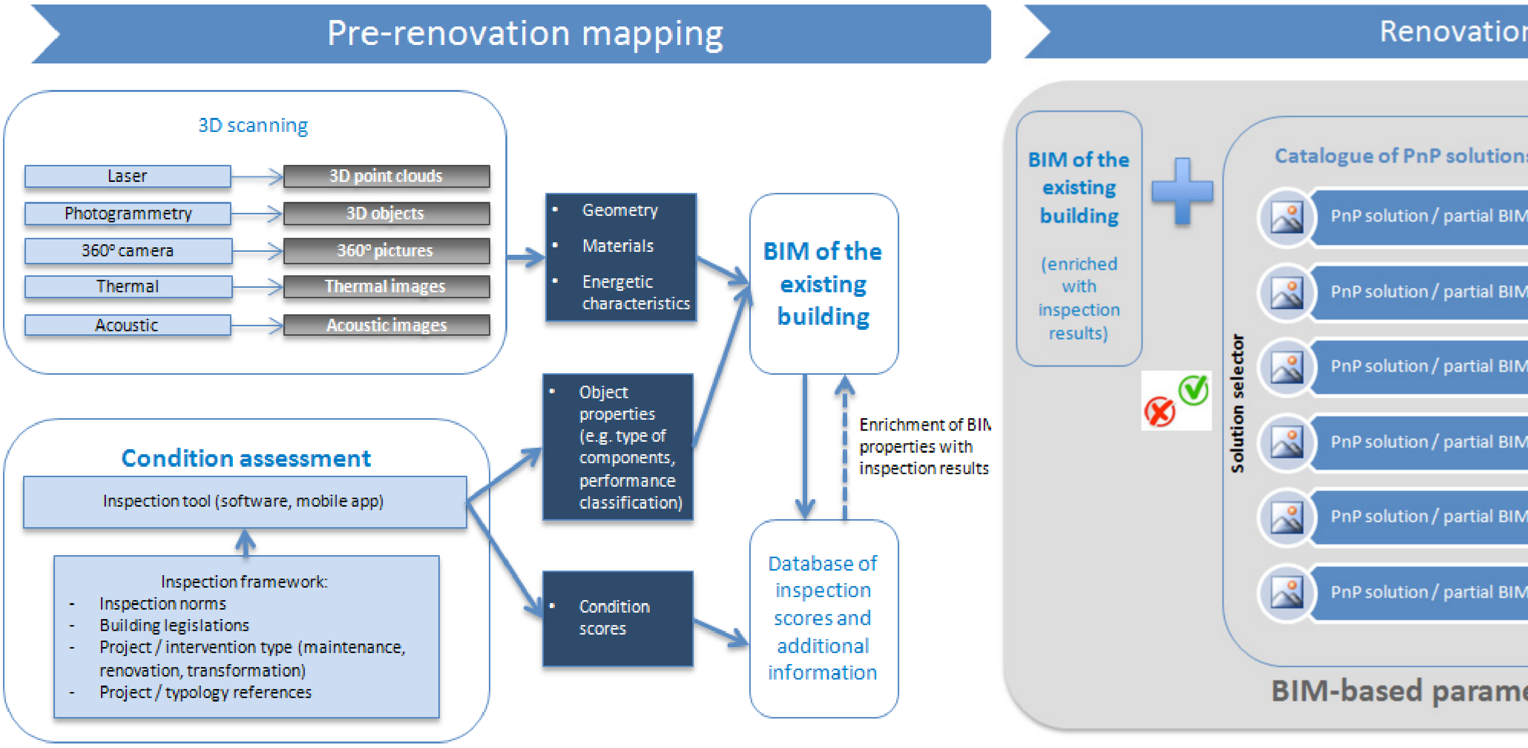
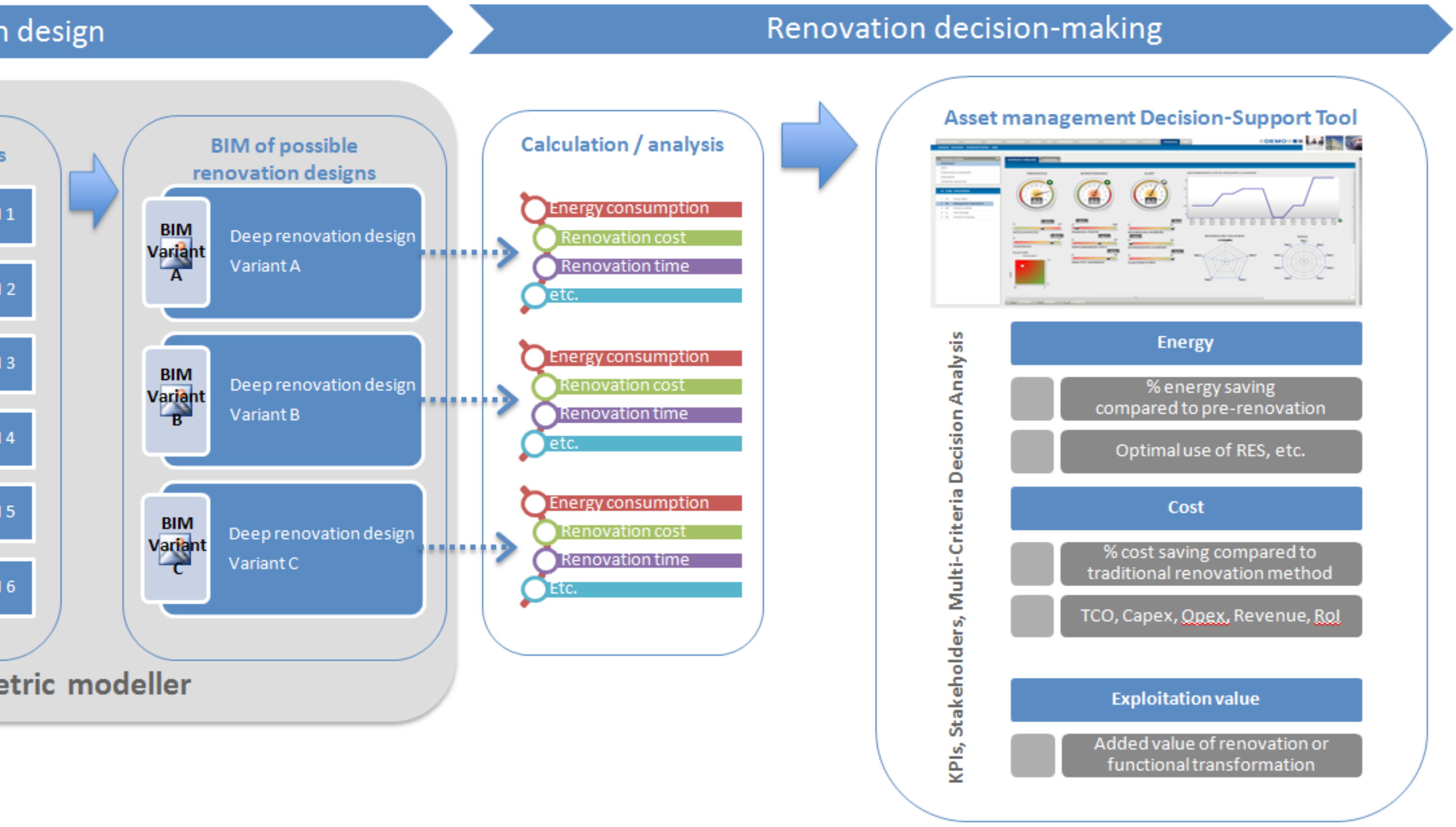


Figure 75: The concpetual model of the P2Endure project (Sebastian, 2017).


n design
Renovation decision-making
BIM of possible
renovation designs
BIM
Variant
A
Deep renovation design
Variant A
BIM
Variant
B
Deep renovation design
Variant B
BIM
Variant
C
Deep renovation design
Variant C
etric modeller
Calculation / analysis
Energy consumption
Renovation cost
Renovation time
etc.
Energy consumption
Renovation cost
Renovation time
etc.
Energy consumption
Renovation cost
Renovation time
Etc.
Asset management Decision-Support Tool
KPIs, Stakeholders, Multi-Criteria Decision Analysis
Energy
% energy saving
compared to pre-renovation
Optimal use of RES, etc.
Cost
% cost saving compared to
traditional renovation method
TCO, Capex, Opex, Revenue, RoI
Exploitation value
Added value of renovation or
functional transformation

9.3| GREENCALC+ CASE 1

The outcomes of the calculations on the thermal performance of the renovation design options in the case of Paushuize, are visualized in figure 76-79. The calculations are performed with the Greencalc+ method. The values are expressed in environmental costs instead of kWh or CO_2. The environmental costs integrates the needed amount of energy to produce and install the measure (NIBE, 2009).

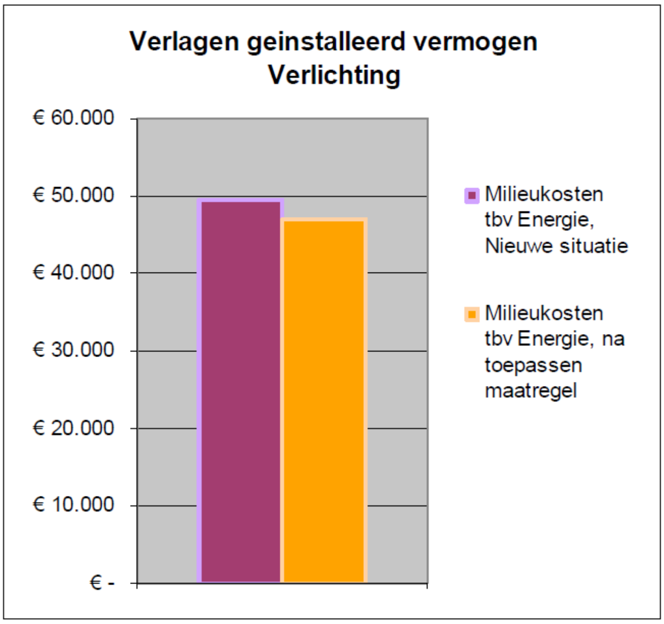


Figure 76: Design option: Led lights (Source: NIBE, 2008)

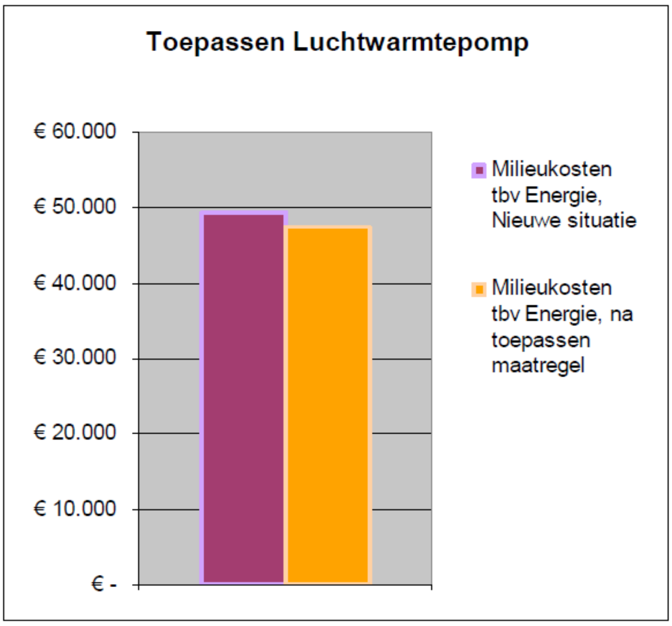


Figure 77: Design option: heat pump (Source: NIBE, 2008)

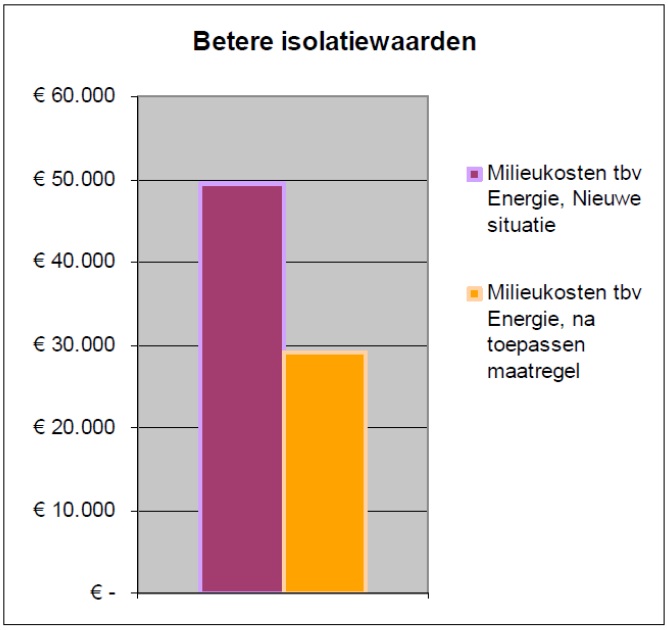


Figure 78: Design option: insulation (Source: NIBE, 2008)

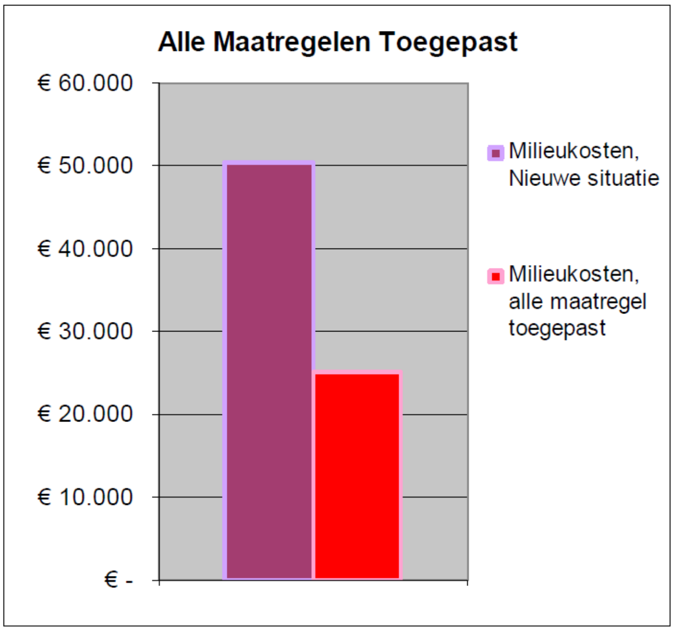


Figure 79: Every design option (Source: NIBE, 2008)

9.4| GREENCALC+ CASE 2

The outcomes of the calculations on the thermal performance of the renovation design options in the case of Zuiveringshal West, are visualized in figure 80. The calculations are performed with the Greencalc+ method. The values are expressed in the amount of CO2 emission. The red color reflects the value for the use of electricity and the blue value reflects the value for the use of gas (NIBE, 2013).

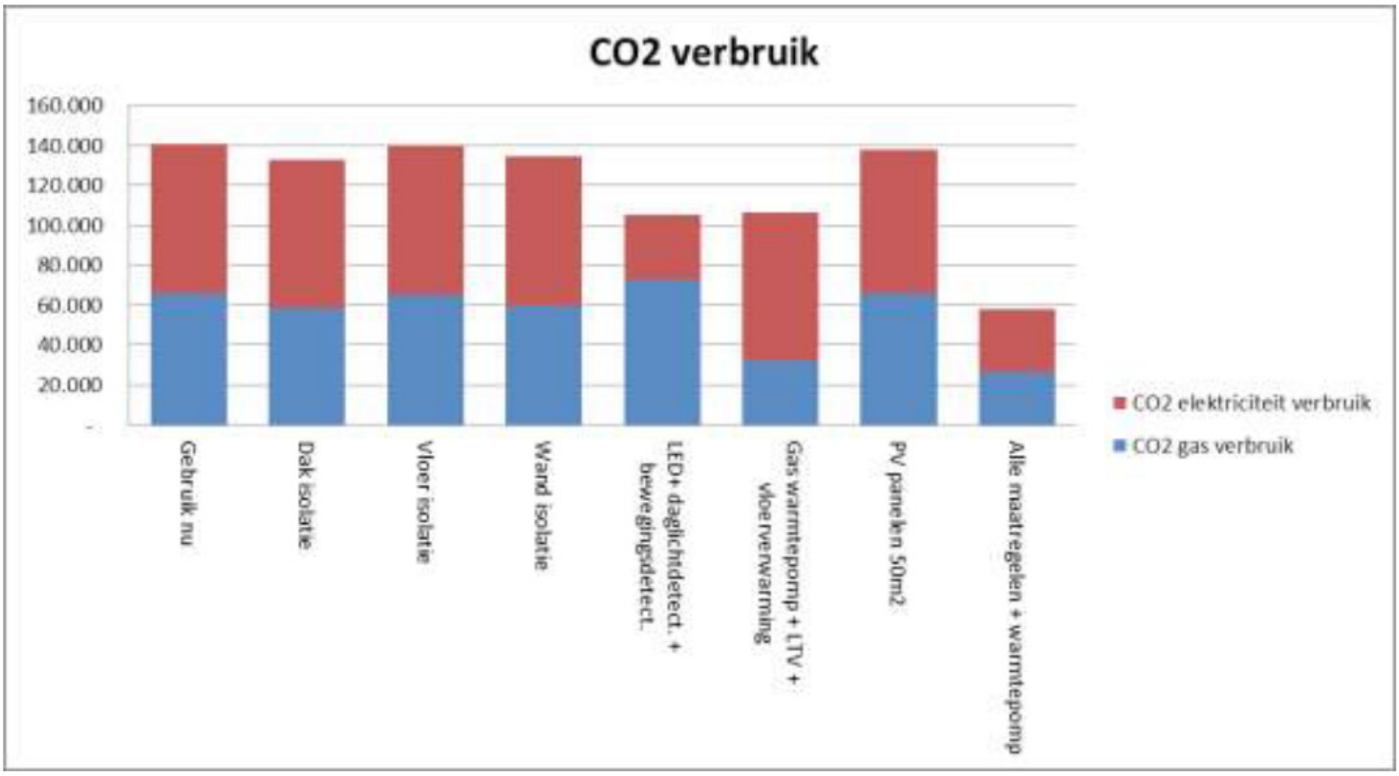


Figure 80: Comparison design options (Source: NIBE, 2009)

9.5| CULTURAL VALUES IN BIM

The following step-by-step plan shows the steps that are taken to implement cultural values (the classes and corresponding description) in BIM by using Autodesk Revit software. In this example, the cultural values are implemented in the wall components of the BIM model. The steps are visualized in the corresponding figures (81-84).

1: By selecting a wall, the user of the model can read its properties in the **properties dialog** (Fig. 82). This is the location where it is desired to show the information about the monumentality of the component.

2: In order to insert information in the properties dialog, go to **Schedules/quantities** in the project browser and right-click -> **New schedule/quantities** (Fig. 83).

3: In the new schedule dialog, select **walls** and **phase: existing.** (Note: check in which phase the wall is created).

4: In the schedule properties dialog, select the fields that are of importance for your project. It is not possible to select 'monumentality' from the available fields list. Therefore, click on the **new parameter** icon.

5: In the parameter properties window, select **project parameter** as type, name it: **monumentality,** select **instance, common, integer, other -> OK.**

6: Add another parameter and call it **Mon_Descr** (Monumentality Description). Select **instance, common, text, other, values can vary by group instance -> OK.**

7: In the wall schedule it is now possible to insert the monumentality class of each component and the corresponding description in column L & M. (Note: Because it was not possible to insert classes, integer is chosen. This means the following: Class A = 1, Class B = 2, Class C = 3, Class D = 4, Class E = 5) (Fig. 84).

8: Run a test and select a wall. The information about its monumentality is now displayed in the properties dialog.

These steps can be repeated in the same way for other kinds of elements like windows, floors etc.

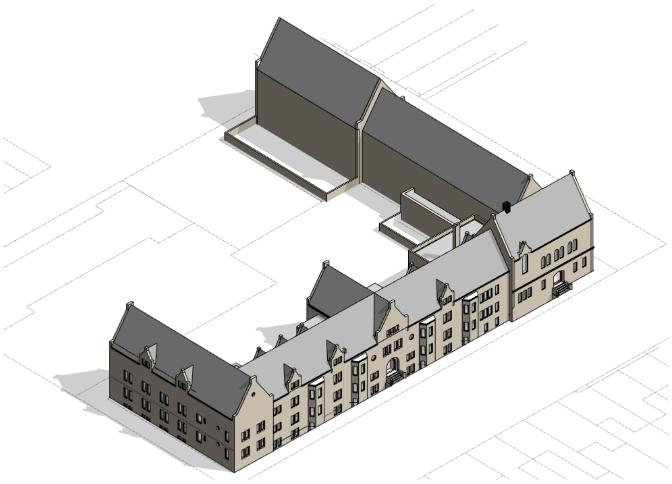


Figure 81: BIM model of the test case (own illustration)

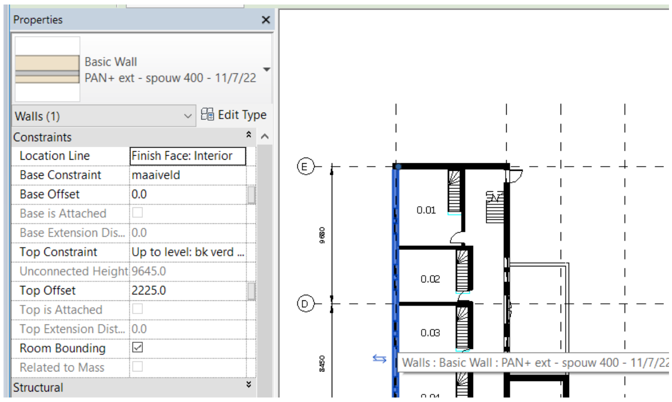


Figure 82: Properties of the wall (step 1) (own illustration)

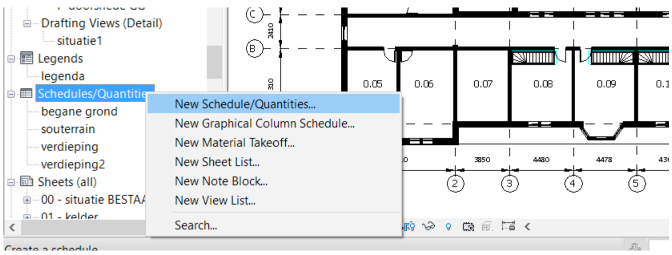


Figure 83: New schedules/quantities (step 2) (own illustration)

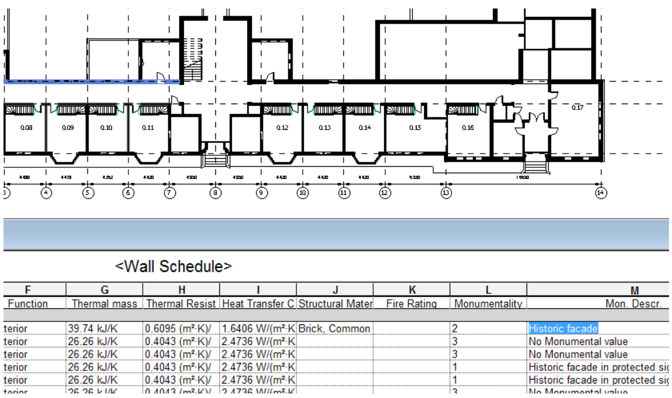


Figure 84: Monumentality and Description added (own illustration)

9.6|VISUALIZING C.VALUES

The following step-by-step plan shows the steps that are taken to visualize the cultural value classes that are assigned to building components with colors. In this way, an overview can be created in 3D and 2D. The 'Color schemes' tool in Revit is only applicable for rooms, areas, spaces and zones, pipes and ducts (Autodesk Inc, 2017). In order to visualize information with colors of other components like walls and windows, it is necessary to install the plug-in: 'Color Splash', created by BIM One. Consequently, the following steps need to be taken in order to visualize the information that is attached to the building components about is monumentality in the 3D model with colors.

1: install the Color Splasher for Autodesk Revit.

2: Click on Color Splasher in the BIM One tab.

3: Select **walls as category, monumentality as parameter** (this is the parameter that is created in the previous step-by-step plan), assign proper colors to each value an click -> **Apply color set.**

4: The walls will get the color that corresponds with the assigned monumentality class.

These steps can be repeated in the same way for other kinds of elements like windows, floors etc.

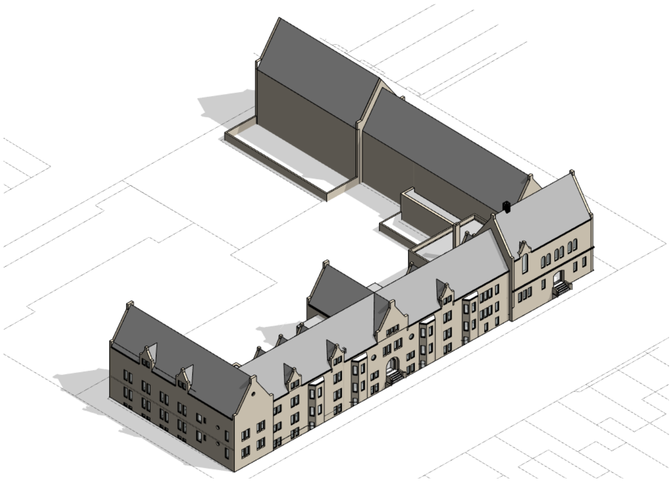


Figure 86: BIM model of the test case (own illustration)

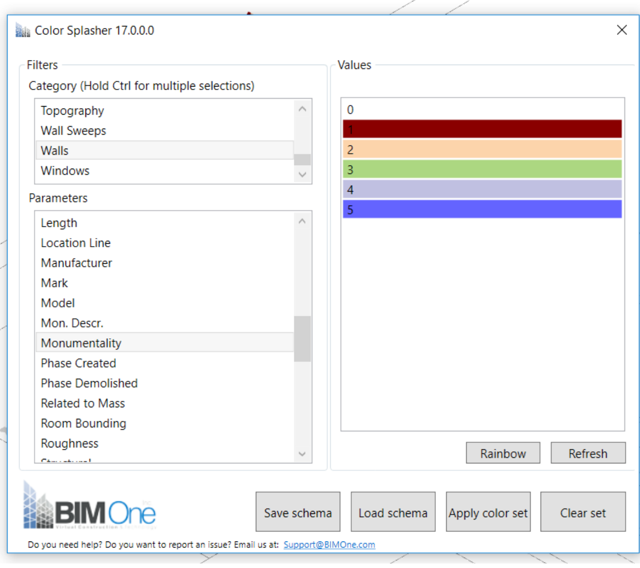


Figure 87: Color scheme assigned to cultural values (own illustration)

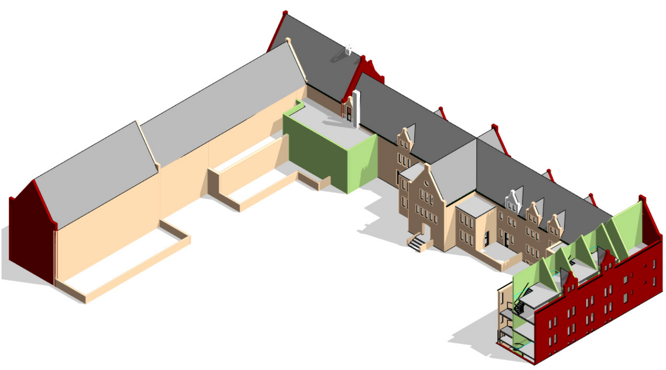


Figure 85: Cultural value class of walls in color 1 (own illustration)

Figure 88: Cultural value class of walls visualized in color 2 (own ill.)

9.7| FILTERING, DESIGN SUPPORT

The following step-by-step plan shows the steps that are taken to perform an analysis with the information that is inserted in the model. Since the information about the cultural values and thermal performance is integrated in the BIM model, building components that are suitable for change can be filtered. These components are suitable due to low cultural value and for example a high U-value. The following example consists of an analysis, whereby walls that are suitable for change are filtered.

1: Open the **wall schedule**.

2: Click **edit Filter** in the schedule properties dialog.

3: Filter by **monumentality is greater than or equal to 3** and **Heat Transfer Coefficient (U) is greater than 2.4545.** -> OK.

4: The result is a wall schedule with all the elements that have the filtered properties.

5: These elements are highlighted in the floor plans and also in the 3D model.

These steps can be repeated in the same way for analyses with different parameters.

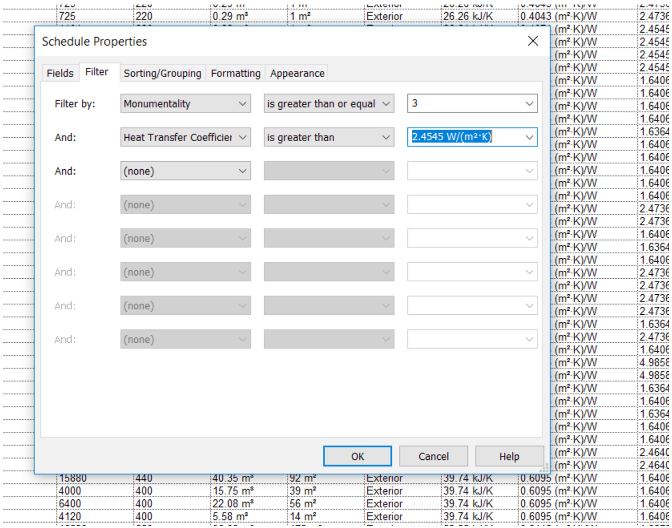


Figure 89: Filtering of information (own illustration)

<Wall Schedule>

	B	C	D	E	F	G	H	
Code	Length	Width	Volume	Area	Function	Thermal mass	Thermal Resistance (R)	Heat Transfe
	5305	220	3.32 m³	15 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	23025	220	12.33 m³	56 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5305	220	3.32 m³	15 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5305	220	3.60 m³	16 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	7830	220	4.93 m³	22 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5300	220	3.32 m³	15 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5300	220	3.32 m³	15 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5300	220	3.47 m³	16 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	12510	220	6.27 m³	29 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	1220	110	0.33 m³	3 m²	Exterior	12.95 kJ/K	0.2006 (m²·K)/W	4.9858 W/(m²
	1220	110	0.33 m³	3 m²	Exterior	12.95 kJ/K	0.2006 (m²·K)/W	4.9858 W/(m²
	1560	220	0.19 m³	1 m²	Exterior	26.44 kJ/K	0.4058 (m²·K)/W	2.4640 W/(m²
	70650	220	33.48 m³	152 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	8048	220	4.30 m³	20 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	7810	220	4.25 m³	19 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5300	220	3.51 m³	16 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	12510	220	6.89 m³	31 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5300	220	2.90 m³	13 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5300	220	3.36 m³	15 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	7810	220	3.48 m³	16 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5710	220	3.25 m³	15 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	16700	220	7.48 m³	34 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5300	220	2.88 m³	13 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	5710	220	2.66 m³	12 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	700	220	0.37 m³	2 m²	Exterior	26.44 kJ/K	0.4058 (m²·K)/W	2.4640 W/(m²
	700	220	0.37 m³	2 m²	Exterior	26.44 kJ/K	0.4058 (m²·K)/W	2.4640 W/(m²
	700	220	0.37 m³	2 m²	Exterior	26.44 kJ/K	0.4058 (m²·K)/W	2.4640 W/(m²
	700	220	0.37 m³	2 m²	Exterior	26.44 kJ/K	0.4058 (m²·K)/W	2.4640 W/(m²
	5710	220	3.21 m³	15 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²
	7810	220	3.95 m³	18 m²	Exterior	26.26 kJ/K	0.4043 (m²·K)/W	2.4736 W/(m²

Figure 90: Filtered walls Monumental = 3 & U > 2.45 (own ill.)

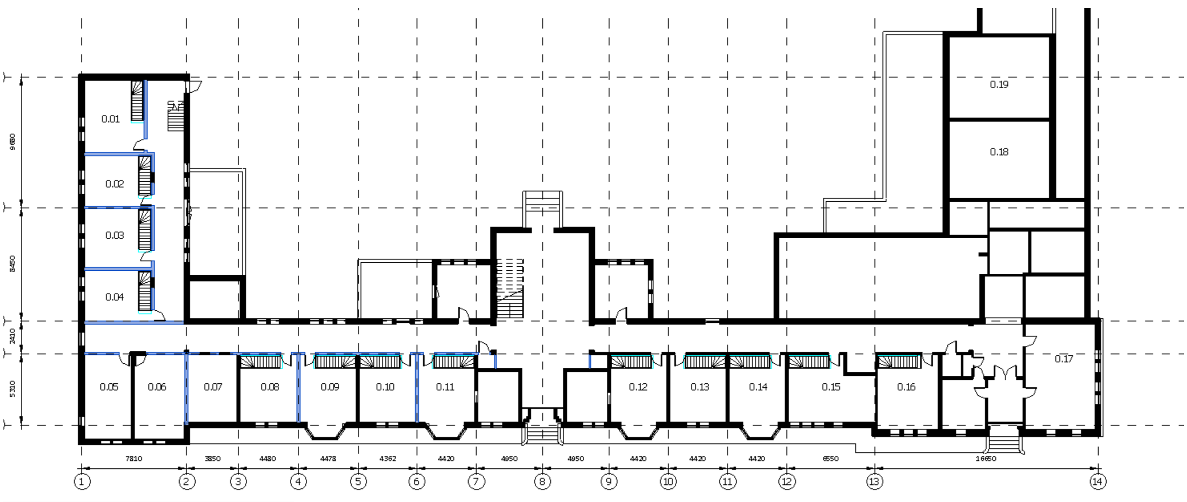


Figure 91: Filtered walls Monumental = 3 & U > 2.45 visualized in floor plan(own ill.)

9.8| WORKSETS

The following step-by-step plan shows the steps that are taken to test whether the stakeholders could be managed in the BIM environment in order to safeguard the cultural values. Fictional user names are created in order to simulate a collaboration between multiple stakeholders.

1: Click **collaborate** and **save** the model. Navigate to **worksets** in the collaborate tab.

2: The workset dialog box opens and **create a new workset** and type in **High Monumental –> OK**. Repeat this step for the other monumental classes.

3: Select the components that need to be inserted in the workset. In this example it is demonstrated for the walls. Go to wall schedule, **filter on monumentality equals 1**.

4: When all the walls with value 1 are selected, go to the **properties dialog** and **select workset high monumental.**

5: Select the workset in the active workset selector where it is desired to make changes.

6: In order to receive an overview which elements are included in that workset, select ‘**grey inactive worksets**’.

7: **Manage ownership of the worksets**, in this case, the project manager (jwolswinkel) is responsible for the preservations of the building components with monumental value 1. Therefore, jwolswinkel is the owner and nobody else can make changes. Objects with value 2 and 3 are owned by ‘specialist 1’ who controls the changes over these components. Objects with values 4 and 5 are owned by nobody and can therefore be changed by every user.

8: In order to test if this really works, specialist 1 tries to change a wall with a monumental value 1. A warning appears and specialist 1 can only send a request to jwolswinkel and this stakeholder can grant permission

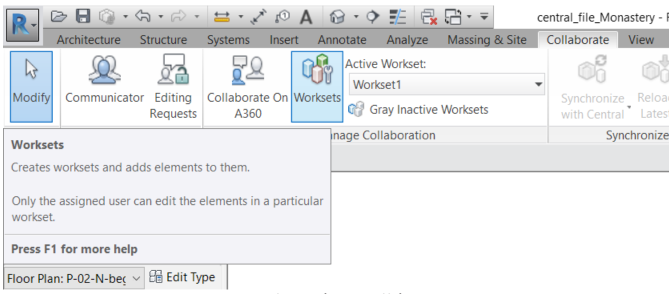


Figure 92: Create a new workset (own ill.)

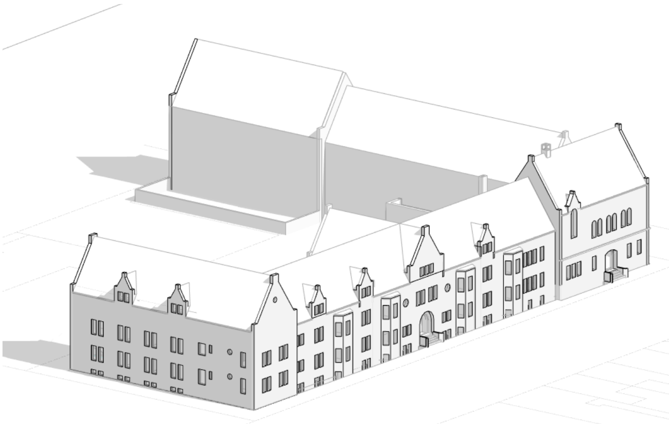


Figure 93: Components not in workset turn grey (own ill.)

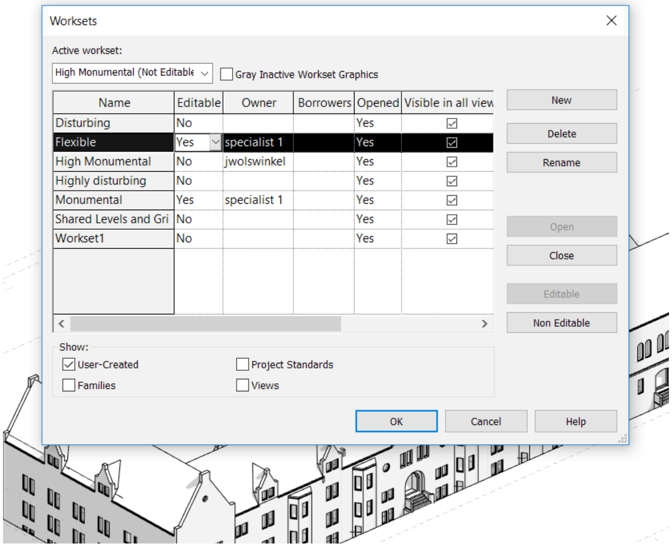


Figure 94: Divide responsibilites of stakeholders (own ill.)

Figure 95: Not possible to amend the wall, due to the CV (own ill.)