Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Franziska Mack
Student number	5366305

Studio		
Name / Theme	Building Technology graduation Energy & Climate	
Main mentor	Dr. Eric van den Ham	AE+T Climate design
Second mentor	Dr. Nicholas Clarke	AE+T Heritage & Architecture
Argumentation of choice of the studio	Related to the author's interest in the field of building renovation and the question how we can preserve buildings and their cultural-historical values while adapting their building performance to today's requirements concerning energy efficiency and indoor environmental quality.	

Graduation project	
Title graduation project	Providing comfort for multifunctional use in monumental church buildings in the Netherlands
Goal	
Location	The Stevenskerk in Nijmegen, The Netherlands
The posed problem,	The large interior of the Stevenskerk is covered with high vaults, resulting in an impressive indoor space and a volume of approximately 34.000m^3 (Nusselder & Zandijk, 2015). During the winter period, the immense heating load, cold bridges and air leakages of the building skin together with an ineffective heating system make it difficult to heat the Stevenskerk to a comfortable temperature (OOM Advies, 2018). In order to reach a comfortable temperature level inside the Stevenskerk, a higher heating temperature is necessary which would, however result in a harmful environment for the monumental inventory such as the organ. Additionally, the not insulated enclosing building components such as the windows or the vaults radiate their cold surface temperature increasing the thermal discomfort for the users. To conclude, the large heating demand and the insufficient energy performance of the building skin in the multi-functional Stevenskerk leads to closing the church during the winter period because the thermal conditions do not correspond with the requirements for the usability of the space

research questions and	The main research question: How can the renovation of the stained glass windows and indoor space adaptations improve the thermal comfort for the occupants in the multi-functional Stevenskerk all year around while incorporating the preservation of heritage values, proportionate financial investment, sustainability, usability and the indoor environmental quality? Sub-questions: *Heritage:* What are the monumental values in the Stevenskerk and what are their conservation requirements? *Thermal comfort:* How can the thermal indoor comfort in the Stevenskerk be assessed and measured? What are the thermal comfort requirements and how can they be combined with the heritage preservation requirements? *Strategy 1: Stained glass renovation* Which renovation methods for stained glass are already existent and how can their performance be assessed? How can the renovation of stained glass improve the thermal comfort in the Stevenskerk and in other multi-functional church buildings? *Strategy 2: Indoor space adaptations* What are possible indoor space adaptations with the potential to improve the thermal comfort in a multi-functional church building? What are the requirements for the spatial adaptations in the Stevenskerk regarding the monumental values and the utilization of the church?
design assignment in which these result.	The main objective of this research is the identification of suitable measures for the improvement of the thermal comfort for occupants in the Stevenskerk. First, this research will investigate how the renovation of the stained glass windows can help to achieve this goal as this strategy has already been identified as an effective measure to decrease the energy demand in the Stevenskerk (Schoch & van der Zanden, 2019). Second, the strategy of indoor space adaptations which was part of other church transformations with the aim to improve their usability (Parcum, n.d.) will be examined. Thereby, this thesis should support the Stevenskerk foundation in determining appropriate renovation methods. As similar challenges regarding the thermal comfort appear in other multifunctional church buildings in the Netherlands, the aim is to identify measures that could also be suitable in other cases.

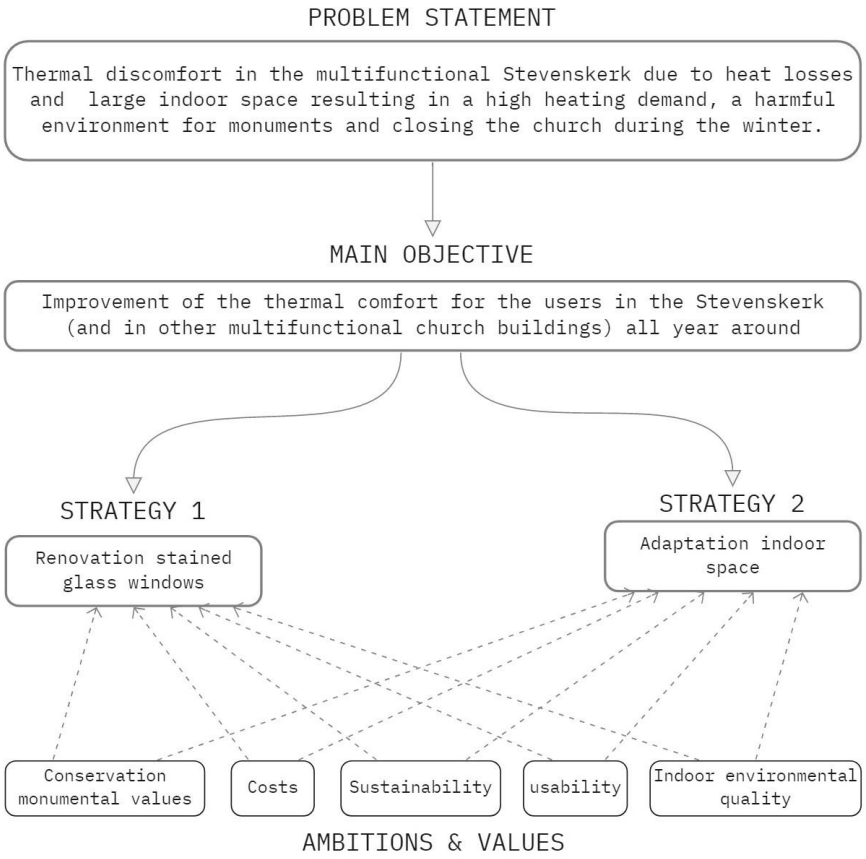

Figure 1: Graduation topic structure: problem statement - main objective - strategies - ambitions

Process

Method description

For illustration see figure on the next page

First literature study
A first visit to the Stevenskerk helped to gain insight in the local conditions, its monumental values and the challenges the foundation is dealing with. Afterwards, the thermal comfort was identified as the focus for this research. The first literature review helped to get an overview of existing research while gaining knowledge about the subject and to define the main research question, the main objective and the ambitions. The literature review included existing research about the Stevenskerk that had been conducted regarding the energetic renovation and the heating system. Afterwards, the stained glass renovation and spatial adaptations were chosen as strategies with potential to deal with the thermal challenges in the Stevenskerk. The renovation of the windows had been identified as an effective measure to decrease the energy demand in the Stevenskerk (Schoch & van der Zanden, 2019) whereas indoor space adaptations were part of other church transformations with the aim to improve their usability (Parcum, n.d.). For researching both of these strategies a different research methodology was developed.

Methodology strategy 01 - Stained glass
Firstly, literature review about the renovation of stained glass windows was conducted to gain an overview about existing techniques and their advantages and disadvantages. Furthermore, the analysis of the stained glass windows in the Stevenskerk and their performance is important to identify challenges, restrictions and potentials. For this, photographs with a thermal infrared camera were taken. After identifying protective glazing as a measure with potential for improving the thermal performance of stained glass, a physical calculation model is set up for examining this system mathematically. In order to check if the calculation model indicates a realistic physical behaviour it needs to be validated with the actual conditions in the Stevenskerk. Therefore, in-situ measurements at the windows of the Stevenskerk with sensors available at the climate design department of the TU Delft will collect data about the windows' performance. This data will be analysed and help to improve the physical calculation model for protective glazing on stained glass windows.
Furthermore, other renovation measures for stained glass will be investigated and compared according to their suitability for the Stevenskerk. Subsequently, computational simulations of the indoor space of the Stevenskerk, such as one of the side chapels, will help to understand and visualize the influence of selected window renovation methods on the thermal indoor climate for the user. Finally, the findings and collected data will help to assess different strategies for stained glass window renovation with regards to the improvement of the indoor thermal comfort and other research ambitions.

Methodology strategy 02 – Spatial adaptation
In order to identify concepts for spatial adaptations that could be suitable for the requirements in the Stevenskerk, literature and case study projects will be reviewed. Then, concepts appropriate for the achievement of the research objective are selected and organized according to the type of resulting indoor space.
A few selected concepts showing potential will serve as the basis for creating designs for the indoor space of the Stevenskerk. In order to assess and test the influence of the different designs on the thermal indoor comfort of users in the Stevenskerk, a computer simulation will be set up. This will generate data which will be analysed and help to compare the different concepts.

Final result
Finally, the conclusions from both research paths will lead to recommendations for renovation and adaptation strategies in the Stevenskerk to improve the thermal comfort. The final product should support the foundation Stevenskerk in the decision making process and illustrate a broad overview for strategies with potential to improve the thermal comfort.

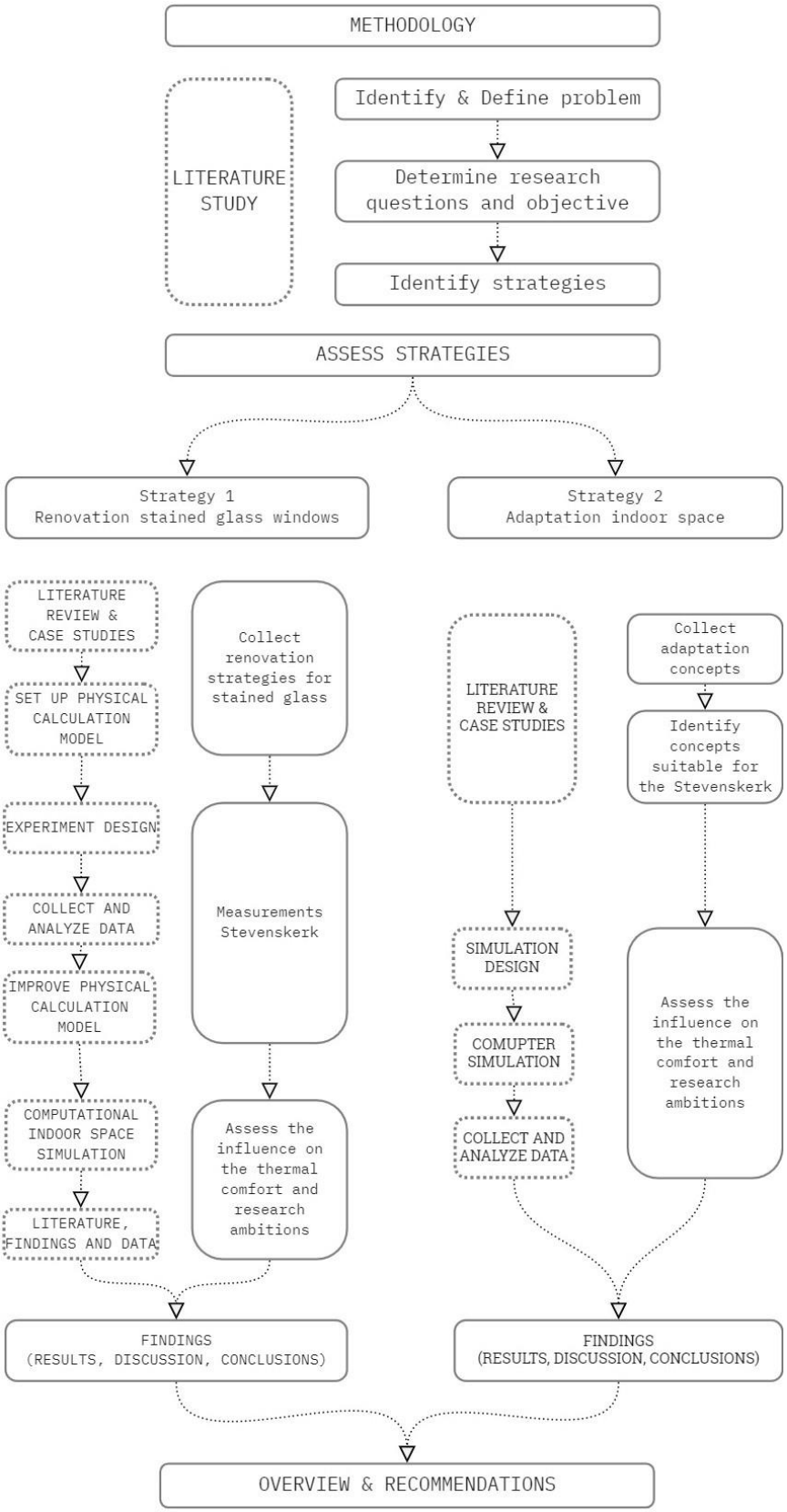

Figure 2: Diagram methodology

Literature

Aarle, M. v. (01.01.2007). Een hypocaust hetelucht vloerverwarmingssysteem, stevenskerk te nijmegen. (Thesis).

Ankersmit, B., & Stappers, M. H. L. (2009). Managing indoor climate risks in museums [Book]. Springer International Publishing Switzerland. doi: 10.1007/978-3-319-34241-2

Bluyssen, P., Bayon, R., & Hamilton, K. (2009). The indoor environment handbook how to make buildings healthy and comfortable [Book]. London, New York: earthscan.

Brand, S. (1994). How buildings learn: What happens after they're built [Book]. London: Penguin Books.

Camuffo, D. (2010). The friendly heating project and the conservation of the cultural heritage preserved in churches [Conference Paper]. Retrieved from https://www.researchgate.net/publication/264352471_The_friendly_heating_Project_and_the_conservation_of_the_cultural_heritage_preserved_in_churches

CBS. (2018). Over half of the dutch population are not religious (Vol. 2022) (Web Page No. 09/01). Retrieved from https://www.cbs.nl/en-gb/news/2018/43/over-half-of-the-dutch-population-are-not-religious

Engelshoven, V. (2019). Uitreiking pieter van vollenhovenprijs [Youtube video]. Nationaal Restauratiefonds. Retrieved from https://www.youtube.com/watch?v=HqjZQqMFWr0

European Comission. (2013). Energy use in buildings [Web Page]. European Comission. Retrieved from https://ec.europa.eu/energy/eu-buildings-factsheets-topics-tree/energy-use-buildings_en

Gantner, V., Hartmann, D. R., Kraemer, D. S., & Mager, D. T. (201). Kirchengebäude und ihre Zukunft Sanierung, Umbau, Umnutzung [Book]. Ludwigsburg: Wüstenrot Stiftung.

Global Alliance for Buildings and Construction. (2020). 2020 global status report for buildings and construction (Report).

Itard, P. d. L. C. M., & Bluyssen, P. d. i. P. M. (2004). Fundamental aspects of thermal comfort (Report).

Kuipers, M., & de Jonge, W. (2017). Designing from heritage strategies for conservation and conversion [Book]. TU Delft - Heritage and Architecture. Retrieved from https://books.bk.tudelft.nl/press/catalog/view/isbn.9789461868022/529/170-1

Lubelli, B., Pottgiesser, U., Quist, W., & Rexroth, S. (2021). Dealing with heritage assessment and conservation [Book]. TU Delft - Heritage and Architecture.

Netsch, S. (2018). Strategie und praxis der umnutzung von kirchengebÄuden in den niederlanden (Thesis). doi: 10.5445/KSP/1000085540

Nicol, J. F., & Humphreys, M. (2002). Adaptive thermal comfort and sustainable thermal standards for buildings [Journal Article]. Energy and Buildings (34), 563-572. Retrieved From https://www-sciencedirect-com.tudelft.idm.oclc.org/science/article/pii/S0378778802000063

Normcommissie 342346. (2010). Nen-en 15757 (en) conservation of cultural property – specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials [Standard]. Retrieved from https://connect.nen.nl/Search/Detail?collectionId=0&compId=10037&colAdmin=false&pState=2

Nusselder, E., & Zandijk, C. (2015). Gebouw-analyse en advies scenario's duurzame monumentenzorg (dumo) (Report).

Oidtmann, S. J. C. (1994). Die Schutzverglasung eine wirksame Schutzmassnahme gegen die Korrosion an wertvollen Glasmalereien (Thesis). doi: 10.6100/IR427994

OOM Advies, P. N.-H. (2018). Handleiding energie besparen voor kerken in noord-holland (Report).

Parcum. (n.d.). Database of repurposing churches [Web Page]. Retrieved from https://www.parcum.be/nl/herbestemming-kerken

RCE, Rijksdienst voor het Cultureel Erfgoed. (n.d.). De nationale kerkenaanpak [Web Page]. Retrieved from https://www.cultureelerfgoed.nl/onderwerpen/religieus-erfgoed/de-nationale-kerkenaanpak

RCE, Rijksdienst voor het Cultureel Erfgoed. (1973). Rijksmonumentomschrijving [Legal Rule or Regulation]. Retrieved from https://monumentenregister.cultureelerfgoed.nl/monumenten/31181

RCE, Rijksdienst voor het Cultureel Erfgoed. (2021). Sublieme schoonheid sublieme duurzaamheid ideeën voor een duurzame toekomst van iconische kerkgebouwen (Report).

Schellen, H. L. (2002). Heating monumental churches indoor climate and preservation of cultural heritage (Thesis). doi: 10.6100/IR561673

Schoch, H., & van der Zanden, H. (2019). Energievisie Stevenskerk te Nijmegen (Report).

Vis, J. (2020). De groene grachten anamnese stevenskerk (Report).

Wolf, S., Trümpler, S., Wakili, K. G., Binder, B., & Baumann, E. (2013). Protective glazing: The conflict between energy-saving and conservation requirements [Conference Paper]. Retrieved from https://www.researchgate.net/publication/259590262_Protective_glazing_The_conflict_between_energy-saving_and_conservation_requirements

Reflection

What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

The graduation topic combines the building physical challenge of improving the thermal comfort on the one side with the architectural design challenge of preserving heritage values on the other side. The thesis is related to several elements of the Building Technology Master such as climate design, façade design, research and innovation etc.

What is the relevance of your graduation work in the larger social, professional and scientific framework?

Social relevance
Although the preservation of monumental buildings such as the Stevenskerk is protected by law as they contain cultural-historical values which are relevant for future generations, the usability and the accessibility are crucial arguments for the existence of a building. *«Investing in a monument that does not have a function is useless since the monument will deteriorate anyhow. Additionally, monuments should keep their central place and function in society»* (former minister of Education, Culture and Science van Engelshoven, 2019). Enabling the accessibility of the Stevenskerk all year around is one central aspect in developing a sustainable future perspective for the building in which it can take its social responsibility in the use of the space for the community.

Scientific relevance
Stained glass windows
The literature research on stained glass renovation has shown that there is few scientific research available about the physical performance of second glazing on the preservation of the stained glass and the thermal performance of the glazing. Besides, those documents focus on specific types of protective glazing while there is no broad overview of renovation methods and their advantages and disadvantages available. Furthermore, there is a lack in scientific literature about the impact of stained glass window insulation on the thermal indoor comfort.

Sustainable transformation of monumental buildings
Referring to the responsibility of the transformation of the existing built environment for the fight against the climate crisis, this thesis provides and compares ideas how to improve the energy performance of a monumental building while enabling usability and preservation of its heritage values. The proposed interventions for the Stevenskerk are an example for the sustainable transformation of the built environment in a challenging case. The results of this thesis may not only be relevant for the foundation Stevenskerk, but also for the owners of other multi-functional churches aiming for a sustainable improvement of their building's climate performance.

Professional relevance
Finally, there is not sufficient research available for the foundation Stevenskerk to decide on which measures to implement on this specific building with its specific requirements. *« Heritage buildings are always an intrinsic part of the built environment and apart from the influences of weather and changing tastes of occupants also subject to various usage requirements and building codes. Due to this physical reality, a heritage building cannot be treated exactly like other heritage objects. »* (Kuipers & de Jonge, 2017).

Time planning after the P2 presentation

TASKS ORGANIZED ACCORDING TO 4 MAIN TOPICS										
MONTH	WEEK	Ps	LITERATURE RESEARCH / PRESENTATIONS / DEFINITIONS	EST. TIME	STRATEGY 01 RENOVATION STAINED GLASS	EST. TIME	STRATEGY 02 SPATIAL ADAPTATIONS	EST. TIME	COMPUTER SIMULATIONS	EST. TIME
after the P2										
February	week 1		Include feedback from the P2 presentation	2 days	**Physical measurements Stevenskerk** Placement of the loggers and punctual airflow measurements **Physical calculation model for PG** Improve detail of the model	3 days				
	week 2				**Further research on other renovation methods for the windows**	3 days	**Case studies** Further investigation on case-studies about adaptations in church renovations or conversions	2 days		
	week 3		**Evaluation methods for the research ambitions** Define them more in detail; Evaluate one renovation method as an example to define the steps and the visual presentation of the evaluation result (Matrix?)	3 days	**Window renovation** Select most promising methods how could these be applied to the Stevenskerk? How can the influence of these methods on the indoor thermal comfort be assessed?	2 days				
	week 4		Organize the new information and content for the final report	2 days			**Case studies** Finish investigation and report on case-studies about adaptations in church renovations or conversions; **Develop conceptual design ideas for the Stevenskerk**	1 days 2 days		
March	week 1								**Inform about computer programs for thermal simulations** Select programme depending on licence availability, type of simulation etc., Start watching tutorials etc.	5 days
	week 2						**Further development design ideas for indoor spatial adaptations** (approximately 3 different concepts); Generate simple plans, illustrations and explanatory sketches, possbily build a simple model for first simulation exercise?	3 days	Watch tutorials and make exercise simulation; How can the different strategies (window renovation and spatial adaptation) be simulated?	2 days
	week 3		Start writing the reflection Prepare P3 presentation	2 days	**Physical measurements Stevenskerk:** Remove loggers, collect, sort and analyze data from the sensors	3 days				
	week 4	P3	Finish P3 documents & presentation *P3: Hand in draft reflection to main mentor, present graduation plan, project and reflection* Organize the new information and content for the final report	1 day 2 days 2 days						
April	week 1		Include feedback from the P3 presentation	3 days	Evaluation of the PG types; adaptation of the physical calculation model according to the data from the physical measurements	2 days				
	week 2				Evalutate renovation methodologies according to objectives & ambitions; create explanatory illustrations etc. Create an evaluation overview	3 days			**Perform first simulations for window renovation measures:** probably the simulation will be done for one of the side chapels	2 days
	week 3		Write the P4 report	1 day			Evalutate indoor spatial adaptation methods according to objectives & ambitions; create explanatory illustrations etc.	2 days	**Perform first simulations for indoor space adaptation methods** those simulations should be done for the large church indoor space, which will be simplified in the model	2 days
	week 4		Write the P4 report Including new info & content	2 days			Create an evaluation overview	1 day	Simulations	2 days
May	week 1		Write the P4 report	2 days					Simulations	3 days
	week 2		Write the P4 report and the reflection, Work on P4 presentation *Send P4 products and the final reflection to mentors and delegate of the Board of Examiners: at least 1 week for P4 date, Upload P4 report on Brightspace plagiarism scan at latest one week before P4.*	5 days						
	week 3	P4	Finish P4 presentation *P4: Present research result / graduation project and reflection using digital presentation and drawings*	3 days					Simulations	2 days
	week 4		Include feedback from the P4 presentation	3 days	Illustrations	1 day	Illustrations	1 day		
June	week 1		Finish the Final report	3 days					Create illustrations	2 days
	week 2		Create and rehearse the P5 presentation	5 days						
	week 3	P5								
	week 4									