

# 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](mailto: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	Carmen Guchelaar
Student number	4661427

Studio		
Name / Theme	Building technology graduation studio – Façades and products	
Main mentor	Ir. Arie Bergsma	Façade and Product Design
Second mentor	Dr. ir. Marc Ottelé	Materials and environment
Argumentation of choice of the studio	<p>With the rising need to make our buildings more and more sustainable, the popularity and the need for green facades is increasing. Vertical greenery systems have great benefits considering among others health, biodiversity, city cooling and acoustics. But knowledge of and regulations are lacking in regards of fire safety for these systems, which can cause limits for use in practice.</p> <p>I have always been fascinated with façade design and the technical functionality of façades and has found it a loss that in their bachelor and master program fire safety was never really highlighted. This topic allows me to dive into the topic of fire safety and connect it to façade performances. It also allows me to learn more about the technological background of vertical greenery systems.</p>	

Graduation project	
Title of the graduation project	Fire safety of vertical greenery systems: a systematic design approach for safely greening the building envelope
Goal	
Location:	Netherlands. Case studies on campus TU Delft
The posed problem,	As found in literature and news articles, there is a lot of doubt revolving around the fire safety of vertical greenery systems (Alalouff, 2023; Dahanayake & Chow, 2018). The lack of knowledge and wide spread research on this topic could pose as a barrier for the use of these systems in practice (Kotzen et al, 2023). Which would be a huge loss, as the systems can provide numerous environmental and health benefits to the

	<p>urban landscape where horizontal space is scarce (Bustami et al., 2018). Designers could be discouraged to make use of vertical greenery systems as it would be easier to opt for more conventional façade systems with clearer standards and approved methods of use in terms of fire safety, but might not have the benefits vertical green can provide. Furthermore, building plan assessors, such as the fire department and the municipality, might not approve of plans with vertical greenery systems due to lack of knowledge and guidelines on the fire safety aspects of these systems.</p> <p>Another problem arising from lack of knowledge and awareness on the fire risks of vertical greenery systems is that it could be that systems are being used which are not actually providing the safety necessary. Since the testing methods and regulations are found to not be appropriate for vertical greenery systems, it could be that systems are applied which suffice according to the standards, but might not be performing according to what is expected.</p> <p>With an ever urbanizing world where space is scarce, the implementation of vertical greenery can provide health and environmental benefits other façade systems cannot. It is important that these systems can be implemented in a responsible and safe manner. Therefore it is necessary that a systematic approach is developed which takes the fire risks into account and provides adequate solutions in different safety levels (Kotzen et al, 2023). A clear design guide for designers could make the use of vertical greenery systems easier to implement and create safer situations.</p>
<p>research questions and</p>	<p>The main research question the current thesis aims to answer is:</p> <p><i>"How can a systematic design approach for outdoor vertical greenery systems be developed which provides responsible fire risk management relevant to a building's characteristics?"</i></p> <p>To make sure the design approach is understandable, repeatable and able to be developed further by future researchers, it is highly important the approach is systematic and the steps and choices are clearly explained and documented in this thesis. The clear explanation and documentation will also help in creating a transparent approach which will help to make sure that people understand it. Furthermore it is important to take the different aspects of different building into account. There is not a 'one-fits-all solution', as buildings and their use vary greatly.</p>

	<p>To be able to answer the main question, several sub-questions need to be answered. The sub-questions are organized by theme.</p> <p><b>Vertical greenery systems</b>  <i>"What are the different vertical greenery systems currently in use and how do they differ in configuration and materials?"</i></p> <p><i>"What are the advantages and disadvantages of vertical greenery systems?"</i></p> <p><b>Fire safety</b>  <i>"What are current legislation and regulations on fire safety in buildings?"</i></p> <p><i>"What fire safety aspects are relevant to vertical greenery systems?"</i></p> <p><i>"What is the current approach of fire safety of vertical greenery systems in practice?"</i></p> <p><b>Risk assessment</b>  <i>"How can the fire risks of vertical greenery systems be assessed?"</i></p> <p><i>"What are relevant and credible scenarios in terms of fire in vertical greenery systems?"</i></p> <p><i>"Which different risk groups can be developed for different types of buildings and their use?"</i></p> <p><b>Design solutions</b>  <i>"Which design solutions can be developed regarding the found risk scenarios?"</i></p> <p><i>"How can a decision-making framework be developed regarding the risk groups of buildings?"</i></p>
<p>design assignment in which these result.</p>	<p>The overarching research goal of this thesis is to develop a comprehensive and systematic design approach designed specifically for the enhancement of fire safety in vertical greenery systems and the understanding thereof. The approach is to provide critical information in understanding how to work with and make informed decisions on designing safe vertical greenery systems.</p> <p>The approach of this study is threefold: firstly, to critically evaluate and describe potential fire hazards associated with</p>

vertical greenery systems and to illustrate instances where such systems pose minimal to no risk; secondly, to design fitting solutions on different scales and different impact levels relevant to different building characteristics; and thirdly, to develop a design-orientated decision-making framework which can guide designers in making informed decisions on design problems and solutions. The framework will take into account the building's characteristics, the user's wishes in terms of sustainability and the appropriate risk level for the building. Using these input, the framework comes with suggestions for fitting designs and solutions for the specific cases. The framework will be iteratively validated and practically applied using case-studies during the research.

## **Process**

### **Method description**

The following methods will be used during the research. A short description for each method is provided. The research framework is also visualized in Figure 1.1.

#### **Literature research**

To start the graduation research an extensive literature review is necessary to become familiar with the topic and find out what the current knowledge and lack of knowledge is. The literature review will be used to gain knowledge about vertical greenery systems, fire safety in general, current knowledge on fire safety in VGS and the processes of risk assessment and decision-making frameworks. The knowledge gained from the literature research will be used to ask appropriate questions in the interviews.

#### **Interviews**

Interviews will be conducted with different parties involved with the fire safety of VGS, such as manufacturers, fire safety experts and insurance companies. Interviews will be held early on in the research process to gain information about VGS and fire safety and what experience the different parties have herewith. The interviews can help with identifying risks and give first directions in possible design solutions. Later on in the research process, interviews will be held to validate the designed solutions and framework with experts.

#### **'What-if' risk analysis**

From the knowledge gained in the literature review and the interviews, a risk analysis will be conducted to get clear where the problems currently lie and how they are connected to the sustainability aspects. Furthermore a categorization of different risk groups will be developed depending on the characteristics of different buildings. Not every building needs the same level of safety, so the solutions developed will take into account the desired levels.

#### **Case-studies**

Fueling the 'what-if' scenarios, case-studies will be used. Design assignments will be developed for different cases, ranging from simple to complex. During these assignments, problems will be encountered. These problems help with creating the 'what-if' scenarios. The 'what-if' scenarios will also help with fine tuning the case-studies.

Case-studies will also be used to evaluate and test the decision-making framework. This will be a highly iterative process, where the case-studies and the framework will be developed together. The case-studies serve as a practical application of the framework and an evaluation of the outcomes of the framework. This evaluation is then used to further develop the framework.

### **Research by design**

Using the information from the fire risk analysis, design solutions will be designed, systematically derived from the found risks. The solutions will be on different scales and with different levels of impact, so solutions can be chosen fitting a specific context. Solutions will be on strategic, technological, and management levels.

Combining the developed solutions and the different risk groups of buildings, a design-oriented decision-making framework will be developed. To evaluate the framework, the framework will be tested on case-studies. As mentioned above, this will be an iterative process.

### **Evaluation**

During the research process, steps will need to be evaluated, to check if the outcomes are in line with the preceded information. As mentioned earlier, case-studies and interviews with experts will be used as evaluation methods. Furthermore mathematical validation or model simulations might also be necessary in certain cases.

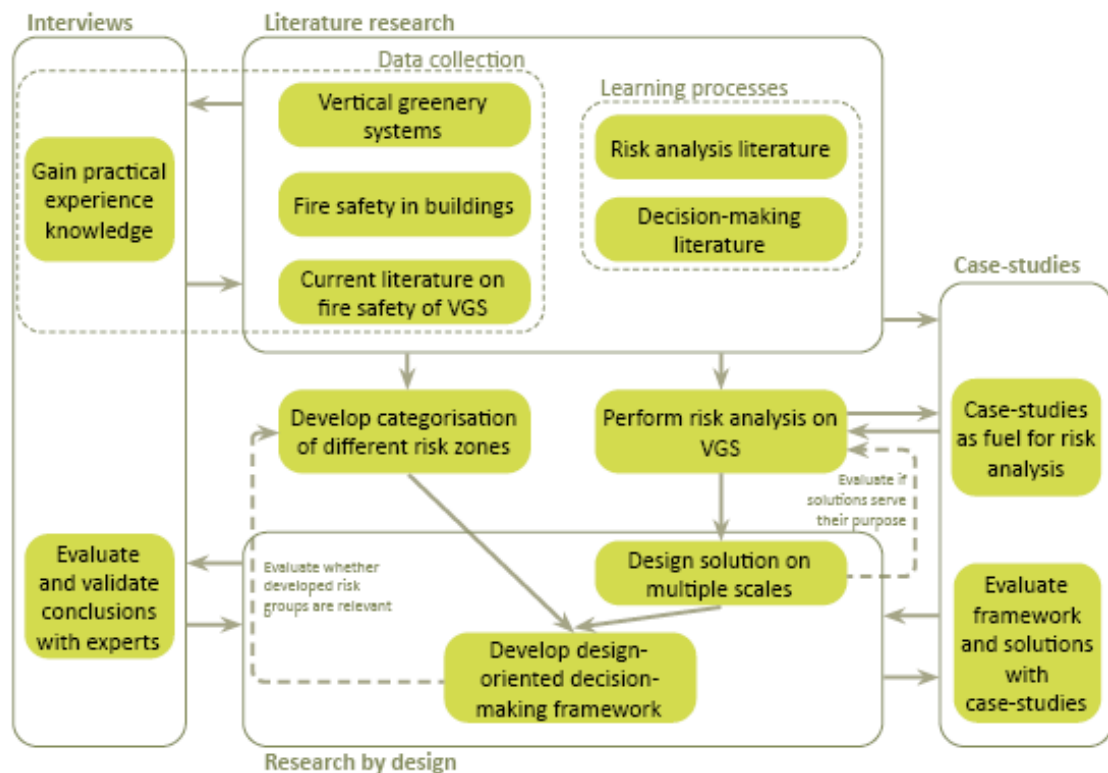


Figure 1.1: Research framework (own work)

## Literature and general practical references

General practical references:

Already in contact with:

- Sempergreen (Vertical greenery system manufacturer)
- Efectis (Fire safety experts company)
- Univé (Insurance company)

Aiming to get into contact with:

- Fire safety department
- More manufacturers
- NIPV

The literature:

Bielawski, J., Papis, B.K., Krajewski, G., & Węgrzyński, W. (2024). An exploratory investigation into moisture content and wind impact on the fire behaviour of modular living walls. *Fire Safety Journal* 142, 104024. <https://doi.org/10.1016/j.firesaf.2023.104024>

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Maas, J., Verheij, R.A., Groenewegen, P.P., de Vries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: how strong is the relation? *Journal of Epidemiology & Community Health* 60(7), 587-592. <https://doi.org/10.1136/jech.2005.043125>

Manso, M., & Castro-Gomes, J. (2015). Green wall systems: A review of their characteristics. *Renewable and Sustainable Energy Reviews* 41, 863-871. <https://doi.org/10.1016/j.rser.2014.07.203>

Meacham, B.J., Charters, D., Johnson, P., & Salisbury, M. (2016). Building Fire Risk Analysis. *SFPE Handbook of Fire Protection Engineering*, 2941–2991. [https://doi.org/10.1007/978-1-4939-2565-0\\_75](https://doi.org/10.1007/978-1-4939-2565-0_75)

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## Reflection

1. 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)?
2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

### Answers:

1. The proposed topic of the thesis is focused on fire safety of vertical greenery systems. As the master track of Building Technology lies between the fields of architecture and engineering, it combines aspects of both these worlds. Within the master programme there is a persistent focus on sustainability and developing sustainable technologies for the built environment. Vertical greenery systems are a development fitting in this context. It combines both technological aspects for the building envelope (Faade and Product design) and sustainability aspects on both building and urban scale (Climate design & Sustainability). Furthermore fire safety is an aspect that is important in faade design and climate design, but it is a topic not heavily discussed (yet) in the department of the faculty. So it is a great opportunity to highlight this aspect.
2. There is a need for making the built environment more sustainable due to problems arising from climate change. Furthermore there is a trend of urbanization. Vertical greenery systems can provide great advantages in the urban landscape, to create a healthier living environment for citizens. In terms of sustainability it would be highly desirable to be able to make use of these systems as much as possible in urbanized areas. But sustainability should not

be at the expense of safety. So it is important that a good understanding about the fire safety of vertical greenery systems is developed by both engineers & designers and in society in general.

The reason the topic came to notice, was because an expert on the field of fire safety working at the TU Delft, expressed their concerns and insecurities on fire safety of vertical greenery systems. These doubts were then found to be frequented in literature, where in news articles and academic research concerns on the fire safety of vertical greenery were expressed. Many references mention the need for further research on the topic.

The concerns and insecurities mentioned are derived from the lack of knowledge and research performance of vertical greenery systems in terms of fire safety. Furthermore legislation and regulations fall behind and the testing methods currently applied (according to NEN norms) have been mentioned to be inconsistent and inappropriate for vertical greenery systems. To overcome the concerns and insecurities the current research aims to provide a clear research and design framework to guide designers in using fire safe vertical greenery systems.

## Planning

Completed for P3:

- Risk analysis
- Concept designs
- Concept framework tool
- Chosen case studies
- Concept thesis & reflection

Completed for P4:

- Design solutions
- Framework tool
- Case studies
- Thesis & reflection

