Architectural Engineering Graduation Studio

SHELTERRA

Reconfigurable Masonry
Settlements for Refugees

Research Plan

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The intention of this report is to give insight into the upcoming research which will be done as an integral part of completing the graduation project. It focuses on providing a clear reason, structure and means needed to complete a research paper in the following months.

Chapter 1 - *Introduction* aims to explain the architectural and societal relevance of the research, the preliminary research of the chosen context, motivation behind the topic, state the problem and main requirements that will be challenged and the developed overall research questions that the future research paper will attempt to answer.

Chapter 2 - *Research framework* focuses on defining the fields of knowledge involved in the research and design project and the applied key concepts. It describes the methodological framework and main methods that will be used to complete the research.

Chapter 3 - *Planning and organization* explains the planning of the work throughout the graduation year and for the research paper. with the means of text and figures.

Introduction

BACKGROUND AND RELEVANCE

Various types of crises are happening in the world regularly. Some of them, like the coastal flooding and the intensity of hurricanes, are directly related to global warming. Others are influenced by economic and political changes. Oftentimes there is an urgent need of shelters for people who were affected by the catastrophe.

Afghanistan has a long history of domination. It was influenced by many conquerors and suffered civil wars. All of which challenged the lives of the Afghan population, destroyed homes and cities.

July of 2021 marked the beginning of another internal conflict, resulting with the reinstated power of Taliban across the country. This was accompanied by many horrible events and massive destruction. According to UNHCR (United Nations High Commissioner for Refugees) Afghan refugees constitute to one of the largest refugee populations in the world of approximately 2.2 million people, with more than 600,000 being forced to flee since January 2021 (2021). At the same time, the IRC (International Rescue Committee) calculated the rise of people internally displaced by conflict in Afghanistan of 73% (2021). The data of IDMC (Internal Displacement Monitoring Centre) shows the total of 80.5 thousand people displaced only in August (2021).

The change of the regime in the country also brought back the progress of women's rights in the country made during the last years. This forced many women into running and hiding. On top of that, the COVID-19 pandemic adds more health risks. Combination of all these disasters leaves the Afghan people with minimal levels of safety and low chances of survival without the urgently needed humanitarian aid, including shelters.

CONTEXT

Afghanistan is a landlocked country. Its topography mainly consists of rugged mountain ranges, plains, river valleys and deserts (United States: Library of Congress Country Studies, 2008). The available materials and climate, generally featuring cold winters and hot dry summers influenced the nature of dwellings found in the country.

Several historic types of structures are described in *Traditional housing of Afghanistan* by Nawid et al. (2020, p. 1218). One of them is the mud house which is usually constructed from "clay mixed with chopped straw". This material is not only easy to find in the Afghan soils but is also simple in use and has several properties that make it very suitable for the climate.

PERSONAL MOTIVATION

The goal of the graduation project is not only to provide a design solution to an existing problem but to also consider all aspects of sustainable development (economy, environment, society) for the built environment. These follow the guidelines explained in goal 11 by the Department of Economic and Social Affairs of the UN (United Nations): "Make cities and human settlements inclusive, safe, resilient and sustainable" (2021). The Economic pillar in this project focuses on affordability and transportability. Environmental part is mainly dependent on the use of materials (embodied energy), climatic design and reusability. The main conditions taken into account for the social aspect of sustainable design are safety, adaptability and capacity of growth.

Choosing for available earthy materials ensures both: economic and environmental qualities needed for the successful solution. The social requirements are guaranteed to be met by the choice of computational design as means of methodological framework of this research.

PROBLEM STATEMENT

The problem statement is presented in a manner of a mathematical problem in order to

provide structure for the research. If the outcome of the research is the solution to the problem, the problem statement is a series of "knowns" – the current status and a set of requirements that need to be met as well as the explanation of the desired outcomes – the "unknowns".

The recent economic-political catastrophe in Afghanistan requires urgent need for shelter to aid and protect the affected people. The solution (design) needs to be smart (high-tech) but able to be implemented with the least additional means, such as complex machinery and therefore have a low-tech construction as a matter of assembly.

The shelters need to be designed from available earthy materials and have a modular construction with dry connections. Therefore, it should have masonry funicular spatial shell structure made up of polyhedral blocks with ensured structural strength and stability and only compression forces acting on the modules.

There should be a few different types of modules to provide the easiest possible assembly procedures for the people, such as dry stacking.

These types of modules should allow for many different variants of assembly. This can allow for the different sizes and types of shelter structures, that would meet the needs of the Afghan population better and allow affordable mass-customization. People woulc be able to "play" with the blocks and come up with different variant of structures by themselves.

Computational design methodology should be used for shape optimization of a "given" topological design for a shell and ensure compliance with the quality criteria.

RESEARCH QUESTION

From the preliminary research of the context and the problem statement, the main research question is formulated as following: *How can we design a set of a few polyhedral cells with which we can make many variations of modular shelters (funicular spatial shell-like structures made of a set of dry-stacked polyhedral blocks)?*

In order to be able to structurally answer this question, the research process is divided into two parts, resulting in two sub-questions: *How do we find/approximate the shape of a compression-only (funicular) structure as a stack of polyhedral blocks? What are the different variants of modules assembly to get different sizes/types of shelters?*

Research framework

This research falls under the domain of architectural design praxeology and material culture epistemes. It will be executed with the help of literature study and computational design methodologies, namely topology optimization and gamification using experimental and simulation research approaches. Therefore, it makes use of the rational-atomistic approach as described by Gunnarsson (2018).

The scope of this research is an integration and intersection between multiple fields of study. The main ones are architectural (parametric) design, mathematics (computational design), structural design and computer science.

METHODOLOGY

The methodological framework of this research is based on the common steps in the design process shown in Figure 1 which were described by Peffers et al. (2007, p. 53).

Figure 1. Common design process elements. Done by author.

Chapter 1 - *Introduction* has already covered the problem identification, motivation and objectives. An extra step – Evaluation is added after that. It focuses on the design of quality and evaluation criteria for the further work.

Design and development phase can be divided into two parts: design and development of the mathematical model and design and development of the algorithm. Demonstration will be performed in two ways: digital graphics and physical models.

Following that is the verification and validation step. Verification can be done with the help of a Python algorithm focusing on testing the mathematical model. Validation focuses on ensuring the structural feasibility. It can be tested with the help of previously produced physical models.

After that, the research can take a set back to the previous stages where improvements are made. All of the phases are completed with the base of the extensive literature study for a theoretical basis.

The final step – Communication will be done in the form of the completed research paper.

After considering these aspects and divisions, the framework for the research can be elaborated more (Figure 2).

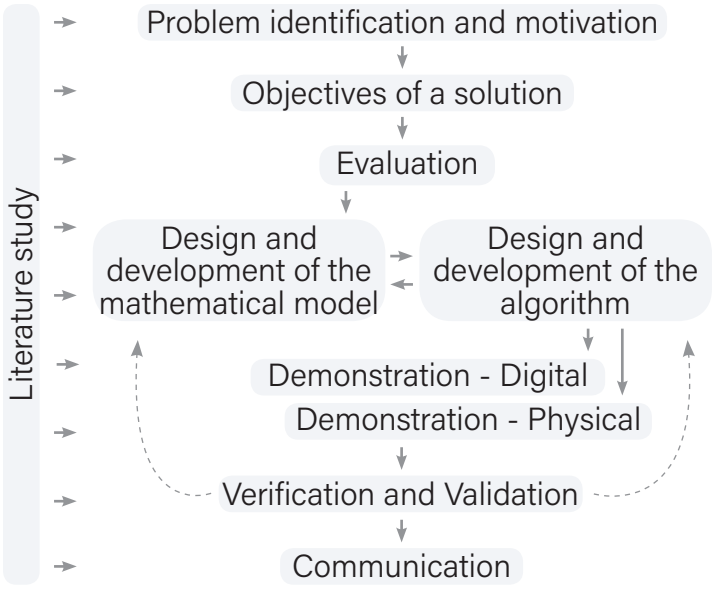

Figure 2. Methodological framework for this research. Done by author.

METHODS

Within the proposed methodological framework, the first phases are fulfilled by executing a literature study. In the design and development phase of the research two main methods will be used: topological design/topology optimization and gamification.

The process of topological design and topology optimization is roughly done in three main steps: pattern generation and tessellation (2D), pattern displacements and module extrusion and is based on the already existing study of Bitting et al. (2021). The next paragraph explains the process of research execution in more detail.

As a starting point, a global grid with a few polyhedral cells subdivision should be decided upon. This ensures the possibility of designing several different shelter variations that can be constructed using (some of the) same polyhedral block shapes. Afterwards, a simple shell 2D projection is placed within the global grid and a topological skeleton is found. The different tessellations are then explored and formed into the mesh subdivision. The next step is the mesh relaxation and form finding with the help of the dynamic relaxation method, force density method, thrust network analysis and the graphic statics. In the end, the shape of the structure is approximated by means of topological polyhedralization.

In the further stage of the design development, the gamification method is used in order to find the different stacking variations for the modules but also to allow the possibility of playing with the blocks and create your own structures. The variations of the designed modules can be approached as a set where each block can be reproduced and stacked on each-other in any way, just like with the set of Lego blocks. As a starting point for the research, a goal of 20 maximum types of modules is set.

Software programs, used for this phase of the research are: Python, Autodesk Rhino and Grasshopper. For the digital demonstration, Adobe Photoshop and Procreate are used. Smaller scale physical models are produced for the physical demonstration and structural validation by means of casting the resulted blocks with the 3D printed molds.

Structural evaluation can also be performed optionally with the help of the Karamba software program.

Planning and organization

Making a planning for the graduation project is crucial to structure the work, understand the position of deadlines and have a clear understanding of the phases and tasks. Because of that, several organization diagrams were made, focusing on different scales and aspects of the project.

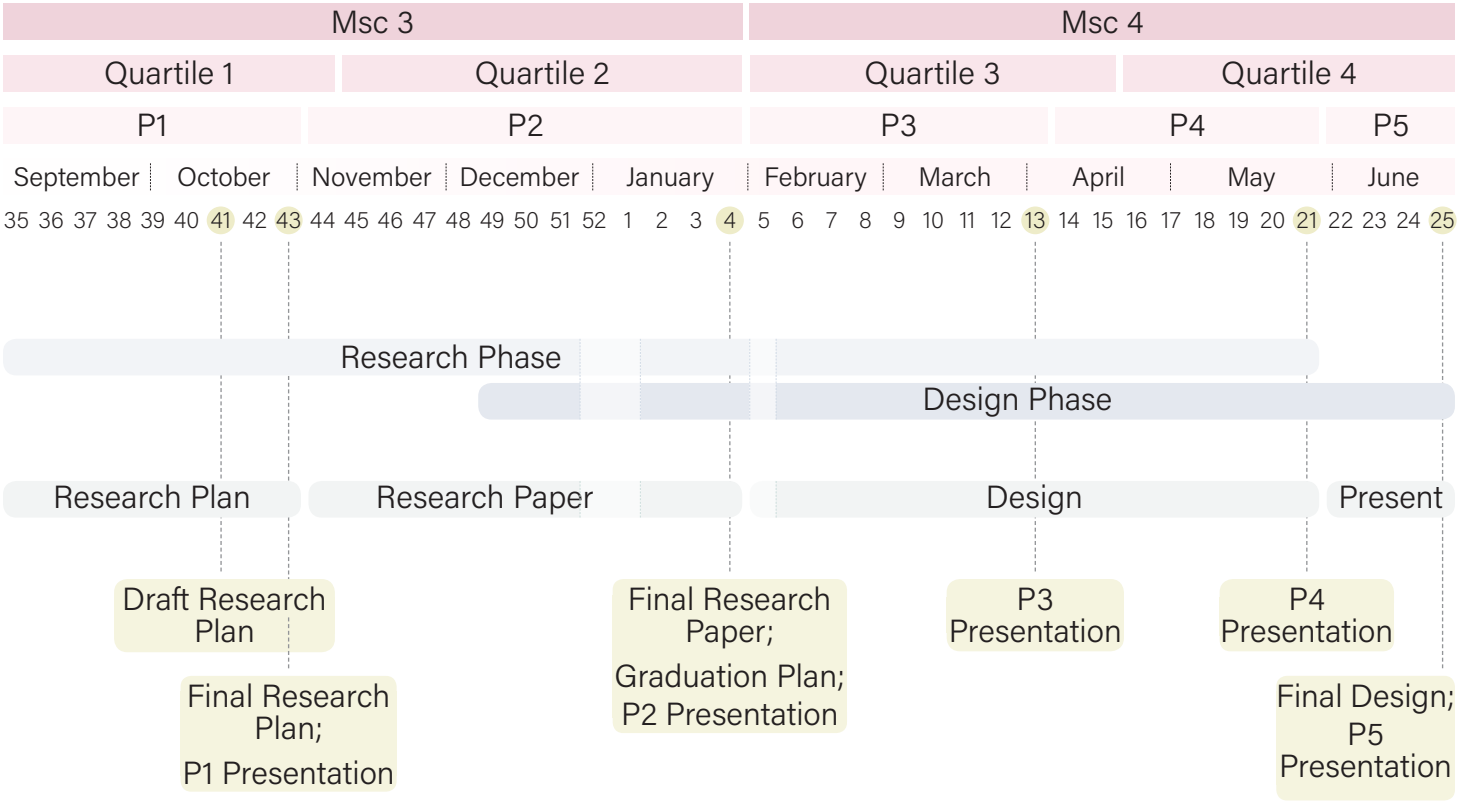

Figure 3. Planning full year. Done by author.

PLANNING FULL YEAR

The duration of the graduation project is one year. The organization can be broken down into different parts depending on the logics behind the division. Firstly, there are two major phases of the graduation: the research phase and the design phase. Even though according to the program these phases are taking exactly one semester each, in reality the research will definitely last until almost the end of the project and the *design* will start with the production of the first design concept, during the production of the research paper.

The organization can also be shown in the four main stages of the graduation: research plan, research paper, design and present. These also show some indication of the deliverables.

Figure 3 shows the full year planning, its possible divisions and the major deadline moments together with the indication of the mandatory deliverables.

DESIGN PART AND RESEARCH PART

The research paper will attempt to answer the previously explained research questions. However, more design related questions need to be investigated at the same time. Figure 4 explains the relations between the design part and the research part of the graduation project. It shows once again that they go simultaneously and focus on different aspects of the design. Towards the end, these two parts merge into one in order to continue the design-evaluate process and produce the final design of the modular shelter.

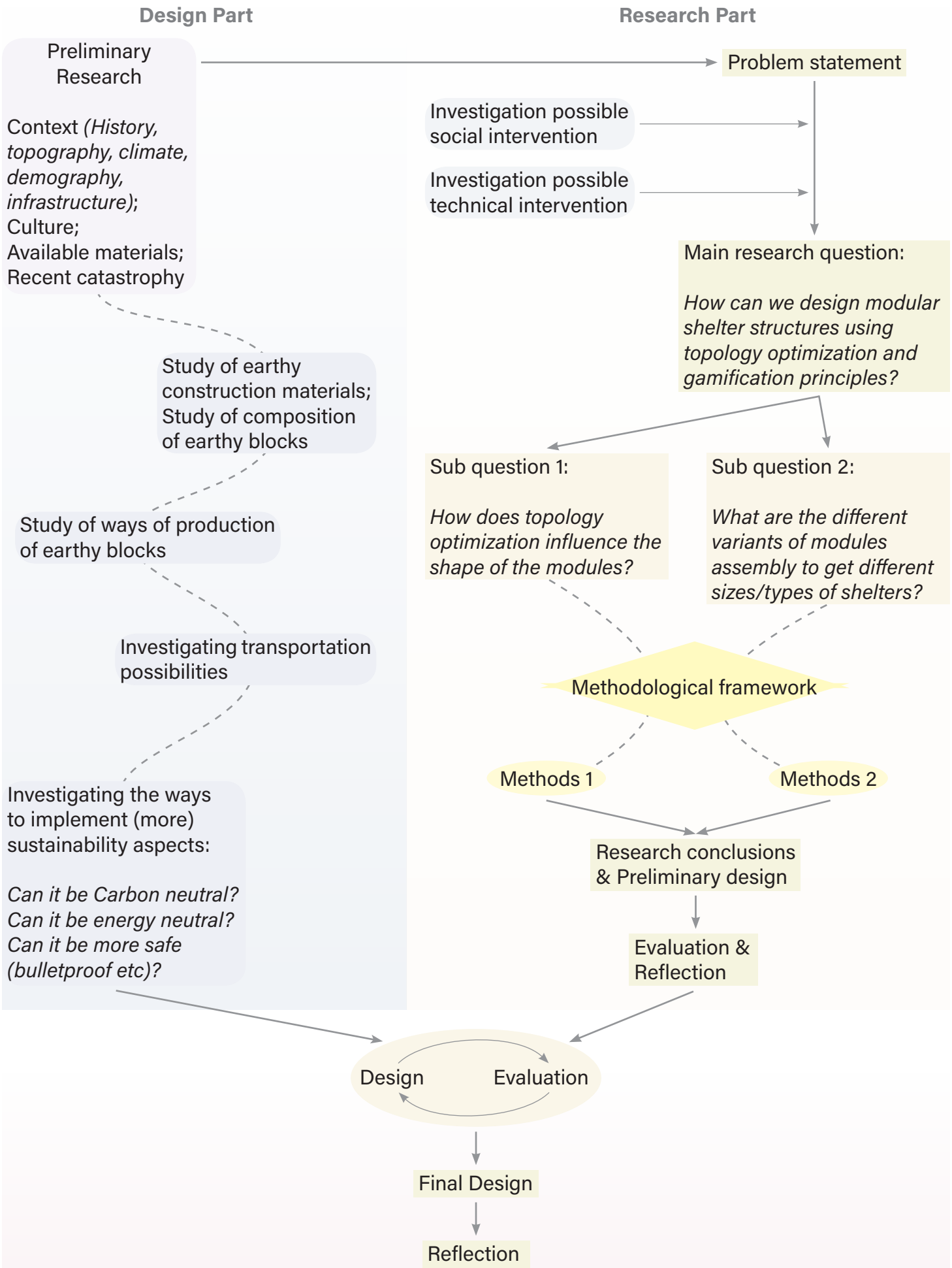

Figure 4. Design part VS Research part. Done by author.

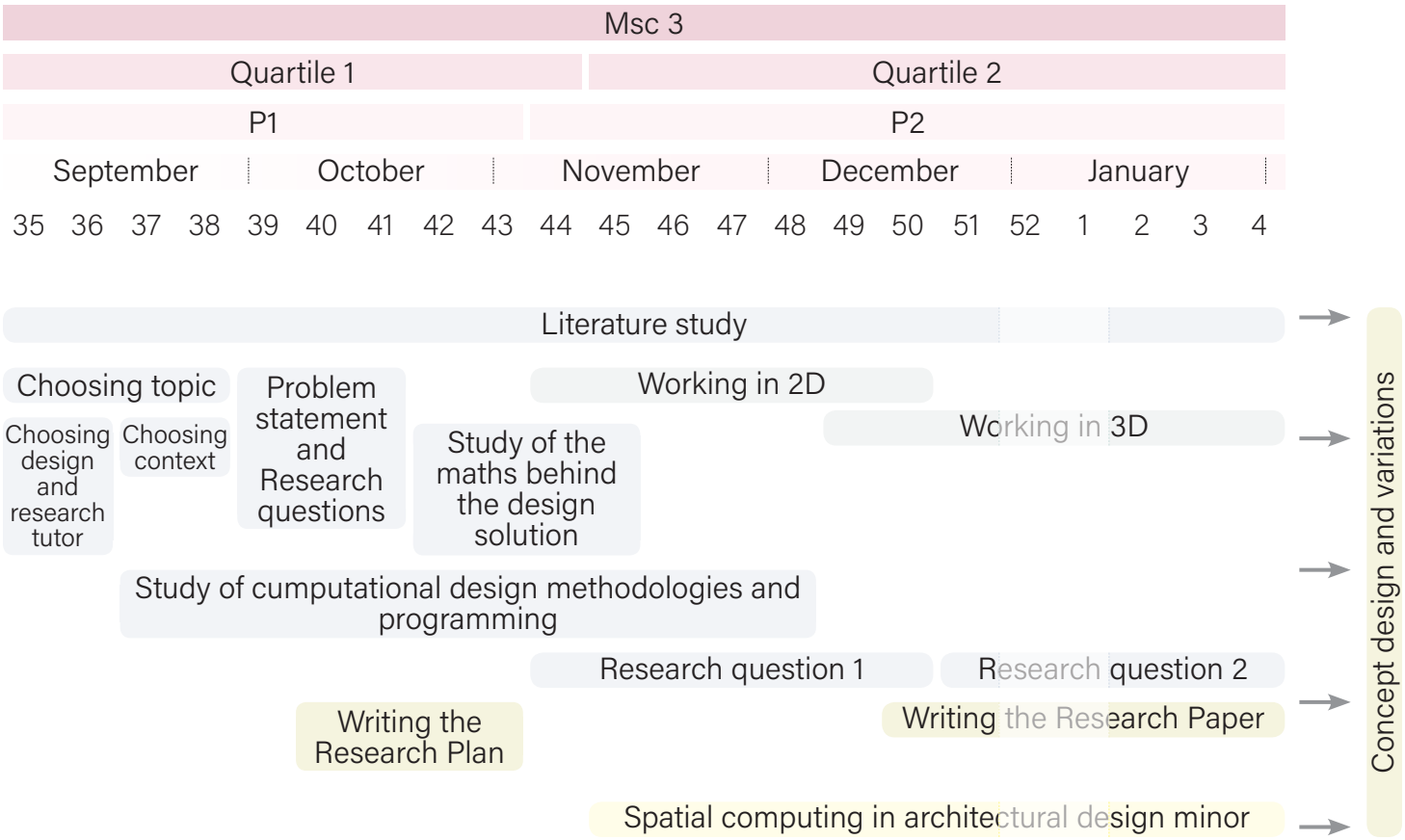

Figure 5. Planning research (First semester). Done by author.

PLANNING RESEARCH (1ST SEMESTER)

The more elaborated planning for the first semester and the production of the research paper is shown in Figure 5. This half year is divided into several stages of work to ensure the delivery of the final product on time. An extra course - Spatial computing in architecture is added during the second quartile to the planning as the essential part of building the knowledge to conduct this research.

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