AR3A010

Research Plan

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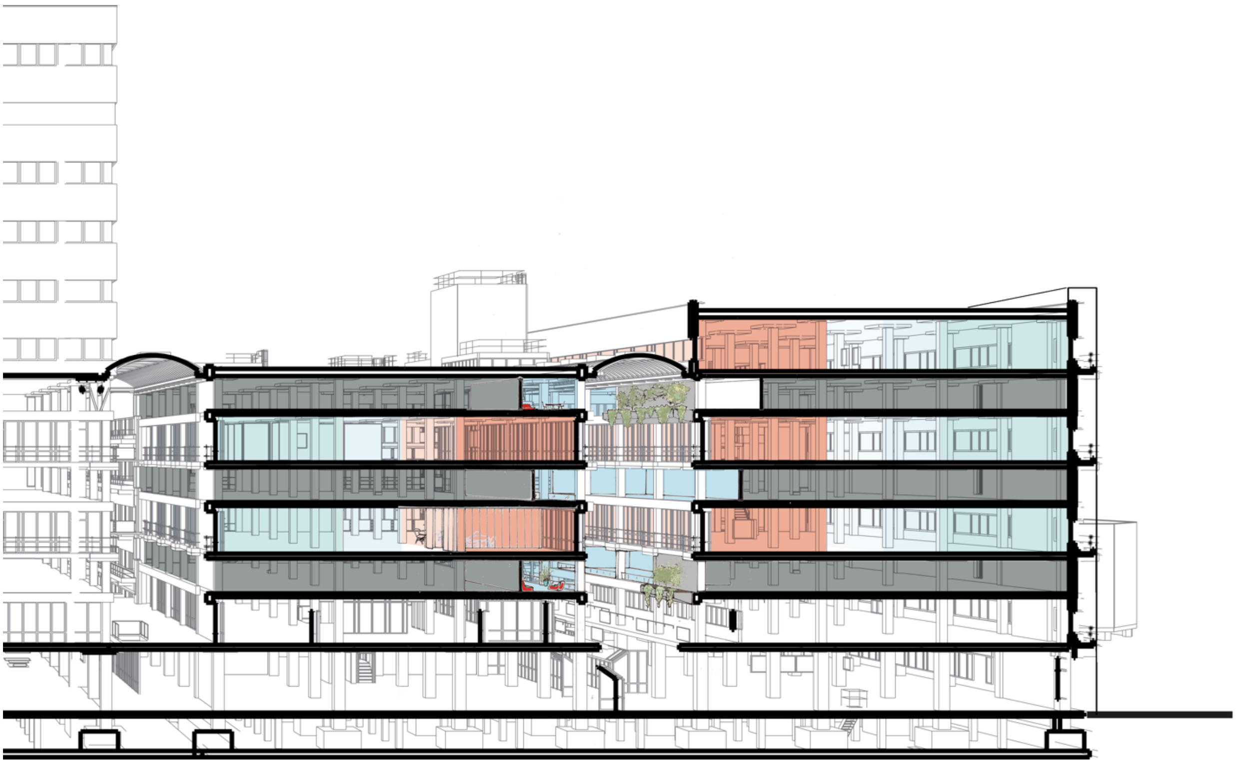


In a world where the need to reduce our energy consumption (and the subsequent CO2 emissions) is well known while the legal requirements for ventilation capacity, air quality and thermal comfort are but rising, it falls upon architects and engineers' shoulders to address this complex question.

While many "lambda" citizens, following the heat waves that have happened increasingly the past years, have energy devouring airco units installed one house after the other, practicing architects and engineers as well as researchers and scholars are exploring ways to achieve increased comfort while reducing the energy demand.

One of the movements towards that goal translates into a race of sorts towards increasingly efficient systems combines with more and more sustainable ways to produce the energy they require. Another approach consists of taking a number of paces backwards as it were, and to aim to achieve the desired ventilation without using energy (not in a human-made energy sense at least). However, the need to redefine some criteria of comfort to work with such solutions, coupled with a certain lack of predictability inherent to relying on naturally occurring phenomena and energy, have so far prevented this approach from becoming the standard, or to be restored as the standard, in our Western countries.

But possibly even more damageable than those "downsides" is the lack of knowledge on how natural ventilation actually works and could fit in our modern world, where remotely controlling some device from our smartphone had come to feel more evident than putting on or taking off a pull-over when the temperature is not ideal.

In this context, the hospital could be seen as the ultimate example of the place where the air is entirely controlled, with all the healthcare-related requirements adding up to the basic requirements for a modern building.

This paper presents and reflects on the process that led me to research the feasibility of natural ventilation and some guidelines to apply that "low-tech" approach to a hospital building in the Netherlands.

To do so, I shall first present and argument the choice of my graduation topic in a top-down approach, from the choice of architecture as an education to the specific topic for my graduation project. I shall then present the problem statement and subsequently the research question of the thematic research supporting the project. Following will be a presentation and reflection on the methodology used during the research process, while then be summarized in a diagram. After a list of the references used, I shall close this paper with a reflection on the relevance of my research.

1. Graduation topic introduction

The choice of my graduation topic is the result of a series of choices throughout my education in architecture, that from the start appealed to me for combining technical aspects with a large part of creativity. In this next section, I have chosen to present those choices in a top-down approach, leading to the choice of my graduation project topic within which my research found its relevance.

Choice Architectural Engineering graduation studio

From a young age, I developed an interest in everything that could help build a more sustainable world. It became important to me that the education and the profession I would choose would allow me to play a role in this direction. Diving into a large variety of topics, I developed a fascination for passive climate and sustainable architecture that led me to choosing architecture as a career path. Although I tried, during my time at the TU Delft, to get a taste of many of the different visions on architecture embodied by different chairs, it was clear from quite an early stage on that the graduation studio offered by Architectural Engineering would be the most accurate crowning of my education given the expectations with which I started. Encountering some teachers and professors from the Architectural Engineering and Building Technology chairs, during my bachelor already, and being introduced to -among others- concepts such as “designing from technique” (“ontwerpen vanuit de techniek”) only contributed to validating that choice.

Choice Second Life

In his lecture “Second Life: Re-use by design”, Prof. Mauro Overend states that more than 70% of EU’s building stock in 2050 has already been built (personal communication, November 22, 2019). This proportion of the existing building stock in comparison with the yet to be built real estate is what makes the sustainable renovation of existing building such a relevant challenge. In particular, buildings from the 1970’s and 1980’s represent a significant portion of our cityscapes. While their concrete structures generally are structurally sound, their architectural expression is not to everyone’s taste and their energy consumption is further and further from the actual standards.

The “Second Life” studio, focusing on preserving and renovating those structures where concrete is prominent, combined with the fact that it addressed a relevant issue for the Netherlands or Europe in general, appealed to me. While my primary interest lies with passive systems which are commonly mostly found in new buildings, Prof. Overend’s statement that “the most sustainable building is the one that has already been built” helped in making the challenge of retrofitting some of those concepts on a building that is the image itself of the un-sustainable building seem like a perfect topic for my graduation.

Choice AMC

Among the building to choose from within the Second Life studio, the AMC complex appealed to me for being different from the standard office(-like) building. The hospital, aside from being much larger, has a more complex layout, with a couple of very specific features such as the man-height technical subfloors and the network of inner streets, that offer rich potential for a design. Also, where there is already a certain number of sustainable renovations of high-rise office buildings, such works on lower and deeper buildings are less abundant.

The initial design brief, based on the actual issues that need addressing in the actual building, mentioned a façade redesign, in which I saw a chance to bring further the work on double skin facades I have done on several designs, such as my graduation project of the Bachelors, or during the Delft Seminars on Building Technology.

Given its size, a redesign of the entirety of the building would not have been a realistic enterprise for the time frame of a graduation project. I made the choice of focusing on the blocks hosting the Faculty of Medicine for several reasons: one of them has to do with the climatic challenge I want to approach. This part of the complex has indeed more spaces with office or comparable function, that do not require as strict a climate as most of the hard medical areas of the hospital itself (operating rooms or isolation chambers e.g.). While the bed towers, hosting the nursing wards, also have less strict regulations, their layout is not very specific nor different from many high-rise buildings. With their limited depth and layout of smaller rooms arrayed between façade and a central hallway, they lend themselves quite easily for a cross-ventilation system for instance. The research facility of the Faculty of Medicine combines some very specific features, like the technical subfloors, with more general aspects that still represent a relevant challenge for the field, namely a very deep yet not very high building, unsuitable for cross-ventilation, with inner streets that can be seen as atria.

Graduation topic

Once the AMC building chosen, I started analyzing the existing building more closely.

The issues that could be addressed within the AMC assignment are numerous. The management of the hospital is facing the challenge of having to renew the entirety of the exterior facades within the coming decade, while also needing to adapt to changing standards in the field of medicine. This last aspect generates a series of problems of the order of functionality and use of the building itself.

From the perspective of my fascination, the lack of passive or even sustainable installation in the climate system was of course a major problem to address and fits quite adequately within the framework of Architectural Engineering.

Functionality and use: a social layout

In matters of functionality and use, the actual problems transpired from a visit of the building and conversations with some users. The problem appeared to be twofold and for a great part related to the age of the building and evolved needs from the users. On the one hand, the very pragmatic fact that the expectations of a lab facility have evolved quite a bit in the past forty years, from needing many standard tiled workbenches with water and gas supply (leading to a rather rigid layout due to the abundant piping and weigh of the benches) to the need for space for (often big) electronic devices. But mostly, not only did the laboratory protocols change, but also the views on productive and fruitful research in the field of medicine. Researchers nowadays spend more time processing the data than acquiring it (which translates into spending more time on the computer and less in the lab). Also, where researchers used to work in small teams, remaining within their department and exchanging mostly with researchers focusing on similar topics, research has shown that exchanging results and views with people with another specialization leads to more creative and novel insights. The problem related to the current research facility at the AMC is the lack of space where researchers can meet and exchange. Each researcher has their given workspace, meeting rooms are scarce, but even more so are the "informal" meeting spots. Except for a couple of lost tables with a set of chairs here and there, the only place where people can sit together is by the main entrance, which is such a walk for most researchers that they barely ever find themselves there.

The design goal resulting from that problem statement is a make-over of the research wing that fits the needs of the users, current and future, with the emphasis on the facilitating of inter-departmental social interaction, planned and spontaneous.

Although there is abundant literature on design for education or social interaction, I chose to approach the design question raising from that goal in a research by design. Being in the architectural engineering graduation studio, a more technical research topic seemed preferable, which confirmed this decision.

Climate: sustainable renovation of a large-scale public building

By the time it was delivered, the AMC building was Europe's largest permanent concrete structure and thus also one of the largest built complexes. It was conceived by the architects as a city, with different building blocks interconnected by a network of covered streets. Much of the following factual information was gathered during an interview with the head of the technical management of the hospital, amongst other in charge of the energy and climate control in the complex.

As to be expected with such a large building, the AMC has a very high energy demand, of the order of 75 GWh/year.

According to the following diagram provided by the real estate management of the hospital, nearly half of that demand is related to ventilation and climate control, making these aspects quite crucial in reducing the energy demand of the AMC.

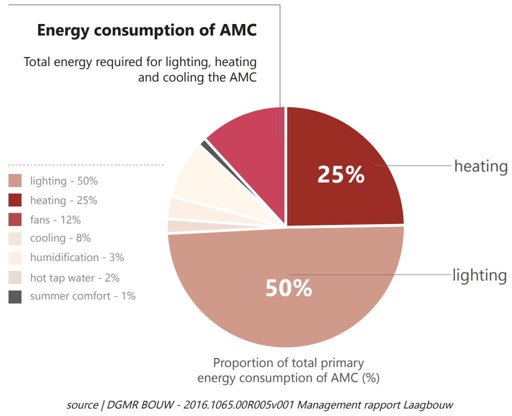


Figure 5: Energy consumption of the AMC

Source: DGMR Bouw (2016)

The climate control of the AMC consists of an all-air system with central AHU's (air handling units). The units deliver a fixed airflow and temperature. Flow adjustments per room are realised by an intricate game of valves that distribute the flow among the spaces. The atria and inner streets are poorly insulated and have no temperature control of their own. While they are the space where patients and visitors wait and where all the restaurants and cafés of the complex are located, they benefit only from the leaked air conditioning of the building blocks.

From an economical as well as from an ecological point of view, the impact of the ventilation and temperature control on the AMC's energy demand must be addressed. Natural ventilation seemed a fitting possible answer in accordance with my own fascination.

2. Problem statement

My first step towards determining my research topic was to research whether my wish of applying natural ventilation, which I mainly knew from smaller scale housing or office buildings, was at all realistic and whether the specificity of the function would be a problem. In their article "Acceptable Temperatures in Naturally Ventilated Buildings", professors Susan Roaf and Fergus Nicol (2018) extensively describe the many advantages of applying natural ventilation in buildings as well as many of the factors responsible for natural ventilation not being the standard nowadays. In the light of the previous question, the specific mention of a significantly reduced risk of spread infections in naturally ventilated hospital confirmed the possibility of applying natural ventilation to such a scale building as well as the economical, health and comfort benefits it could generate. These statements lead to the confirmation of natural ventilation as the choice for my research topic.

The design question subsequently raising reads as follows: how to design a natural and passive ventilation system for the AMC's research facility making use of the restrictions and chances of the existing building?

The phrasing of that design question itself reveals the two main components necessary to be able to provide an answer: on the one hand, the chances and restrictions of the building itself must be listed and analyzed in a fashion that allows to assess which systems or principle are best suited to this particular building and situation. On the other hand, a comprehensive understanding of the phenomena involved in natural ventilation and how different systems relate to them is necessary.

3. Research question

The goal of the research would be to get an understanding of natural ventilation that would allow a designer to make a choice amongst the possible systems in order to integrate natural ventilation into a design. The first aspect mentioned here above was best to be achieved by an analysis of the building and wasn't material for literature research. Some of the general characteristics of the building did however help narrowing down the research question. Although the results of the research should allow a choice for most situations, the initial focus laid on large-scale buildings in the Netherlands.

> During the preliminary research, several of the encountered articles mentioned the same fact, that contrarily to the general conception, the main goal of ventilation in buildings is not about the oxygen rate in the air in a room, but air renewal in order to evacuate pollutants (incl. smells). Ventilation is more related to comfort, which is only emphasized by the aspect air temperature that can be coupled with ventilation. Seeing the part of the energy consumption that is dedicated to that very aspect, I chose to make the possibility to approach the pre-conditioning of the air inlet in a passive way a part of the research criteria. By addressing the temperature of the incoming air, the energy demand can be reduced significantly.

Integrating all the above-mentioned elements together allowed to define the aim of my research as to provide an insight on how to choose a natural ventilation system to offer satisfactory air exchange as well as passive heating or cooling in the optic of a renovation of a building of the scale of the AMC building. The retained research question was divided into which knowledge offers an understanding of natural ventilation and how different applications can be widely compatible or not with the typology of building in question.

During the preliminary research, many articles offering more or less exhaustive and detailed lists of architectural and engineering systems were encountered. Based on the information generally paired with them, I assumed that systems that integrate with the building at a global architectonic level would be more suitable than the smaller-scaled “engineer’s solutions”. Often given examples of the first category are atria, solar chimneys, wind towers or double-skin facades, while the second kind would refer to elements such as roof-mounted wind scoops or wind catchers. Also, given the size of the building and subsequent need for ventilation on the one hand and the Dutch climatic conditions, varying but rarely extreme, I didn’t have the expectation that one single system would offer a complete solution on its own.

4. Reflection on methodology

Despite of the previously mentioned article by S. Roaf and F. Nicol (2018) *Acceptable Temperatures in Naturally Ventilated Buildings* being very complete on adaptive thermal comfort, in the sense of people adapting to a wider range of temperatures than is generally assumed when applying mechanical ventilation, as well as in the sense of the building being able to adapt to the desired comfort, no mention of possible systems nor example is given.

During the preliminary research for my design concept, I discovered that the vast majority of the literature I found on natural ventilation either focuses on one specific system (when not one specific aspect of that system under specific conditions) or presents overviews of existing systems and their general characteristics without offering a comprehensive understanding of natural ventilation as a phenomenon nor of the processes involved. In the first category fall articles such as that of Andersen, K. (2003) *Theory for natural ventilation by thermal buoyancy in one zone with uniform temperature*, of which the title is explicit enough to understand that until the choice has been definitely made for buoyancy in a design, the information provided by the article will be of little use. Another article written by Zhai, Song and Wang (2011) and entitled “A review for the application of solar chimneys in buildings” offers a rather deep understanding of the solar chimney and would provide a designer with usable guidelines to integrate such a system in a project. However, such a paper does not put the system itself in comparison with other concepts and therefore, a scientifically informed choice is hard to make based on the otherwise abundant literature.

An extensive scanning of articles treating largely of “natural ventilation” or “energy-efficient ventilation” yielded one review article, that offers a quite exhaustive yet undetailed overview of the different aspects and systems involved in a natural (or hybrid) ventilation concept. This article itself is partially based on the quite extensive doctorate thesis of Tommy Kleiven, which provided the framework necessary to a structured understanding of the question of natural ventilation.

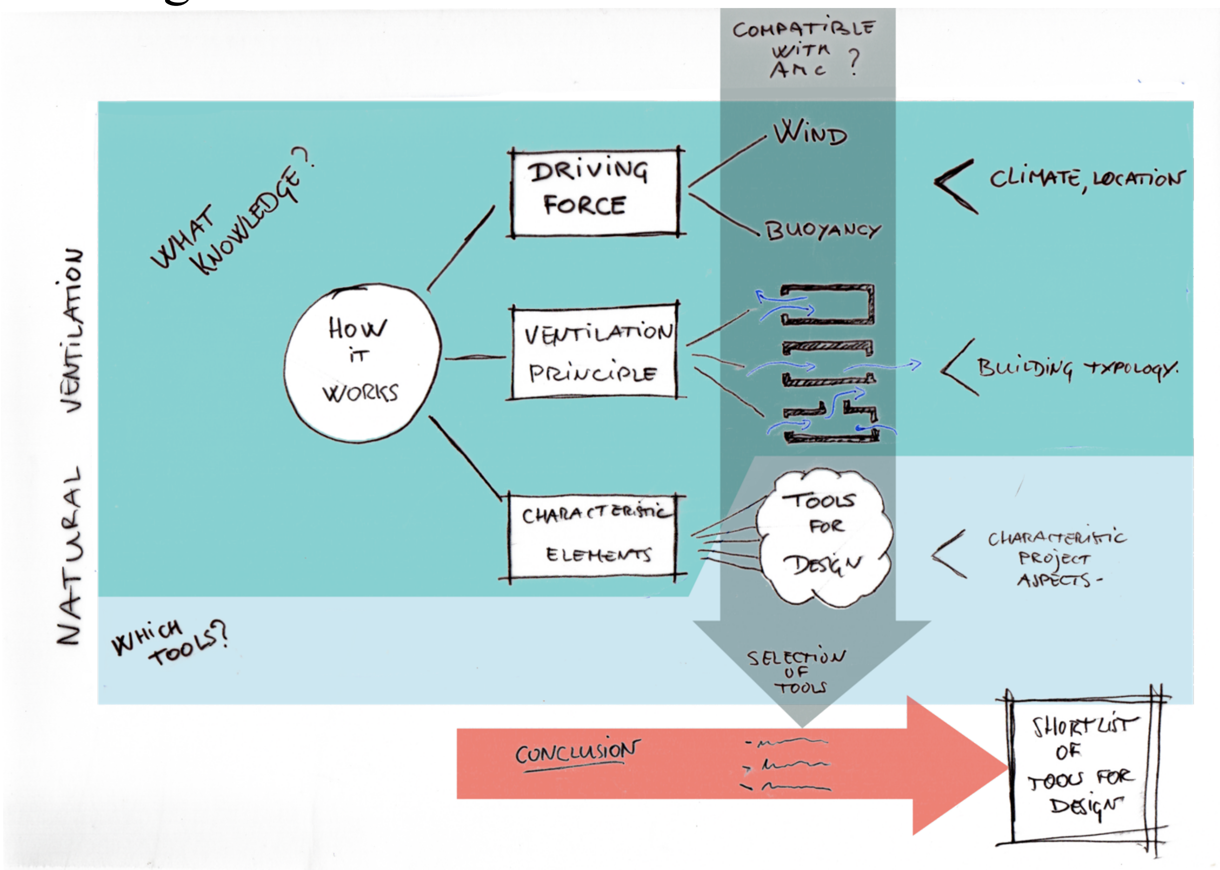
Due to the complexity of the calculations and the number of variables to take into account to assess the relevance of a specific system in a specific climatic and geographical situation, an in-depth evaluation of each system would not have its place in a paper like the one expected within a graduation studio. Yet, to be a relevant support to my project, the paper had to allow me to evaluate which systems would be adapted to a temperate climate. I decided to consider the following two aspects of the temperate climate such as in the Netherlands: relative constrained temperature variations but significantly varying wind conditions (strength and direction) and solar exposure (daylight time varying between winter and summer, and very low solar penetration on rainy day). To primarily assess the compatibility of a system with such climatic conditions will in this paper be reduced to determining whether the system would be able to operate as intended in the absence of sun and/or of wind.

This simplification, however necessary to fit within the scope of the research as it is intended (timeframe and format), is what could be considered this research's greatest weakness in a larger context, since it lacks quantifiable evidence to guide the choice towards one or the other system.

In the context of my own graduation design, which could be extended to any other design process it did allow me to select the principles that could work in a given situation (building typology associated with climatic conditions). In the next stages of the design process, I intend to further develop the chosen elements and to apply some of the encountered calculations to be able to quantify their efficiency.

Ideally, that process repeated for each of the characteristic elements could provide some rules of thumb that, once incorporated to the paper, should allow the reader to get an approximation of what could be achieved with each principle or element.

5. diagram of research structure



6. List of references used during research

The following references have been used during the research process. Most of them ended up being citated in the final research paper, and all have played a role in the choice of the research topic and forming of the research question. All articles mentioned in section 4. as either "too specific" or lacking the presentation of a comprehensive understanding are also listed here below.

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Other references

1. Overend, M (2018) Performance evaluation of natural ventilation strategies for hospital wards - A case study of Great Ormond Street Hospital. *Building and Environment, 56,* 211-222. https://doi.org/10.1016/j.buildenv.2012.03.011

7. Reflection on relevance of graduation project

The current housing crisis in the Netherlands has put (parts of) the built environment in the foreground of the public debate. However, the environmental or energetical aspects of building new dwellings in great quantities, as the leading party of the current government promotes, don't have much place in that debate. Building as they suggest without altering the standards in the building industry, amongst other in matters of energy demand due to ventilation and thermal comfort, would turn the housing crisis into an even worse climate crisis than we already have. In the light of the Chinese energy crisis, and the amount of work our local energy providers need to put in to keep the grid online under the stress of an increasing energy demand, more buildings with a similar energy demand as the existing will lead to increasing struggles.

The climatic changes we are facing are also present enough in everyone’s mind to understand that those standards must evolve. If we take for granted that applying natural ventilation to a large part of the real estate will become one of the main solutions retained to address those issues, it will be important for all architects and other actors involved in the design and development process to be able to access clear and concise information that yet offers an exhaustive overview of the different techniques one may apply, an insight on their working and guidelines to support a choice. Such information and guidelines are what I aimed to provide with my thematic research paper.

In my graduation project, which the research supports, several key aspects in actual debates concerning sustainability in the built environment are addressed in a large scale, mostly concrete-made, poorly insulated building, which could be seen as the archetype of the un-sustainable building. The choice for a renovation is meant to support Mauro Overend’s statement that an existing building is more sustainable than a highly sustainable new building (personal communication, November 22, 2019). The main aspect addressed in the design is applying passive climate design to an existing public building. By designing a sustainable make-over of a large building housing modern and highly technical functions without resorting to very elaborate technology or materials, but on the contrary aiming for a “low-tech” approach with a lower cost and footprint, my goal is to demonstrate that sustainable passive design doesn’t necessarily mean state-of-the-art technology nor an under-developed building as a result, unfit for modern use.

> Beyond the application of natural ventilation and other sustainable principles, an important design aim consists of making those aspects visible, taking advantage of the theoretical status of an academical setting to make my graduation project a showcase of the possibility of natural ventilation and passive climate principles in the renovation of public buildings.