Figure 1: Signal Transmitters and Receivers - Collage (Gumienna, 2020).

Signal as the Medium of Migration

Antenna Architecture

Investigating the Influence of Wireless Technologies on Urbanism and Architecture

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Abstract

At the beginning of XX century, the signal discovery together with antenna invention caused a significant change in field of architecture as well as widely altered ordinary human lives by offering the society a promise of connectivity and technological advancement. The existing research focuses mostly on the historical influence of signal on architecture – sudden appearance of television towers typology in cities or public perception of antenna-related architecture. However, recent changes in architectural environment, caused by signal invention are still not investigated thoroughly. Currently, 5G technology is being implemented in cities without sufficient studies on how it will influence the field of architecture. Therefore, following research aims to translate scientific papers and hard data into architectural and urban implications. This analytical speculation, reinforced by former historical background, will allow to formulate rules and guidelines for efficient and conscious 5G implementation in cities.

Introduction

Living in the era of ongoing globalization triggers architects and researchers to investigate the origins of our contemporary cities. Renowned technological concepts and ideas migrated around the globe, giving shape to our everyday lives and habits. In retrospect, the influence of signal discovery and antenna invention on human lives and architecture becomes clear – the wireless connection became a promise of invisible dimension and a starting point of new architecture, existing solely to transmit and receive the signal. As a matter of fact, antennas on top of dwellings quickly began to nurture the beliefs in freedom and promise of advancement, given by technology. By tracing the origins of signal discovery and related antenna invention as well as through the analytical speculation on future impact of wireless technologies on architecture, the paper aims to create a background for the further, effective and sustainable implementation of wireless technologies in cities. Therefore, by identifying the key changes in the architectural environment, caused by signal progression from 1G to 4G technology and throughout a critical analysis of scientific papers regarding the anticipated implementation of 5G technology, the conducted research will be highly relevant for the design decisions regarding the implementation of this new method of signal distribution in cities. The purpose of the investigation will be to discover the architectural, urban and social consequences of 5G implementation, define rules for antenna devices implementation in cities and focus both on expected physical requirements for the built environment as well as on embracing architectural necessities related to 5G implementation in cities. Ultimately, the understanding of how wireless technologies will continue to shape cities and buildings, provided by the following research, may be a crucial knowledge and solid base for design decisions in contemporary architecture.

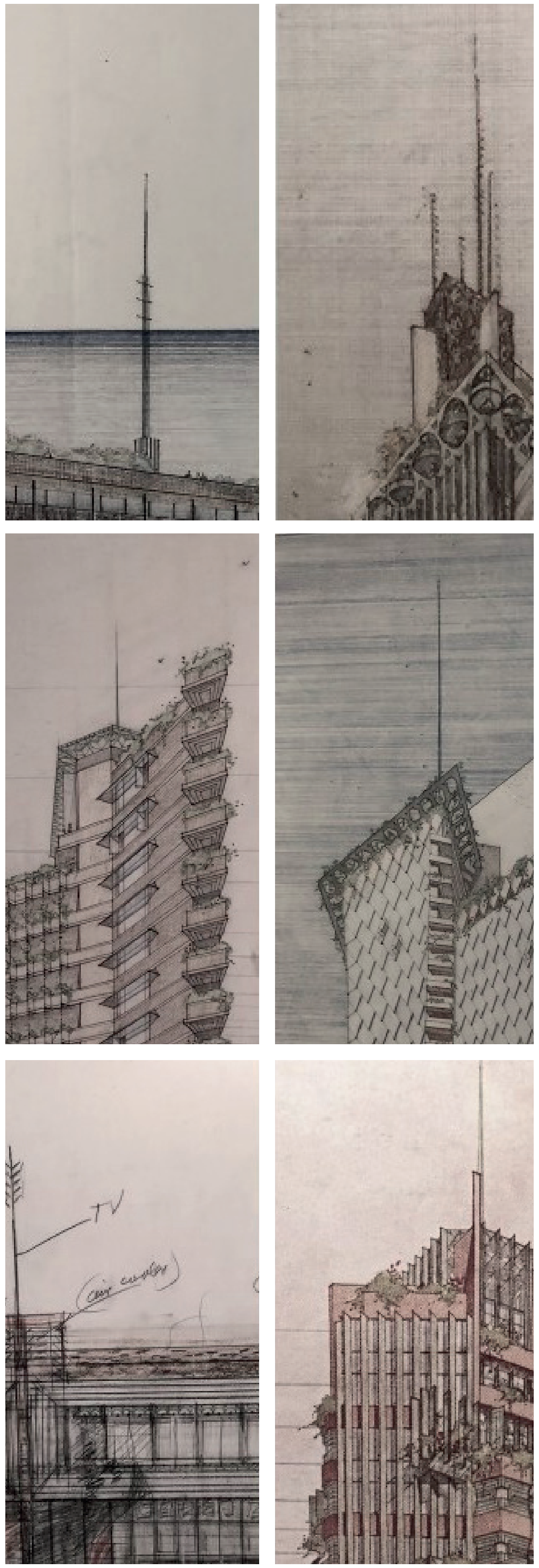

Figure 2: Frank Lloyd Wright Sketches with Demarcation of Antenna (Wright, 1921-1956)

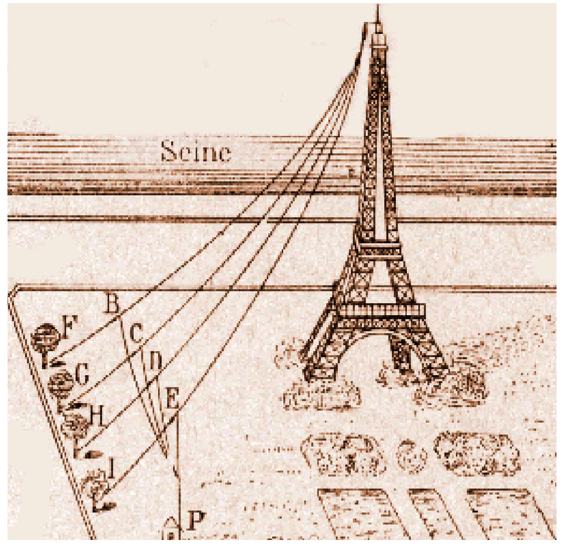

Figure 3: Drawing of Eiffel Tower with Demarcation of Signal Connections (The Telegraph, 1903).

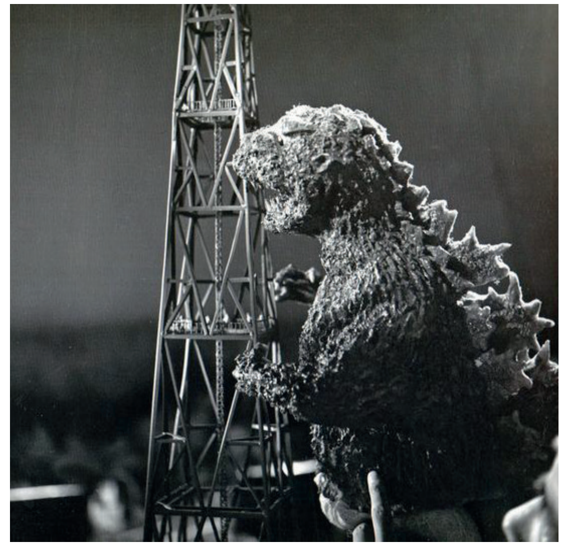

Figure 4: Footage from Japanes Movie of Godzilla Fighting with Antenna Tower (Godzilla, 1954).

History

The history of antenna begins at the end of XIX century with the radio waves first identified by Heinrich Hertz and resulting in the invention of radio a few years after (Raymer, 2009). Soon, the infrastructure of antenna towers gained presence around the globe. Nevertheless, this invention resulted not only in the presence of completely new type of signal-giving architecture but it essentially re-shaped the appearance of all buildings. Antenna became the highest point of almost each building and gradually became a requirement rather than simply add-on. This architectural transformation may be traced on the example of architect's built works and conceptual designs. Already on the early sketches of Frank Lloyd Wright, the thin lines of signal infrastructure were placed atop the buildings (Figure 2). The architect was also underlining the presence of antenna by written descriptions next to the drawings. Gradually, the buildings of Wright were becoming thinner and taller till the point when antenna and tower became one entity on the drawings of Opera House in Baghdad.

Therefore, the existing research about influence of signal on architecture is very much focused on the physical evolution of buildings, being a result of antenna invention.

As explained by Mark Wigley (2018), the technology continues to formally change architecture. As a result, of invention of antenna, the technology atop of the buildings became more interesting than architecture itself. Accordingly, the familiar forms of architecture had to adapt and become at least as appealing, as invention itself (Wigley, 2018). As a result of this transformation, the design of antenna towers was becoming an object of interest for architects and designers. The presence of radio and television towers in cities started the existence of building type, entirely unknown prior to invention of antenna. Their appearance in the urban landscape was a promise of technological advancement and the upcoming era of digitalization (LaBelle, 2010).

However, the history of antenna written only from the perspective of the physical shape of buildings would be not able to portray the true picture of its influence on contemporary world. Antenna essentially re-designed the contemporary architecture in conceptual sense. The promise of far-reaching connection given to citizens resulted in public appreciation of radio and television infrastructure (Wuebben, 2019). Consequently, as proved by the research of LaBelle (2010) it also resulted in creation of culture of transmission that emerged around the material promises of signal invention. As a matter of fact, the invention of antenna was successively adding a meaning to existing and newly constructed buildings. If it wasn't for the antenna, Eiffel Tower would be torn down soon after its completion (LaBelle, 2010). It was only due to the ability of giving signal and opportunities offered by it that residents started appreciating the presence of the tower in the cities (Figure 3). The symbolic importance of television towers may be also understood through their wide presence in pop-culture of 1950s and 60s (Figure 4). Giving as an example the Japanese, culturally significant Godzilla series, where the scenes of destruction were often revealing the tension, fantasies and promises embodied within the presence of antenna in cities (LaBelle, 2010).

Introduction of 5G

As proved by this historical background, the existing research is very much focused on the origins of antenna invention and signal discovery as well as its direct consequences on architecture in XX century. However, still little is written about potential influences of new signal technologies on built environment, while the recognition of signal influence on architecture and humans maybe a key to progress towards understanding of the feasible future for cites. Nonetheless, recently the 5G signal is being implemented without studies on how it will re-shape urban and architectural environment. Therefore, the questions remain, how does wireless technology, together with 5G implementation, promote conceptual and formal change in the discipline of architecture? How will the new 5G signal processing method influence the aesthetics and functional aspects of antenna towers?

There is no doubt that the idea encompassing the invention of antenna is much broader than the sense of connectivity, communication and information exchange. Antenna essentially became another way of sensing the world. Firstly, installed on top of our buildings was a symbol of connection between the material world and the invisible sphere of signal. In the same way, our phones with multiple hidden antennas became the extension of our body through which we gain the ability to reach the digital sphere. The fusion between human and technology became a fact. As described by Adrian Bejan (2020, p.1) people "have always lived attached to items belonging to their immediate surroundings." As a result of signal discovery, humans started living connected to their wireless machines – radios, televisions or phones. The use of signal became a form of entertainment, routine and daily activity. Members of family and friends meeting to watch president's debate or complete strangers gathering on public square to watch live transmission of human's landing on moon – all this became a part of new culture and an example of how signal invention influenced ordinary lives.

With every signal technology improvements, humans were given more possibilities. The evolution from 1G to 4G enabled among others live transmissions, geolocation system or constant connection through social media. Undoubtedly, each of the signal inventions meant a life-quality improvement and allowed human species to advance. Yet, the implementation of 5G technology raises strong human concerns about security or consequences on health. Protesters are burning antenna masts across the cities in Netherlands and spreading conspiracy theories among residents. Fear of 5G technology arises from ignorance, as the infrastructures of signal that still exist in urban areas, started being carefully camouflaged in the skyline of cities (Parks, 2019).

As long as the dispute on 5G will be based solely on emotional background, the negative perception of antennas and signal has little potential to improve. There exists an urgent need of research on 5G signal, guided and narrated by scientific discoveries that will be able to explain the potential that this technology offers in urban, architectural and social scales. Therefore, the methodology will be based on translating scientific papers and hard data into architectural and urban implications. This analytical speculation, reinforced by former historical background,

will enable the discipline of architecture to prepare for the new era of signal and embrace the potential as well as threats of 5G implementation in cities.

Impact of 5G

One of the most widespread implications of 5G technology, found in articles and publications, may be explained as presence of smart cities being recently designed and implemented on small-scale. This includes the existence of numerous sensors near roads and crossings. The mapping of 5G signal already reveals, that the main streams of 5G signal approaching the cities are dictated by the flows of people and vehicles (Figures 5-7). The 5G may allow us to optimize the fuel emissions in cities, help manage the water and waste system or allow to improve services. However, what stands behind these possibilities is an enormous amount of data produced by every electronic devices and sensors distributed around the cities. The report of TechNavio (2020) estimates that by year 2025, the world will have to store 200 zettabytes of data, while the data industry in Netherlands is experiencing an average growth of 18% each year.

Currently, the data centers are mostly large infrastructures, located on the waters of Atlantics or near the cold climate of Antarctic's. The structures tend to exists far from human residencies as they often decrease the value of neighboring properties. Due to this fact, the understanding of signal distribution is very limited, as we continue to push the technology away from cities and its residents. The signal infrastructure that appeared to be harmful for people and environment began to be present in the suburbs and countryside's. What escaped the attention of citizens, remains a problem on global-scale in terms of global-warming and sustainable growth of cities together with digital sphere as the global centers are wasting an average of 90% of energy, initially delivered to power its servers (Glanz, 2012).
Therefore, the presence of data centers far from our cities has at least two disadvantages, being the growing lack of awareness on how

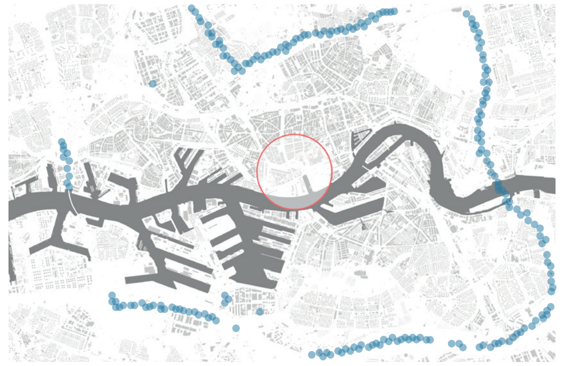

Figure 5: 5G Coverage in Rotterdan - KPN MIbile (Gumienna, 2020).

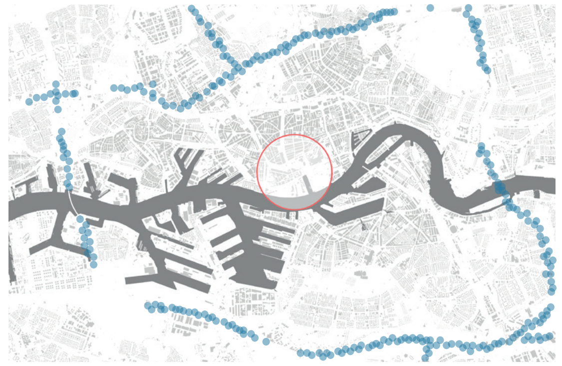

Figure 6: 5G Coverage in Rotterdam - Vodafone (Gumienna, 2020).

Figure 7: 5G Coverage in Rotterdam - T-Mobile (Gumienna, 2020).

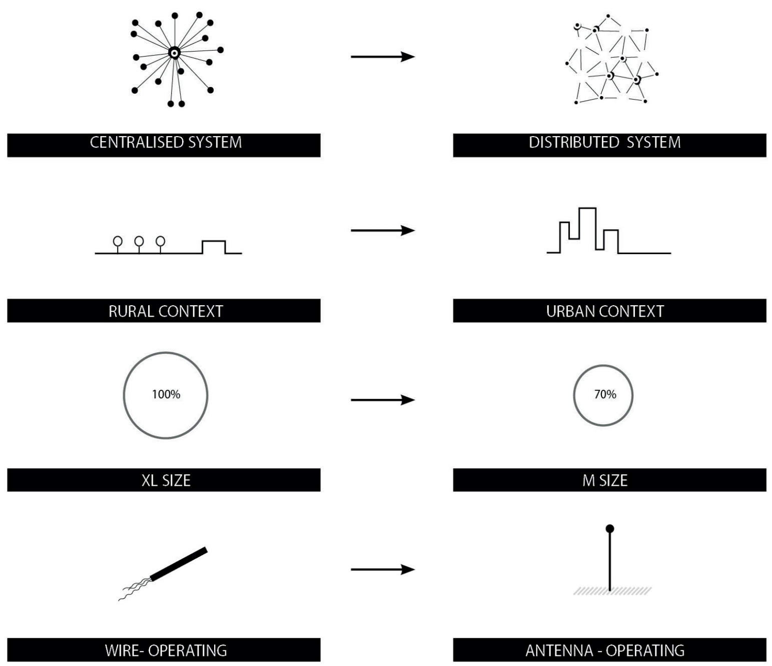

Figure 8: Diagrams Describing Change from 4G to 5G - Location, Sizes and Qualities of Future Data Centers (Gumienna, 2020).

private data is being used and distributed as well as the uncontrolled emission of heat, encouraged by absence of human settlements. This situation could be possibly improved by introducing the infrastructure of data center into the core of our cities, where the energy emitted by racks of servers could be distributed among residents. At the same time, by placing the technology that proceeds the signal closer to end-users, the awareness of signal distribution may arise. As humans tend to care about their immediate surroundings, their attention towards the process or re-using heat and sustainable data processing will encourage and force investors to improve the performances of data centers.

However, the most significant change related to the use of 5G and location of data centers is yet to be explained. The key feature of 5G technology is low latency that results in immediate signal response. Therefore, the hierarchy in signal distribution will be a key in understanding of the possibilities that it offers (Figure 9). The infrastructure of signal consists of three main elements being the 5G microsites, small cells and end receivers. Essentially, the closer is the distance between end-device and the main source of signal together with data storage, the faster one may receive a response. Therefore, data centers under cell sites will be have to be located within the maximum distance of 8 kilometers from the end-user in order to receive a 5G signal of sufficient quality (Shaw, 2019). This process will result in the change of the system of data storage from centralized to distributed. In order for 5G and future technologies to sufficiently distribute the signal, the data will be no longer stored in distinct location but will have to start being present directly in cities (Figure 8). The presence of data center in cities will be no longer a matter of choice but will become a requirement for e-businesses to develop in cities. But this process and effect of 5G in our cities should be not treated solely as necessity but rather become an opportunity to appreciate the presence of antennas in our cities again and improve the positive perception of 5G implementation in cities.

The hierarchy of 5G signal processing will result in an urban change, where the distance towards the data center and 5G macro site will become crucial to remain competitive in the private market. This process will encourage the act of gathering around signal, where within a certain perimeter around signal source, e- finance, businesses and commerce will establish. To understand this act of gathering it is crucial to explain the importance of uptime in receiving the signal. This parameter essentially presents a percentage of time, when reliable signal was received by end-user. Giving as an example, the uptime of 99% means that a company will lose a stable signal connection for about 7 hours and 12 minutes during one month, while the uptime of 99,9999% corresponds to 2.6 seconds of downtime during the same amount of time (Coffman, Kogan & Ramaswami, 2012).

These percentages will establish a hierarchy, where the sectors that are most harmed by signal disturbances will be located the closest to the data center, preferably within the physical connection to servers and infrastructure. The building type of data center will have to transform from inaccessible, isolated archive into a place of work and human interactions. Consequently, the e-businesses accepting a slightly lower percentage of uptime will start gathering and establishing its headquarters in the nearest surroundings.

While analyzing the consequences of distributed data system it is also crucial to analyze the possible location of data center under 5G macro sites in cities. As explained on the example of private businesses, the direct presence of the antenna will be a warranty of immediate signal distribution. However, the implementation of 5G will be not only important for the private investors and finance sector. The use of 5G system will be also crucial for the development of e-healthcare by enabling, among others, remote surgeries in hospitals. This is a place, where human lives will depend on the proximity of antenna and data center. Consequently, 5G microsites will be located in the direct neighborhood of medical centers, where the 5G antenna and data centers will become a protagonist of change.

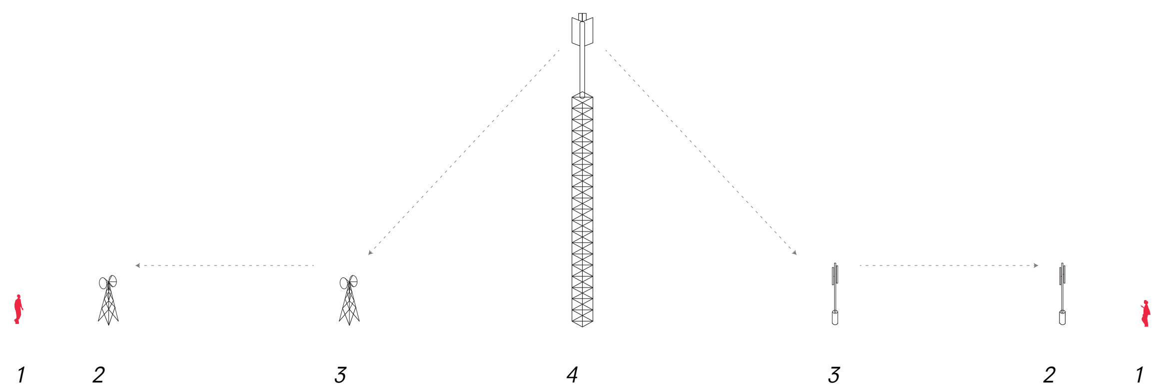

Figure 9: Diagram of Hierarchy in Signal Processing : 1. Femtocells , 2. Picocells, 3. Microsites, 4. Macrosite (Gumienna, 2020).

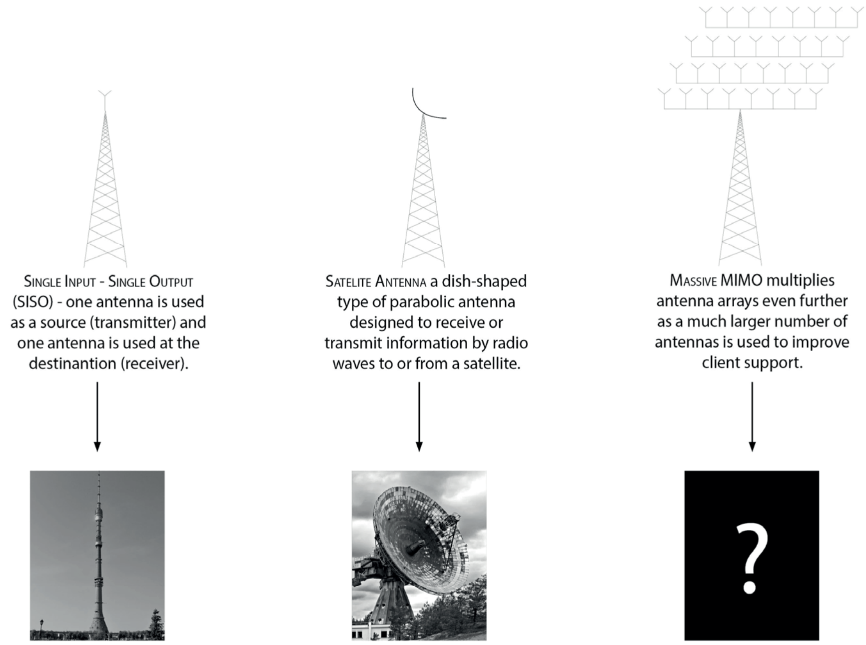

Figure 10: Equation Revealing the Influence of Antenna Types on Architectural Aesthetics (Gumienna, 2020).

The last consequence of 5G implementation in cities is directly linked to the appearance of cell towers. During the evolution in signal processing from 1G to 5G, each method of signal processing meant a physical change of antenna device – from simplest single-ending antenna through satellite disc-shaped device, up till newly invented 5G Massive MIMO antenna. Each of the changes triggered a change in appearance of the buildings. As previously described on example of Frank Lloyd Wright sketches – single thin device encouraged architects to design taller and thinner structures. Accordingly, satellite antennas initiated the fascination in cosmic, disc-shaped architecture. The understanding of this equation is important to speculate on the change related to 5G architecture (Figure 10) . As a result of this new technology, Massive MIMO transmitters will be characterized by multiple devices grouped together. As a matter of fact, according to this technology, the number of antennas exceeds the number of users - the larger amount of antenna devices will be attached to tower, the lower will be the latency (Zaidi et al., 2018). This is to say that the change from single antenna (SISO) into multiple antennas on top of tower (Massive MIMO) will cause a significant change into appearance of the buildings. The antenna towers will no longer be a thin structures ending with single device on top. Instead, as a result of 5G technology, towers will abound with multiple transmitters attached to main structure.

CONCLUSIONS

As proved by the research, the 5G revolution will not bypass the discipline of architecture. Ever since the discovery of signal in XIX century, the invisible sphere of wireless connections continues to re-shape the built environment together with human lives. As long as the technology of signal processing continues to evolve and the journey that started with 1G is not finished, the discipline of architecture will undergo a constant change dictated by improvements in wireless technologies. What always appears in cities together with new antenna devices are entirely new building types, unknown before opportunities for humans and unfamiliar forms of aesthetics, initiated by scientific discoveries. Trying to answer questions, how does wireless technology, together with 56 implementation, promote aesthetic and functional change in the discipline of architecture and how this research may be applied in the design process, it is important to summarize the influence of 5G on three scales, being the urban, architectural and social.

First of all, the presence of 5G will result in urban transformations, where functional signal dependency will become a key to establish a hierarchy of signal distribution. This urban rule will be important during city planning process as well as may become a tool to activate entire neighborhoods by encouraging e-businesses to establish their facilities in direct neighborhoods of 5G Microsites.

Second of all, the new signal processing method will encourage changes in architectural scale, meaning the popularization of new building type that combines 5G microsites with data centers as well as physical change in appearance of antenna towers, where the mMIMO devices will initiate new architectural language and aesthetics.
Ultimately, the architectural research is crucial in reversing the widespread negative perception of 5G signal by proving that this new technology is another promise of advancement and opportunity for residents living in its direct surroundings. By promoting the transparency in 5G implementation and creating a new architectural language for antenna towers, the current policy of infrastructural invisibility should be altered in order to increase the level of public trust. Only the explicit, physical presence of signal-giving objects may bring back the sense of acceptance towards antennas and technology.

Presented speculative analysis, conducted on the base of historical background, scientific knowledge and hard data will constitute a base to test the research topic by design in the city of Rotterdam. By applying the gained knowledge about 5G implementation, the project will embrace the global change associated with 5G revolution on the example of specific city and site. By testing the model of signal implementation on the exemplar design of signal receiver and transmitter, the project will tackle among others the problems of public perception of antennas, sustainability of signal processing as well as embrace the physical change in appearance of cell towers related to implementation of new 5G antenna. Acknowledging, that as a result of the 5G revolution, the earth will be equipped with more antennas than humans populating the planet, the challenge remains for architects to embrace this change by ending the era of infrastructural invisibility.

APPENDIX - DESIGN BRIEF

Figure 11: Project Scope - Transmitter & Receiver Along Planned Business Boulevard - Westzeedijk in Rotterdam (Gumienna, 2020).

The primary design objective is to develop an architectural project that will explore the potential of 5G implementation in the city of Rotterdam. As proved by conducted research, the upcoming presence of 5G antennas in cities will encourage the act of gathering around the signal transmitter as the close proximity to the source will be a guarantee of reliable connection. Therefore, e-businesses and private investments operating in the digital field will establish their company branches in the proximity to 5G Microsites (Figure 11). Acknowledging that the architecture of signal processing is always defined by the main transmitter and receivers, the project will be the architectural representation of these two elements, being the signal source well as an example of e-business headquarter established in the direct proximity of 5G Antenna.

TITLE OF THE GRADUATION PROJECT
Space of Signal

PROBLEM STATEMENT
5G is being implemented in the cities without sufficient studies on how will it re-shape urban and architectural environment

RESEARCH QUESTION
How does wireless technology, together with 5G implementation, promote esthetic and functional change in the discipline of architecture?

PROGRAM AMBITION

The program for transmitter and receiver is based on conclusions of research conducted about 5G implementation in architecture. The investigation into scientific papers revealed that together with the change from 4G to 5G, the data processing will experience a rapid change. Due to the need of immediate exchange of information between the receiver and digital storage space, data centers will have to be built together with thousands of new cell towers in cities, ultimately resulting in the creation of new building type.

At the same time, one of the branches that will experience a rapid growth will appear to be a telecommunication operators that together with implementation of 5G will have to start cooperating closer than any before, while equipping cities and event with billions of new devices and allowing the streams of signal to reach each citizen in the country.

CLIENTS & USERS AMBITIONS

The signal transmitter is planned to be established as extensions of Erasmus MC, essential for enabling the hospital reliable signal source in order to perform remote surgeries and promote e-healthcare. As a result, it is planned as a public investments serving for both public and private use. Consequently, the receiver will be designed for private clients being three 5G Signal Distributors in Netherlands: KPN, Vodafone and T-Mobile. However, the cooperation center will include a large percentage of space, dedicated fro public access, being the 5G Experience Center and related exposition space.

DEVELOPMENT AMBITIONS

By designing two facilities, transmitter and receiver, the graduation project will constitute a model for the 5G implementation in the city. Therefore, the development ambition is a collaboration between public and private investors. The 5G Antenna Tower, by being built in the first place, aims to become a protagonist of change for the neighborhood and encourage its prompt economic development.

URBAN AMBITIONS

Currently, the unemployment rate of Western Archipelago area reaches 19%, while for the city of Rotterdam this indicator is not exceeding 9%. Undoubtedly, this condition reflects social status of its residents. The planned 5G Antenna Tower will become a protagonist of change, announcing the economic revival of Defshaven district. By attracting companies that require reliable signal connection, the working prospects for the region will increase, while contributing to the vision of Rotterdam as city of innovation. Therefore, defined urban ambitions will at the same time allow to improve the social and economic conditions of Western Archipelago Site.

Site Locations

The transmitter and receiver will be distributed between two separated plots. As explained already in the text, transmitter will be a part of Erasmus MC extension, while 5G Cooperation Center will be establish on the plot in the direct proximity of 5G Antenna. At the same time, 5G Receiver will be located directly next to the newly established business boulevard, connecting Boompjes with Creative District. The plots of transmitter and receiver have accordingly the sizes of 650 and 3600 m2. The maximum coverage and requirements were defined by infrastructural requirements compared to city rules and analysis of existing buildings (Figure 12).

Due to the maximum land coverage defined by city for Erasmus MC site as 60 % (current coverage 59%), the 5G Antenna is planned as extension of Erasmus MC placed atop existing office spaces. The height of the transmitter was based on minimal requirements for efficient signal processing, what raised the maximum height established by municipality from 60 to 120m (Figure 13). The site of the receiver is not regulated by the city rules. Therefore, the guidelines for brief were defined solely on the analysis of neighboring plots and current development trends in the neighborhood (Figure 14). As a result, the maximum coverage percentage is reaching 65 %, while the maximum height was set up for 20m, due to the direct presence of high-rise building on the neighboring plot.

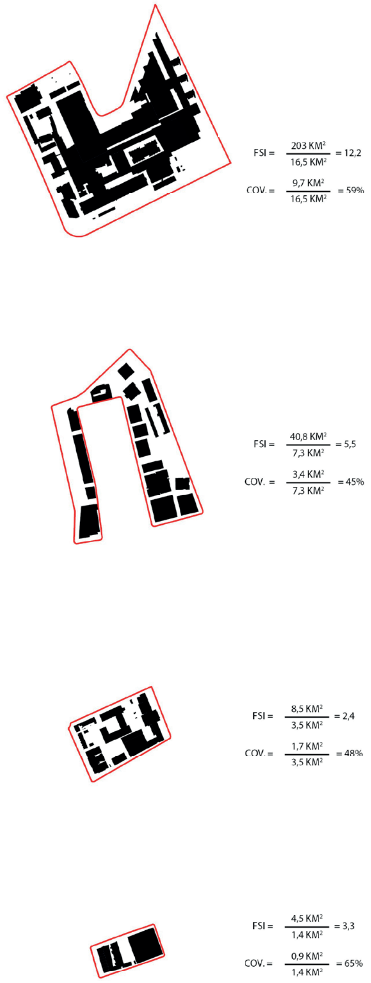

Figure 12: Average FSI and Coverage Analysis for Area of Western Archipelago, Accordingly 2,7 and 55% (Gumienna, 2020).

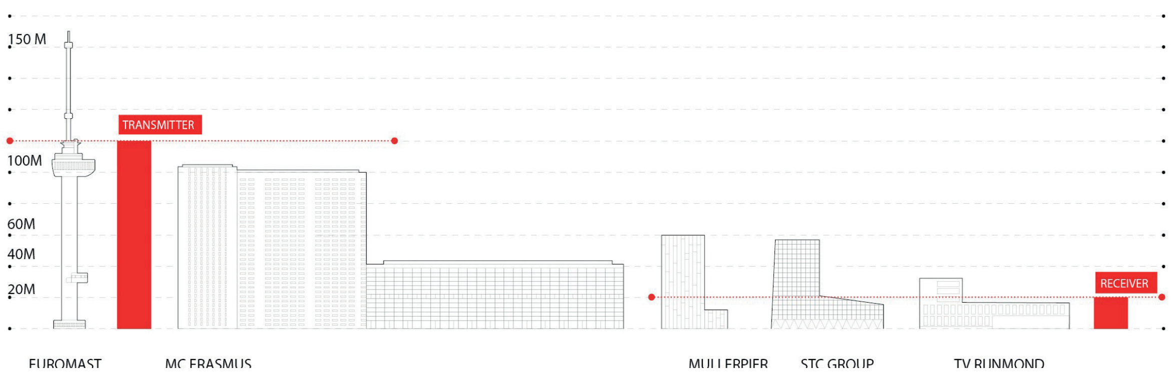

Figure 13: Height Studies for Transmitter and Receiver in Relation to Signal Transmission Requirements and Exisitng Buildings (Gumienna, 2020).

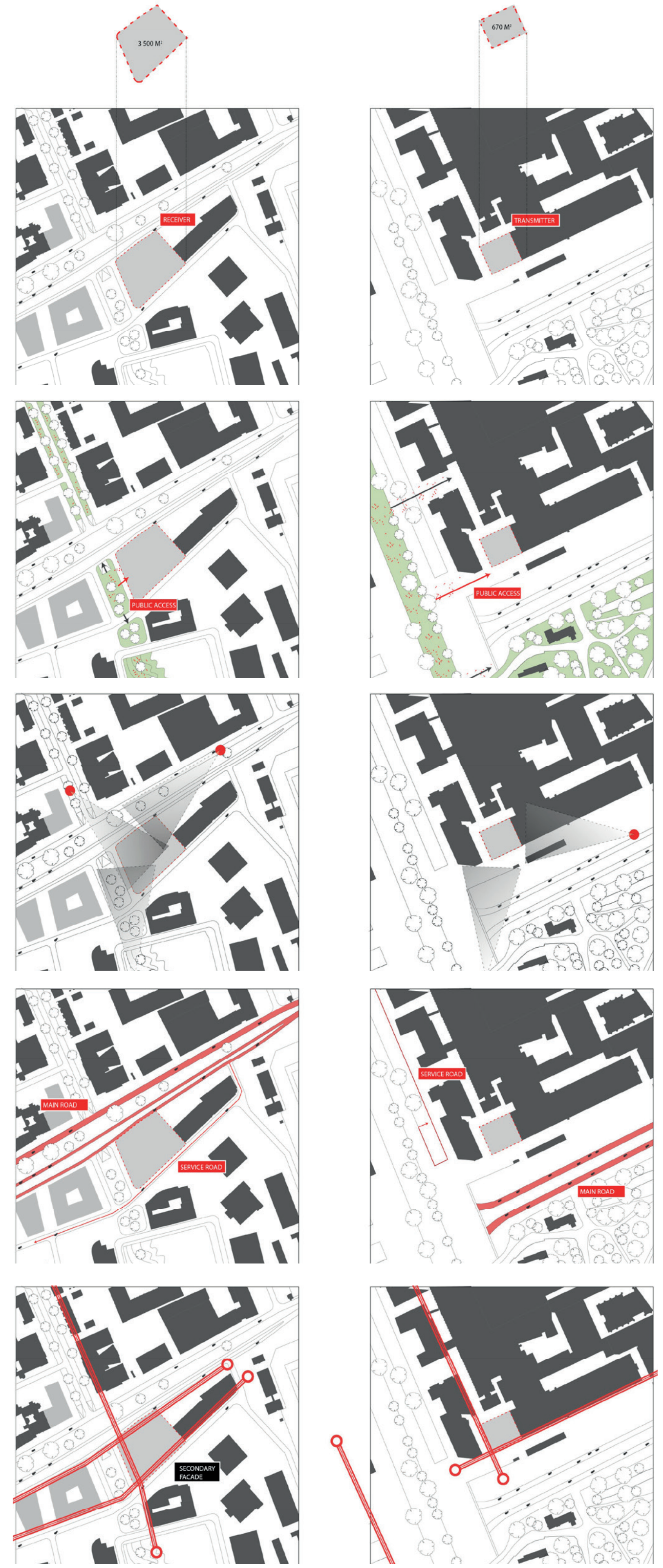

Figure 14: Urban Analysis, From Top: Plot Sizes, Pedestian Flows, Visibility Studies, Primary and Secondary Roads, Building Lines (Gumienna, 2020).

Program Definition

The precise program presented on the attached bars is based on comparative analysis of existing typologies of data centers, telecommunication centers and televisions towers as well as critical analyses of gathered data. In order to ensure the appropriate program definition for both facilities, the research included analyses of 16 case studies, including comparative investigation into program bars and relation schemes of mentioned building types. The proposed sizes of facilities are based on current trends being the distributed system of data collection, where newly built facilities are reduced in size in comparison to existing buildings as well as prognoses growth of telecommunication business by 23%, resulting in analogous growth of required operational space. In this way, the initial size of facilities was determined, being accordingly 13 000 m2 and 16 000 m2 for Antenna Tower with Data Center and Cooperation Center for 5G Operators (Figures 15 and 16).

Furthermore, a research was made into specific spatial qualities to define more precisely functional divisions and requirements. Thus, the 5G Antenna Tower will constitute in 20% of public functions, being observatory, restaurant and related facilities, while 55% of building surface will be dedicated for data server's storage. The remaining part of the tower will serve as office and technical space.

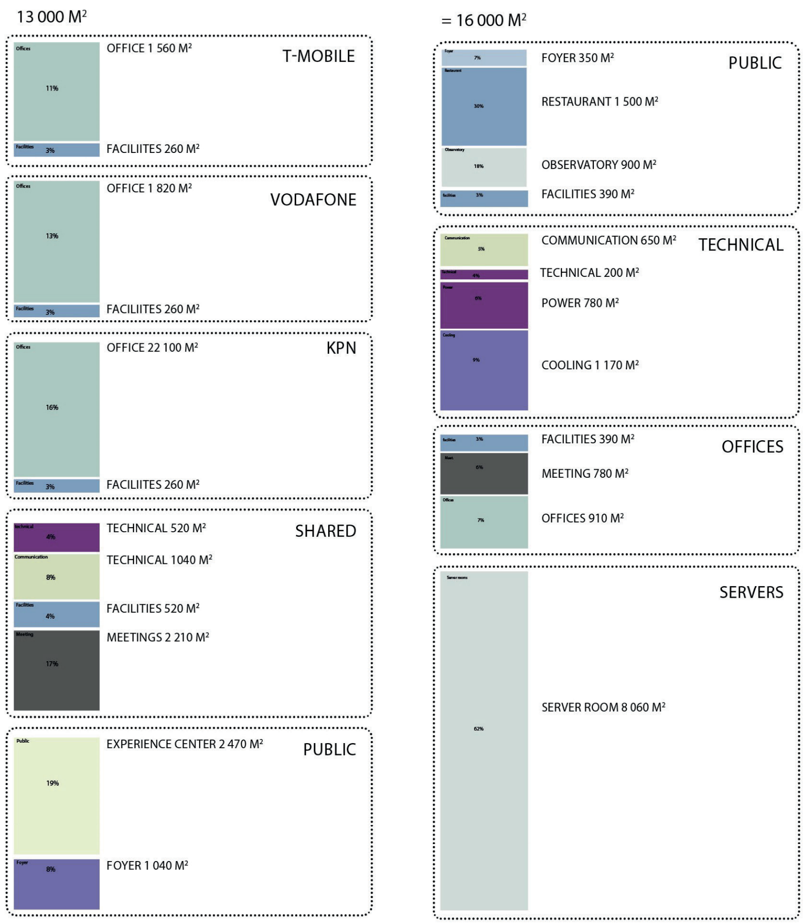

Figure 15: Program Bars for Transmitter - Left Side - and Receiver - Right Side (Gumienna, 2020).

In the signal receiving facility, 45% of building surface will be dedicated for office spaces of KPN, Vodafone and T-Mobile companies, while the space dedicated for their cooperation is estimated for around 4 000 m2 (25%). The program will also include a public zone, where 5G experience center will be established. According to future trends, retail in the telecommunication centers is transforming into spaces, where products may be experienced and tried out, instead of spaces serving purely to exhibit and sell products. As a result, over 20% of total surface will be a flexible space, serving for experience center of recent technologies, introduced as a result of 5G signal implementation.

To conclude, both facilities will be a mixed-use entities, consisting of a 20-25% of public functions, next to the infrastructural and office spaces. By doing so, the infrastructure of signal processing will become more accessible for people what may constitute towards the better understanding of technology surrounding the society and will contribute towards decrease in fear and negative perception of 5G signal.

Relation Requirements

The relation schemes, presented on attached diagrams are primary based on analysis of existing typologies and defined by clear functional divisions.

The primary functional division of 5G signal transmitter is divided between public functions (restaurant and observatory), storage of data with restricted access as well as semi-private office spaces and technical space (Figure 16). The design challenge will be to assure security of data storage, while providing public access towards observatory on the top part of the building.

The relation scheme of 5G Cooperation center is based on functional division between zones of public access, joined cooperation space for the common use of companies as well as three separate office spaces for KPN, Vodafone and T-Mobile workers (Figure 17). The primary objective of this relation scheme is to create a space of interaction while respecting the presence of these three companies as separate entities.

Building Ambitions

The primary design objective is to embrace the architectural esthetics related to the new methods of signal processing being the invention of 5G Massive MIMO Antenna, resulting in the presence of numerous devices atop the 5G Microsites, instead of a single object (SISO). At the same time, the new architectural language for 5G antenna towers and exhibition numerous antennas will constitute towards the transparency of technology implementations in the cities. By doing so, the level of public trust will increase, leaving little space for conspiracy theories emerging out of fear of invisible infrastructures.

Therefore, the 5G Antenna Tower will become an iconic object in the skyline of Rotterdam, while keeping visual relation with Euromast tower, which stands as a historical evidence of technological advancement.

However, together with the 5G technologies, cities will need to accommodate 10 times more antennas than are currently existing (Zaidi et al., 2018). Ultimately, equipping world with more antennas than humans populating the planet. By designing a model for antennas implementation in receiving facility as well as transmitter, the graduation project will aim to propose a model of 5G antennas application in built environment.

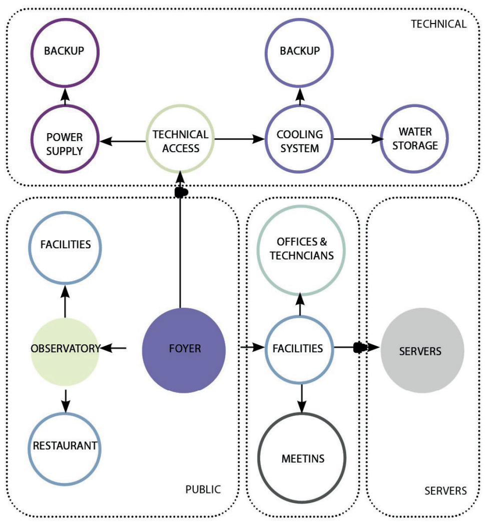

Figure 16: Relation Scheme - 5G Macrosite with Data Center (Gumienna, 2020).

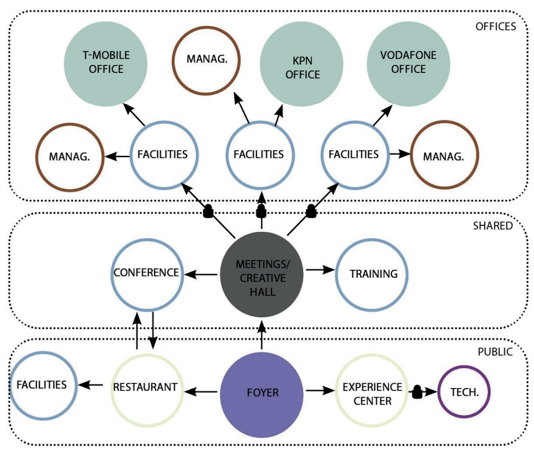

Figure 17: Relation Scheme - 5G Cooperation Center (Gumienna, 2020).

Plan Of Approach - Appendix

Relevance of the Graduation Project

Acknowledging that the world of wireless connections is more extensive than ever before, the research on the influence of 5G signal distribution method on built environment appears to be highly relevant in determining the future functional and aesthetics directions in architecture. The conducted analytical speculation will inform the graduation project and allow to test research by design process. Ultimately, the graduation project will be relevant in the field of urban and architectural studies, as it will define rules and guidelines for 5G implementation in cities.

Methodology

The outlined planning of Msc4 (Figure 18) is split into four phases, being: concept, design, materialization and visuals. Each five weeks of work will be concluded with a presentation that all together will contribute towards the structure of final P5 presentation. This work division will allow to ensure that the design process remains on track and assures satisfying and complete results at the end of semester.

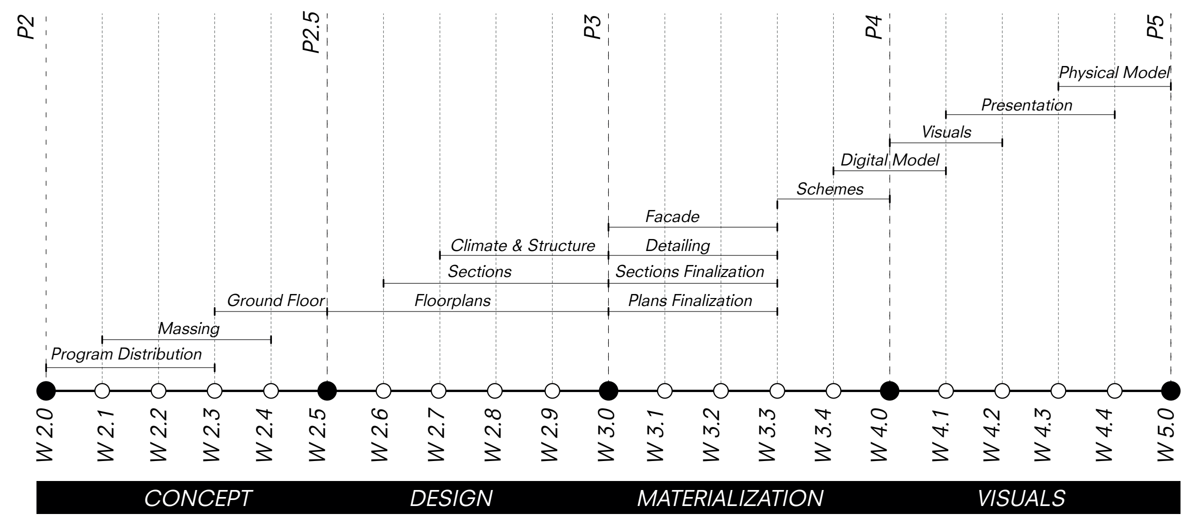

Figure 18: Msc4 Graduation Timeline (Gumienna, 2020).

Timing

Phase 1: Concept
Timing: Weeks 2.0-2.5

The first phase of design will be dedicated for development of design concept together with massing definition and program distribution on both plots.

As the first step, program distribution on the plot will be arranged, according to urban rules defined during the research, while taking into consideration building's connection to the site and by creating architectural response to existing urban conditions. The preliminary program distribution will be based on program bars defined during the research to ensure accuracy of created plans.

At the same time the massing concept will include creation of the design options for antenna devices atop the buildings and focus on answering the question, how will the presence of new antenna type, being Massive MIMO, influence the esthetics of contemporary architecture?

At the end of this phase, the goal is to prepare final massing model for both plots and preliminary program distribution with the given building volume.

Phase 2: Design
Timing: Weeks 2.5-3.0

During the second phase of design, a focus will be made on development of plans and sections. In this period, the design in planned to be developed in 1:200 scale with the focus on spatial qualities and functional layout. Already at this stage, preliminary decisions about structure and climate will be taken into consideration to ensure sustainability of chosen solutions.

The design will be developed continuously with group vision to ensure cohesion of decisions and allow to reach densification, economic and social targets, defined by group during the research period. The ultimate goal will be to strengthen the group vision and contribution of individual project towards the larger context.

At the end of this phase, the building plans and section should be on advanced stage.

Phase 3: Materialization
Timing: Weeks 3.0-4.0

The third phase of design will be dedicated for detailing and materialization. During the five weeks, the climate and structural systems will be defined together with detailing and materialization of the facade. The project will be developed with particular attention towards sustainability to meet the goal of Rotterdam's zero carbon emissions until 2050. Therefore, major attention will be put to heat re-use form data servers. By ensuring the use of side-produced heat, up to 90% of required energy may be saved.

Together with the clarification of structural and material choices, the plans and sections will be completed. By the end of this phase, the design process and detailing should be completed to ensure further, proper graphical representation.

Phase 4: Visuals
Timing: Weeks 4.0-5.0

The final phase of MSc4 will focus on development of building visuals together with completion of final P5 presentation. During this phase a focus will be primarily made on graphical representation and creation of clear, visual language. At the same time, the goal will be to prepare the physical model on urban scale, being able to present both of designed facilities at once.

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