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ROLE OF INFRASTRUCTURE IN DETERMINING THE ARCHITECTURAL COMPOSITION IN XXI CENTURY

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Немања С. Кордић

УЛОГА ИНФРАСТРУКТУРЕ У ДЕТЕРМИНИСАЊУ АРХИТЕКТОНСКОГ СКЛОПА У XXI ВЕКУ

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SUMMARY

Title: Role of infrastructure in determining the architectural composition in XXI century

Today, within the neo-liberal market of the 21st century, architecture became a tool of capital, demanding minimal investments with maximum spatial and environmental performances. Permanent social and economic changes that follow the rapid development of an information-based society imply a new take on the architectural composition, which became increasingly programmatically unstable and market-driven, especially within the mixed-use city centers. A need for programmatic flexibility and the possibility of transformations are driven by the necessity to answer the ever-increasing need for efficiency at all spatial levels from urban to building. As the infrastructure of a building considers all technological components that support the operation of its program, programmatic transformations should also be based on infrastructural tenets.

Therefore, it is necessary to establish infrastructural tenets in the process of design, oriented towards intensifying: land use, spatial efficiency, and the resilience of buildings increasingly based on programmatic flexibility. As the traditional understanding of architectural composition is perceived through part-to-whole relations on three basic levels: form, function and structure, the mentioned correlation could be translated today as volume, "program range", infrastructure. The volumetric typologies are determined with urban parameters, while programs within are still driven by the planned building usage through top-down planning decisions – which is problematic since the program transformations are most often not envisioned by urban planners, investors and architects. A new design approach is needed to investigate the capacities of programmatic transformations for different building typologies, by pursuing the tenets of flexibility and performativity while maintaining optimal spatial efficiency. Besides, the relation between the program structure envisioned within the design process and its possible transformations after a project has been realized is yet to be determined. Changes within architectural objects are complex, and for that reason, reconstructions, where major reprogramming happens, are rare and most often not feasible on a larger scale – for various reasons: legal (ownership structure, zoning laws), economic (lack of profitability), infrastructural (lack of infrastructural capacities, or an unsuitable and not upgradeable infrastructural layout).

Within the research process, several methods have been used to analyze the role of infrastructure in contemporary architectural context: analysis and systematization of sources, multi-variational analysis of the historical research context, and logical argumentation. Methods of case studies and comparative analysis are used to establish typological relations between volumes and different programs and to indicate the intersecting scopes within infrastructural layouts necessary for programmatic transformations and/or achieving mixed-use compositions. Research has investigated 22 different projects of two dominant programs (office and housing) facilitated within the two chosen volumetric typologies which are emerging in urban settings of different densities. Furthermore, a quantitative and qualitative analysis is performed. The analysis investigated relationships between urban parameters, spatial efficiency indicators, and typical building layouts. The developed methodology has been tested on a location in Belgrade, demonstrating the principles through the process of critical analysis using computer simulation and graphical narration.

Within this research, infrastructure is perceived as a design parameter of architecture by expanding the notion of *infrastructural tenet,* a term that integrates and organizes infrastructural elements of a building within the boundaries determined by the capacities of a plot (as an infrastructural ground). The role of infrastructure in (determining) the architectural composition in the 21 century could be: to maintain spatial efficiency, obtain functional neutrality (transformational capacity and mixed-use ability) while maintaining an economical, ecological and social equilibrium of a building.

Methodology tested the principle of multi-functional infrastructural layouts investigating the relationship between the spatial efficiency and infrastructure that can support both office and housing programs within the same volume.

The result of the process is an intersecting scope of spatial efficiency parameters for the two-volume and program types, which enabled establishing a repository of functionally neutral typical plans presented as a typological gradient. Besides that, a set of urban parameters is formulated and used to realistically locate the functionally neutral and mixed-use buildings within urban contexts of mixed-use city centers. Finally, an algorithmic model is proposed to simulate, quantify and visualize the land use potentials for plots in mixed-use city centers using the previously established repository.

The proposed model based on infrastructural tenets can be used to boost the development of mixed-use and functionally neutral buildings desirable in today's unpredictable and increasingly rental oriented real estate market. For the developing of an urban automation tool (UAT) - a concept for a software platform (envisioned as an additional – operative part to the main body of the research), the same model is used to simulate potential developments in a transparent and readable way for different stakeholders, which could be a step forward towards a participative – process based architecture and a more sustainable and inclusive development of contemporary cities.

Keywords: infrastructure, infrastructural tenet, architectural composition, spatial efficiency, transformation, infrastructural ground, functional neutrality, process-based architecture, urban automation, real estate;

Scientific field: Architecture and Urbanism

Scientific subfield: Architectural design and contemporary architecture

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САЖЕТАК

Наслов: Улога инфраструктуре у детерминисању архитектонског склопа у XXI веку

Данас, у оквирима неолибералног тржишта 21. века, архитектура је постала инструмент капитала, захтевајући минималне инвестиције, а максималне просторне и енвајронменталне перформансе. Константне друштвено-економске промене које прате брзи развој информационог друштва иницирају нови приступ поимању архитектонског склопа, који вођен тржиштем постаје програмски нестабилана категорија - нарочито у зонама градских центара. Потреба за програмском флексибилношћу и могућности трансформације вођена је неопходношћу да се одговори на растуће захтеве за ефикасношћу на свим просторним нивоима: од урбаног - до нивоа самог објекта. Како инфраструктура архитектонског објекта подразумева све технолошке компоненте које подржавају његов програм, следи да ће и могуће програмске трансформације бити засноване на инфраструктурним принципима.

Стога, потребно је успоставити инфраструктурне принципе у процесу пројектовања усмерене према интензивирању: коришћења земљишта, просторне ефикасности, и отпорности објеката - која се све више заснива на програмској флексибилности. Архитектонски склоп се као однос делова и целине традиционално разматра на нивоима: форме, функције, и структуре, док се данас ова корелација може разумети као однос: волумена, "програмског опсега" и инфраструктуре. Типологије волумена објеката одређују урбанистички параметри изграђености, док је програм и даље углавном одређен кроз *топ-даун* (top-down) планске процедуре, што је проблематично са обзиром да програмске трансформације и даље нису предвиђене од стране планера као ни од инвеститора и архитеката. Потребан је нов приступ процесу пројектовања, који би истражио капацитете и могућности програмских трансформација и који одговара потребама различитих типологија објеката водећи се принципима: флексибилности и перформативности, истовремено одржавајући неопходне нивое просторне ефикасности. Поред овога, неопходно је одредити однос између трансформација предвиђених у процесу пројектовања и оних могућих након реализације. Промене у архитектонским објектима су комплексне, из разлога што су реконструкције у којима се дешава репрограмирање ретке и најчешће неизводљиве у већим размерама - из различитих разлога: правних (власничка структура, правила градње), економских (недостатак профитабилности), инфраструктурних (недостатак инфраструктурних капацитета или неодговарајући - ненадоградиви инфраструктурни распоред).

У процесу истраживања коришћено је више метода да би се тема инфраструктуре разматрала у размери архитектуре: анализа и систематизација извора, мулти-варијациона анализа историјског контекста и логичка аргументација. Методе студије случаја и упоредне анализе коришћене су за успостављање типолошких односа између различитих типова волумена и програма као и за утврђивање заједничких именитеља унутар инфраструктурних распореда анализираних пројеката - неопходних за постизање програмских трансформација или склопова мешовите намене. Током истраживања испитана су 22 пројекта - стамбене и пословне намене, кубичних и издужено-призматичних волумена, који припадају контекстима различитих густина изграђености. Коришћењем метода квантитативне и квалитативне анализе истражени су односи између: урбанистичких параметара, индикатора просторне ефикасности склопа, типских планова. Методологија је тестирана на одговарајућој локацији у

Београду демонстрирајући успостављене принципе кроз процесе и методе: критичке анализе, компјутерске симулације, и графичке нарације.

У овом истраживању инфраструктура је посматрана као пројектантски параметар архитектуре проширујући разумевање појма *инфраструктурног принципа* који интегрише и организује елементе инфраструктуре архитектонског објекта унутар просторних оквира (волумена) одређених капацитетима парцеле као инфраструктурног тла. Улога инфраструктуре у детерминисању архитектонског склопа 21. века је одређена: одржавањем просторне ефикасности, постизањем функционалне неутралности (која укључује могућност трансформације и мешовите намене) као и одржавањем економског, еколошког и друштвеног еквилибриума објекта.

Користећи представљену методологију, тестиран је принцип фунционисања мултифункционалног инфраструктурног распореда којим је истражен однос између просторне ефикасности и инфраструктуре која може да подржи и стамбену и пословну функцију у оквиру истог волумена. Ово је резултирало формирањем репозиториума функционално неутралних типичних планова поређаних тако да формирају скаларни - типолошки градијент архитектонских склопова. Након овога, утврђен је и опсег урбанистичих параметара у оквиру којих се функционално неутрални или објекти мешовите намене могу наћи - а то су зоне мешовитих градских центара.

На крају, предложен је и алгоритамски пројектантски модел који тежи да: симулира, квантификује, и визуализује потенцијале коришћења земљишта за парцеле у мештовитим градским центрима користећи се претходно успостављеним репозиторијумом. Предложени модел могуће је користити за поспешивање развоја функционално неутралних и мешовитих типологија пожељних на данашњем непредвидивом тржишту некретнина које се све више окреће рентирању простора. Алат за урбану аутоматизацију (УАТ) - концепт софтверске платформе (замишљен као додатни - оперативни део овог истраживања) користи овај модел да различитим *стејкхолдерима* (stakeholders) симулира потенцијалне грађевинске подухвате на транспарентан и читљив начин. Стога, истраживање нуди предлог за корак напред према партиципативној и процесној архитектури као и одрживијем и инклузивнијем развоју савремених градова.

Кључне речи: инфраструктура, инфраструктурни принципи, архитектонски склоп, просторна ефикасност, програмска трансформација, инфраструктурно тло, функционална неутралност, процесна архитектура, урбана аутоматизација, некретнине;

Научна област: Архитектура и Урбанизам

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CONTENTS

GLOSSARY OF TERMS AND ABBREVIATIONS

List of terms:

Architectural composition

The traditional understanding of composition of an architectural object is perceived through sets of part to-whole relations on three basic levels: form, function (program and its performance) and structure (Arnheim, 1979). In the context of this research the mentioned array can be translated as: volume, “program range”, infrastructure - where infrastructure integrates the structural and performative aspects of architectural composition).[1]

Functional neutrality

Functional neutrality is a concept proposed by Theo Van der Voordt (2016) meaning the possibility of giving a building another function. The members of Chair for Real Estate and housing at TU Delft have developed a significant research on this topic after the 2000. Functionally neutral building are designed is such a way to satisfy the functional demands of more than one program within the same volume and can easily change its function from one to the other. This research explores the infrastructural and spatial demands for office and housing programs in order to determine a typological series of functionally neutral architectural compositions (suitable for both programs). [2]

Figure ground condition

A relation between a building (figure) and ground (plot).

A Figure ground diagram describes a mass to void relationship also a relationship between built and unbuilt space within urban fabric. A reverse figure ground diagram was introduced by Frederick Gibberd (1955) to emphasize the more complex nature of urban fabric through the existence of poché and the more complex nature of the ground level. In the modern period, Le Corbusier promoted the “free ground level” though his prototypical projects such as Villa Savoye and Marseille block. Koolhaas (1993) calls for more rich figure ground relation as continuous poché to interconnect architecture within the urban fabric. [3]

Kipnis (1996) summarizes figure ground condition through three examples: appropriation, staging, liberated ground. In the context of this research the figure ground condition is determined through the encounter of urban and building infrastructures within the zone of a building plot.[4]

Infrastructure (of architectural composition)

Infrastructure of an architectural composition can be defined and located in a simple way a s a difference between Gross Floor Area (GFA) and Gross Leasable area (GLA) . However in order to precisely locate the infrastructures this difference needs to be found within the volume as well. It is expected that different three dimensional layouts of these elements are depending on typologies in which applied and they suggest regularities - infrastructural tenets which determine the architectural composition.[5]

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1 Explained in section Introduction / Research context
2 Explained in section 2.1, 2.1.1
3 Wikipedia. 2020. “Figure-ground diagram” 20.10.2020. https://en.wikipedia.org/wiki/Figure-ground_diagram.
4 Explained in section 1.5
5 Explained in section 2.2.2

Infrastructural elements (of architectural composition)

This research considers the infrastructures of architectural objects as elements that relate to: movement (stairs, lifts, ramps, escalators, foyers…), comfort (active and passive HVAC systems, openings, illumination and ventilating systems), division and distributions of space (subdivision walls, shades…) and structure.

Infrastructural ground

Infrastructural ground is the space where capacities of urban infrastructures provided by the city converge into the architectural composition determining its volumetric and programmatic potentials and boundaries, including the scopes of its possible future transformations. This term integrates theoretical positions of Stan Allen and Gilles Delalex: understanding of the field intensities – a thick 2D (Allen), and architectural objects as extensions of urban infrastructures (Delalex).[6]

Infrastructural tenet (design process - methodological) [7]

The term is originally coined by Jeffrey Kipnis (1996) to signify the design procedure of extending urban infrastructures into the building. Since a building itself can be perceived as extension of urban infrastructure, infrastructural tenets are methods that organize the infrastructural elements within building volumes determined with the infrastructural ground.

Within this research, infrastructural tenets are presented through typology related layouts and sets of recommendations aiming towards programmatic transformations.

Infrastructural layout (operative – typology related)

Infrastructural layout is an operative design tool for distribution and configuration (2d and 3d) of infrastructural elements. Within this research it is implemented to achieve functional neutrality within a selected scope of program and volume typologies and written through generic typical plans.

Process based architecture

Process architecture is based on planning and designing infrastructure with respect to the current and the future needs of its users. An architecture whose content is transforming since its conception all the way through design, construction, and exploitation. An architecture ready to grow and diversify its functional units as the user-groups change their needs through time - a resource equally important as space.

Spatial efficiency

Spatial efficiency of a building can be measured on urban level (land use: maximal build up in relation to the urban parameters such as FAR, height, site occupancy), and a building level (relations between the gross areas (GFA) and leasable areas (GLA) and volumes, and to which extent the building approaches the boundaries of typological standards related to program, economy, ecology.)

Spatial efficiency within this research is related to the economic or ecologic value but it doesn't include spatiality in a sense of social and architectural value. It is used in this research as a methodological tool - a set of measurable parameters convenient to evaluate efficiency for the more commercial architectural typologies such as office and housing. [8]

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6 Explained in section 1.5
7 Explained in section 1.5
8 Explained in section 2.2.2

Volume typology[9]

Volume typologies of architectural objects are based on the rough proportions (X * Y * Z) of architectural objects.

This term originates from the research of Alejandro Zaera Polo (2008) about the architectural envelope typologies and the technical and political implications of their proportions, context and environmental characteristics. Zaera Polo focuses on the outside of the volume – the envelope while this research focuses mainly on the inside infrastructural implications.

Zaera Polo sets four types of volumes which can be (but not necessarily) read programmatically: flat horizontal X=Y>Z (malls, factories – loose-fit); spherical X=Y=Z (HQs, public buildings-relaxed fit); flat vertical – tight-fit X=Z >Y (housing slabs); vertical slim fit Z> X=Y (office highrise). This research uses the two volume typologies for the case studies:

-spherical X=Y=Z - later named "Cubes", which stand for buildings of similar base and height proportions like cubes

- flat vertical X=Z > Y - later named "Slabs", which stand for buildings of elongated narrow base and height dimension bigger than the width of the base – an elongated prismatic volume

List of abbreviations

AI - Artificial Intelligence

BIM - Building Information Modeling

COV - Site coverage %

CTF - Core to facade distance

CBD - Central Business District

CL - Cost of land

CC - Construction cost

IC - Total investment cost

FAR - Floor Area Ratio

FTC - Floor to ceiling height

FTF - Floor to floor height

GEAM - Groupe d'Études d'Architecture Mobile

GFA - Gross Floor Area

GIS - Geographic Information System

GLA - Gross Leasable Area

GUP - General Urban Plan (Serbian: Generalni Urbanistički Plan)

9 Explained in section 1.3.3

HEI - Height index, number of floors

HVAC - Heating, Ventilation, and Air conditioning

IT - Information Technology

ITIL - Information Technology Infrastructure Library

LEED - Leadership in Energy and Environmental Design

MEP - Mechanical, Electrical, and Plumbing

NGO - Non-governmental organization

PACK - Floor package thickness (FTF-FTC)

PDR - Plan of detailed regulation (Serbian: Plan detaljne regulacije)

PGR - Plan of general regulation (Serbian: Plan generalne regulacije)

PPP - Public Private Partnership

UAT - Urban Automation Tool

VAT - Value-added tax

VMU - Vertical Mixed Use building

VR - Virtual Reality

INTRODUCTION

Infrastructure, as a general term, usually is related to the technical structures that empower the society and the city as its dominant spatial pattern. In the field of urban design infrastructure has been recognized as a tool that organizes and instrumentalizes the processes of generating and evolution of the urban fabric. Since architecture is an integral part of urban fabric, infrastructure becomes an integral part of the architecture on a new scale, and becomes a tool that organizes the architectural composition. In the new era of collaborative planning[1] and co-creative design processes the architect transcends the old designer role and becomes a mediator in a "dialog" and a coordinator of a more complex process (which includes negotiations and formulating the design brief with the stakeholders, design, construction supervision, usage management, maintenance, reconstruction and reuse…) changing the meaning of the architectural composition which is not designed as a permanent thing any more but rather as a process based one.

The subject of the thesis determines the architectural composition in the 21st century using the infrastructural tenets. Infrastructural tenets will be defined as sets of guidelines, methodological procedures, and algorithms which determine and evaluate the roles and spatial organization of the elements of infrastructure within the typologically specific architectural compositions.

Infrastructural tenets will be established throughout three segments of research: (1) in architectural theory, (2)architectural practice, by analyzing the built projects through case studies looking at the zoning laws (in particular contexts where projects are being developed) and spatial efficiency parameters and other indicators to locate and evaluate the building infrastructures. (3) demonstrations of design algorithms based of typology related infrastructural layouts on the suitable case study locations.

1 Innes Judith "Planning Theory's Emerging paradigm: Communicative Action and Interactive Practice") *Journal of Planning Education and Research*, no.14 (1995): 183-189. Patsy Healey has also published a number of texts exploring communicative and collaborative planning inspired by theories of Jurgen Habermas and John Forester.

RESEARCH MOTIVE AND ACTUALITY OF THE RESEARCH SUBJECT

The research begins with the condition of the architectural profession today, based upon the theoretical standpoints of Stan Allen and Reiner De Graaf who both recognized the crisis in the architectural profession two decades after the fall of the Berlin Wall. Since the `70s and the Postmodern movement, the process of planning and governing the cities has been taken away from the hands of architects and planners and placed into the hands of investors facilitated by engineers[2]. This process culminated in the `90s when the omnipresent process of privatization brought a constant rise in real estate values which brought architecture to a mean of financial revenue, and the architect's position further declined[3]. Now, when global market, investment funds and real estate agencies demand minimal investments and maximum spatial and energy performances, architects are downgraded to a peripheral, consultative position. This implies that the space for action of the profession has been narrowed down and design can be conveyed within the boundaries of spatial efficiencies only by using necessary infrastructural components which make the building functional, performative and therefore profitable.

Considering the fact that fast social changes are influenced by the development of information technologies and the overall technological improvements, introducing the possibility of transformation within architectural objects is distinguished as one of the most prominent themes in contemporary architectural discourse. Flexibility and the potential for transformation have substituted historically appreciated Vitruvian values such as durability and strength (lat. Firmitas). Such a new situation creates opportunities for the architectural profession to partially recover its position by designing architectural compositions with newly envisioned and planned infrastructural layouts that enable transformations, extend life-cycle and boost the performativity, as well as profitability of architectural objects. This could be accomplished mainly on the scale of a building considering the fact that the role of an architect in planning the urban and territorial infrastructures is even more indirect and limited by the interests of the large capital systems or the complex decision-making mechanisms.

2 Stan Allen, "Infrastructural urbanism", in *Points + Lines, Diagrams and projects for the city* (New York: Princeton Architectural press, 1999) 51-52.
3 Reinier de Graaf and Nick de St., "'Architecture Is Now a Tool of Capital, Complicit in a Purpose Antithetical to Its Social Mission'," *Architectural Review*, accessed January 5, 2020, https://www.architectural-review.com/essays/architecture-is-now-a-tool-of-capital-complicit-in-a-purpose-antithetical-to-its-social-mission/8681564.article) 8.

RESEARCH PROBLEM

Infrastructure is a term usually related to the technical structures that empower the society. As the majority of population nowadays lives in cities, infrastructure is widely recognized as tool that organizes and sustains the processes of social life on the city scale. Since architecture is an integral part of the networks organized by urban infrastructures, infrastructure becomes an integral part of architecture on a new - architectural scale. Therefore, infrastructure can be understood as a tool that organizes the architectural composition as well.

The research problem is to determine the role of infrastructure within the architectural composition in the 21st century and to distinguish the ways it can enable achieving programmatic transformations in functionally neutral buildings, during design process and after the buildings are completed.

The first part of the problem refers to establishing infrastructure as a term on the scale of the architectural composition by forming the clear and hierarchical relations relative to current understandings of the term in the realm of urban design and adjacent fields.

The second part of the problem refers to determining the infrastructural tenets[4] as methodologies of the design process. Infrastructure tenets are to be defined as methodological procedures that determine the relations between infrastructural elements and systems on one side and typological architectural compositions[5] on the other. Using the infrastructural tenets, the infrastructure is to be located within the architectural compositions and then evaluated using the qualitative and quantitative criteria based on the spatial efficiency indicators.

The third part of the problem is related to the possibility of achieving programmatic transformations within architectural compositions. Transformations are problematic since reconstructions that aim to adapt a building to a new program are rare and in most of the cases not feasible for following reasons: Legal (ownership structure, zoning laws), Economic (lack of profitability), Infrastructural (lack of infrastructural capacities, or an unsuitable and not upgradeable layout of infrastructural elements[6]). Therefore it is necessary to establish the: 1) infrastructural tenets for developing the functionally neutral[7] buildings and 2) determine the prerequisites for their development such as: particular the urban zones, economic boundaries, typological scopes. Once these are determined, developing the design methodology based on infrastructural tenets will suggest operative ways to facilitate programmatic transformations having in mind main design goals: flexibility, performativity and process based[8] building life-cycle .

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4 Infrastructural tenet is a term borrowed from Kipnis that he used to describe the design methodology of OMA meaning introducing the urban infrastructures into a building, however in this research infrastructural tenet will receive a new expanded meaning; Jeffrey Kipnis, "Recent Koolhaas", *El Croquis*, No. 83 (1996): 32.

5 The research partly relies on the theoretical standpoint of Alejandro Zaera Polo stated in the essay: Alejandro Zaera Polo, "The Politics of the Envelope A Political Critique of Materialism", *LOG*, No 17. (2008): 76-105, where he discusses four envelope(volume) typologies in terms of their socio-economic and political influence to a public space, their spatial and technological characteristics which imply certain infrastructural regularities.

6 see: Infrastructural elements, Infrastructural layout, in Glossary of terms and abbreviations

7 see: Functional neutrality, in Glossary of terms and abbreviations

8 see: Process based architecture, in Glossary of terms and abbreviations

RESEARCH CONTEXT

Infrastructure

In the 21st century infrastructure[9] as a term has become problematic considering the fact that it is used to describe lots of things, so it became a part of the everyday language of the economists, IT and traffic engineers, politicians, journalists and media.

> Infrastructure is the set of fundamental facilities and systems that support the sustainable functionality of households and firms. Serving a country, city, or other area, including the services and facilities necessary for its economy to function. Infrastructure is composed of public and private physical structures such as roads, railways, bridges, tunnels, water supply, sewers, electrical grids, and telecommunications (including Internet connectivity and broadband access). In general, infrastructure has been defined as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions" and maintain the surrounding environment.[10]

In short: infrastructure supports all activities of human society and their material achievements. The word itself originates from the engineer's circles of the 19th century[11], but it hasn't come into everyday use until the end of WWII, as an internal slang of NATO's military alliance.[12] In the domain of political economy the term *base* which Karl Marx presented in *A Contribution to the Critique of Political Economy* (1859) is interpreted as today's infrastructure in its broadest sense. According to Marx, the base articulates the relations in the production process, technical division of labor, ownership relations, and relations between the employer and the employees[13]. Marx's theory didn't specifically relate to any single type of infrastructure in the material or technical sense; instead, it referred to a mechanism that regulates socio-economic relations. In fine arts *infrastructure of a painting* is mentioned as a methodological tool in the abstract paintings of Braque and Picasso[14]. In the realm of social sciences the term social infrastructure encompasses two notions: the first one relates to the institutions and facilities that provide social services (schools, hospitals, prisons etc.), the second one being related to people's communities gathered around specific goals. The term has been distinguished through participative models in the art of `60s and `70s Today, social infrastructure is very present in the sphere of Internet services which uses the components for user's participation and social networking.

In the field of architectural and urban design, the term was introduced in the 60's with avant-garde architectural collectives and individuals such as TEAM 10, Archigram, Yona Friedman, Rayner Banham and others, but haven't been further elaborated during the postmodern period until the end of the 20th century when Kipnis, Allen and the others activated the topic again.[15] Infrastructure of an architectural composition (of a building) can be defined and located in a simplified way as difference between Gross Floor Area (GFA) and Gross Leasable area (GLA).

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9 The word originates from Latin prefix *infra* – under, and French – *structure* - structure

10 Wikipedia, the Free Encyclopedia "Infrastructure," (2003), accessed March 24, 2021, https://en.wikipedia.org/wiki/Infrastructure.

11 Borrowed from French as a term used by French engineers, while designing railroad in the 19th century meaning – sub-grade, signifying a type of aggregate to be placed under the railway tracks.

12 Stephen Lewis, "The Etymology of Infrastructure and the Infrastructure of the Internet," Hak Pak Sak, September 22, 2008, https://hakpaksak.wordpress.com/2008/09/22/the-etymology-of-infrastructure-and-the-infrastructure-of-the-internet/)

13 Karl Marx,. *A Contribution to the Critique of Political Economy* (Moscow: Progress Publishers, 1859)

14 Pepe Karmel and Kirk Varnedoe, *Jackson Pollock: Interviews, Articles, and Reviews* (New York: Museum of Modern Art, 1999) 159-160.

15 Evolution of the term within the fields of architectural and urban design is elaborated in Chapter 1.2

However to fully understand the characteristic of an infrastructural layout[16] of a building we need to locate this difference within the volume as well. This research considers the infrastructures of architectural objects as following elements that relate to: movement (stairs, lifts, ramps, escalators, foyers…), structure, technical systems for achieving a desired level of comfort and operational services (HVAC systems, openings, illumination and ventilating systems, security systems), structural elements (walls, pillars, load-bearing surfaces), partitions (outer, inner), openings (external and internal) etc. It is expected that different configurations of these elements are dependent on the typologies which are applied to suggest regularities which determine the architectural composition.

As an addition to the listed elements the research ponders about the non-physical information infrastructure which gathers and structures the requests of: end-user (lessee), operator, developer, landowner, and the city authorities as a regulator. The interdependence of the physical and information infrastructures will often influence the process of architectural design based on the infrastructural tenets.

Architectural composition

The word *composition* means a synchronized relation of a part to the whole. Architectural composition is one of the key categories of the architectural design process because it integrates a multiplicity of different yet complementary aspects that together make a whole: form (appearance and perception), function, structure etc. In the architectural analysis as a part of a design process, a composition is developed when pre-elaborated elements (typical units) are connected into a functional unity which represents the essence of a future object.[17]

The functional aspect of architectural composition is traditionally determined by the program and activities of the future user of the architectural object, which is manifested by defining and assigning programs to the appropriate spatial units. However, today's functional segment of the architectural composition is far more complex as the program includes multiple factors: comfort, security, spatial efficiency, flexibility, potential for change.

Infrastructure within the architectural composition

Since the functional(programmatic) aspect of the architectural composition in the 21st century has largely become an economic category, hence the compositions are often predefined by the laws and flows of the market. With the rise of the market economy, information technologies and other (physical) technological systems are omnipresent in today's architectural objects, so that architectural composition becomes all the more complex and infrastructure became an integral part – be it physical or informational. With todays ubiquitous migration of people and capital and the changing market conditions and supply-demand ratios the functional aspect of the architectural composition is becoming obsolete, so this research aims to contribute to the research on *functional neutrality*[18] where building infrastructure plays a significant role. Infrastructural components and systems have overcome their original functions of channeling different flows through the building (air, water, energy, people…), and already for a long time they impact on the programming of spaces. Their performativity is a subject to constant evaluation, adjustment, management, and optimization – a process where infrastructures obtain shapes and forms, which are sometimes translated into the overall scale of the object, indicating both

16 see: Infrastructural layout in Glossary of terms and abbreviations

17 Rudolph Arnheim, *The Dynamics of Architectural Form*. (Berkeley and Los Angeles: University of California Press. 1977) 130-150.

18 Functional neutrality is a concept proposed by Van der Voordt, d. J. M, *Architecture in use* (Milton Park, Abingdon-on-Thames, Oxfordshire: Taylor & Francis, 2016) meaning the possibility of giving a building another function. The members of Chair for Real Estate and housing at TU Delft have developed a significant research on this topic after the 2000.

existence and the solution to a problem which their presence had initiated.

The role of infrastructure in the architectural composition based on the infrastructural tenets is determined by: establishing the clear hierarchical relations between infrastructure on the scale of a city and the scale of a building, identifying and classifying the elements and systems of infrastructure in the architectural object, identifying the inter-relations between infrastructural layouts and programs within architectural objects. Besides that, determining and evaluating the capabilities of infrastructure to enable programmatic transformations within an architectural composition follows the models of: flexibility, performativity and process.

RESEARCH BOUNDARY

As the topic of infrastructure is very broad, this research is limited to the infrastructure on the scale of architectural composition and its relation to the adjacent urban infrastructures so the research is essentially situated within the field of architectural and urban design. The research is limited to the architectural theory and practice of the 21st century. However, in order to understand the current discourses in contemporary architectural theory and practice the theoretical part of the of the research addresses a longer period (since the rise of modern architecture at the begging of the 20th century until the 1989 a year which marked the begging of a new economic context that dominates the 21st century) is also relevant for this research. Most of the essays discussed in the theoretical part of the research (authors stated in research subject) were published between 1989 - 2019. Almost all the projects and urban plans selected for the case studies have been built or published in the 21st century.

In terms of the building typologies considered for the research, the scope is defined on three levels:

1) Morphological - Meaning that two particular volume/envelope typologies are selected together with the gradients between them: Cubic volumes and Slab volumes (elongated rectangular prism)[19]

2) Programmatic - Two dominant program typologies (which are most likely to be mixed) are selected : office (administrative) buildings and housing buildings

3) Urban - the particular urban setting studied in this research is the one where the chosen programmatic typologies most often coexist - mixed use city centers - high density city areas indexed with high Floor Area Ratio parameters.

The scope of analysis oriented towards determining the infrastructural tenets as a base for designing functionally neutral within architectural compositions is limited to:

1) Analysis of zoning laws and urban parameters for the plots where building have been developed - and their relation with the adjacent urban infrastructures

2) Analysis of typical plans (and sections) in terms of spatial efficiency (with respect to the program and volume typology), potentials for functional neutrality, mixed use ability, structural and facade characteristics.

3) Qualitative and quantitative analysis of building economy: investment cost, investment return, and real estate strategy (rental and sales)

4) Qualitative analysis of sustainability strategies (HVAC, MEP and energy consumption) with respect to its spatial repercussions (on the volume, program, facade transparency etc.)

19 see: Volume typology in Glossary of terms and abbreviations

RESEARCH HYPOTHESIS

With respect to the subject, problem, context and objectives of the research three hypothesis are formulated establishing relations between the infrastructure on the architectural scale (indirectly on the urban scale) and the architectural composition in the 21st century which is economy driven and characterized with spatial efficiency and functional neutrality.

The first:

Changes in socio-economic conditions initiate the new methodological concepts of infrastructure in the process of architectural design, oriented towards intensifying land use and spatial efficiency.

The social and economic changes and technological achievements during and after the 20th century's development of liberal capitalism and the rise of modernism are followed by the changes of discourse in the field of architectural design. During a longer historical period (with a focus on the 21. century) the interconnected relationships can be drawn between: architectural movements, understandings the role and meaning of infrastructure within the field, design tools & methodologies, mutually influencing the development of: rules, regulations, spatial and energy efficiency guidelines.

During the four historical periods: (I Prehistory (Modern period): 1900-1989, II New pragmatism 1989-2000, III Parametricism 2008-2015, IV Contemporary period: 2015 - present.) land use have been treated in different ways together with the understanding of the figure ground condition. Today, as a newly developed strategy for the densely populated cities, the land is treated a most valuable resource and maximizing its real estate potential is a prerequisite for all actors in the process. A plot, as an extended area of building footprint is saturated with infrastructures[20] densified and intensified to achieve greater performativity and maximize land use potential.

Within the field of architectural design, infrastructural tenets will be examined following the conceptions and evolution of the typical plans in terms of its spatial efficiency together with the ways they reflect the land use.

The second:

The typological relations between volume and program can determine the infrastructural layouts and the possible strategies and scopes for programmatic transformations.

Volumetric and program typologies qualified with urban density parameters and zoning laws determine the land use potentials of a plot. As the land in the cities gains and looses value or changes purpose over time, the volumetric and more often program typologies of buildings prove to be inappropriate. Therefore the architectural composition in the 21st century needs to become projective and process-based. Following the infrastructural tenets that define the typology specific infrastructural layouts within architectural compositions, a degree of functional neutrality can be achieved and the possibility for programmatic transformations promising the time resilience of a building.

20 In this context infrastructures refer to : access routes, horizontal and vertical circulations, technical spaces and installations, garages and retail zones, public spaces and podiums

The third:

The use of algorithmic design procedures to apply infrastructural layouts within volumetric typologies can result in spatially efficient, functionally neutral and therefore time resilient architectural compositions that maximize and maintain the land use potentials of plots.

As the land use potentials of each plot need to be maximized and maintained in the 21 century (most evident in mixed use city centers), a projective and process based design is recommended to ensure the best use for present building and its time resilience in the foreseeable (or unforeseeable) future. Using Algorithmic design procedures and technologies such as: Building Information Modeling and parametric design tools it is possible to simulate and evaluate the spatial impact of infrastructural layouts[21] applied to particular volumetric typologies and programs.

Using these tools, possible spatial configurations preconditioned by urban parameters and zoning laws can be evaluated in a generative way and specific scenarios can be distinguished, scenarios which can achieve optimal relations between the capacities for programmatic change and adaptation on one hand and spatial and energy efficiency on the other. The output could result with qualitative, quantitative and economic information which could be visualized and possibly distributed through on-line software platforms and shared with all the shareholders within a wide decision making chain (city/ developers/ operators/ lessees/ end users).

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21 ...that configure elements such as: horizontal and vertical circulations, fireproof and structural cores, structural grids, MEP shafts and ceiling packages, facade elements...

RESEARCH SUBJECT

Research subject is oriented towards proving that conceptions of contemporary architectural composition can be based on infrastructural tenets. Infrastructural tenets will be established through, analysis, discussion and interpretation of the following sections of the research matter:

1) Architectural theory: throughout the essays mostly written 1989-2019. The research starts with the essays by Reyner Banham and Alison and Peter Smithson which have been announcing the problem of infrastructure within the field of architectural design before the mentioned period. While the main theoretical discourse will be discussed through the essays of Bruno Latour, Jeffrey Kipnis, Stan Allen, Rem Koolhaas, Hadas Steiner, Jeremy Till & Tatiana Schneider, Alejandro Zaera Polo and Reinier De Graaf.

2) Throughout case study analysis of the built examples from architectural practice: by evaluating the infrastructures, spatial efficiency and transformational capacities using the project documentation of 22 projects divided into four groups - defined by two volume typologies (Cubes and Slabs) and two dominant programs: office and housing. The projects chosen for the analysis were predominantly built within European metropolitan cities in the 21st century.

3) A case study demonstration of design algorithms and procedures: through critical evaluation of an actual urban plans for an undeveloped Block 18 area in Belgrade where the findings will be demonstrated to using the generic design proposals for the new buildings. To perform this case study the Belgrade planning documentation will be used : General and detailed urban plans, Urban design competition entries from 2016, Serbian building codes and guidelines.

RESEARCH OBJECTIVES & TASKS

The general goal of this research tends to improve the design process towards integrating the transformative capacities for architectural compositions and to extend the life cycles of buildings by designing them as functionally neutral. By rethinking building infrastructures on the scale of an architectural object, through model of collaborative design the research aims to integrate the interests of the profession, investors, users and institutions within the creation and exploitation of process-based architecture.

It is expected that the general goal could be approached through understanding the possibilities of predicted and unpredicted within an architectural object, both during the process of design and after the object is completed. It is the elements of infrastructure within the architectural composition which should help perform the programmatic changes within the buildings after they are completed. A few steps are to be made towards this direction.

The first step considers expanding the theoretical knowledge regarding role of infrastructure on the architectural scale, through: historical development of infrastructural elements and systems, and infrastructural ground as a figure-ground condition, infrastructural tenets as design methodology procedures oriented towards achieving functional neutrality.

The second step aims to instrumentalize the theoretical knowledge within the process of architectural design by developing design guidelines (as a base for algorithmic tools) based on infrastructural tenets. Infrastructural tenets are based on the qualitative and quantitative spatial efficiency parameters used in the process of architectural analysis that precedes actual design. The quantitative parameters originate from real estate industry, building regulations and zoning laws, and from regulations and functional standards for different building typologies. While qualitative parameters originate from architectural theory (Zaera Polo, Koolhaas, Kipnis) and practice. With determining the infrastructural tenets for different volume and program typologies, specific infrastructural layouts will be collected within a repository of functionally neutral plans together with the related design guidelines and applied within algorithmic design procedures.

The third step, aims to implement the research by demonstrating how: 1)the design algorithms for functionally neutral and mixed use buildings could improve the spatial efficiency when applied to the right plot, 2) urban automation procedure could help the project developments maximize the land use potential, 3) by providing a transparent reading of urban plans and zoning laws for a larger number of stakeholders: city institutions, developers, architects, end users and local communities.

The tasks of this research are set to determine the role of infrastructure in the contemporary architectural composition oriented towards functional neutrality:

1) Establishing a theoretical framework for defining the key concepts within the field of architectural and urban design: infrastructural tenet and infrastructural ground

2) Structuring the theoretical framework by establishing three theoretical segments related to:

- Infrastructure - 1) determining the different scales on which infrastructure is being understood within architecture and urbanism (ranging from the scale of a territory to the scale of an architectural object), 2) introducing a term infrastructural ground as a connecting term between urban and architectural scale and as a new figure ground condition

- Development of infrastructural tenets and its influence to the design process through multiple historical analysis of the economic contexts, architectural movements, understandings of transformational conceptions for architectural objects and the development of zoning laws and spatial (and energy) efficiency parameters

- Conceptions of transformation of the architectural compositions : flexibility, performativity and process model[22]

3) Determining infrastructural specificities, transformational potentials and limitations for the chosen programmatic and volumetric typologies. This is to be done by establishing criteria, parameters and indicators of spatial efficiency. Following the established set of criteria the projects for case studies can be chosen and structured into four groups with respect to their scale, volume and program typology.

4) Using the zoning laws and spatial efficiency parameters the projects are to be analyzed: 1)in terms of the land use and ground conditions, 2) in terms of the efficiency of their typical plans and sections. The case studies are to be completed by structuring the results of the analysis through charts, comparing the results for the two programs within each of the two volume typologies, and by using the results to determine a scope of spatial efficiency for functionally neutral building typologies and a mixed use program.

5) Formulating infrastructural tenets for functionally neutral / mixed building typologies through design algorithms based on typical plans, related scopes of spatial efficiency parame-

22 see: Process based architecture in Glossary of terms and abbreviations

ters, and design guidelines[23]. (Chapter 2.4)

6) Using a mixed use city center as an exemplary urban context for a case study to apply the design algorithms towards possible application within a proposed urban automation process.

7) Synthesis, conclusions. Indicating the potentials for development and implementation of the research towards developing an urban automation GIS based software tool which could be a step to a platform based dialogue between: city government institutions, architects and planners, real estate developers and local communities.

RESEARCH METHODS

Within the research several scientific methods were applied in order to establish a sufficiently flexible methodological apparatus capable of responding to different segments of research while the general flow of the research can be tracked through a flow chart (Diagram 2.)

First segment - Theoretical background (Chapter 1)

Using a method of analysis of primary and secondary sources, an overview and systematization of knowledge on the topic of infrastructure in architectural theory and the related fields have been established by structuring and classifying information using a chronological discursive map (Diagram 1) with four branches tagged as: infrastructure (subject), design process (method), spatial efficiency (boundary), and transformation (goal). The four branches of this research were elaborated through three theoretical segments. The first segment includes infrastructure as a term, beginning with the context of architectural and urban design, as well as with critical analysis of the research background and sources, then structuring the knowledge with respect to the three scales on which infrastructure can be understood: territorial, urban and architectural[24]. Within the latter, which is singled out the research subject is brought up closer towards a field of architectural design whereas two terms were elaborated: infrastructural tenet – as a methodological term and infrastructural ground – as a theoretical one. Within this segment the two branches (design process and spatial efficiency) were merged and a method of chronological multi-variational analysis of a research context was applied to determine the way in which the design methodology and approach were evolving with respect to: socio-economic changes, standards and legislation on the one hand, and paradigm changes in architectural discipline and takes on the conceptions of infrastructure within the architectural composition on the other. Chronologically, this segment follows the 20th century time-line of the development of capitalism, since the early Modernism until nowadays following the paradigm changes in the field of architectural design and structures information from four key theoretical branches: infrastructure, design process, transformation of architectural composition, and spatial efficiency. In this time-line the four key historical periods are defined to be elaborated (I Prehistory (Modern period): 1900-1989, II New pragmatism 1989-2000, III Parametricism 2008-2015, IV Contemporary period: 2015 - present.). The periods were formulated

23 ...on the following topics: urban indicators, economic indicator, mixed use ability, functional neutrality, structure, facade, HVAC MEP and energy

24 A monography *Infrastructure Space*, (ed. Ilka &Andreas Ruby) published in 2017 after Lafarge Holcim 5th International Building Forum: Infrastructure Space 2016 Detroit, starts with and overview of infrastructural scales: architectural, metropolitan, territorial and planetary

by placing the key events (from each theoretical branch of Diagram 1 – (discursive map)) on a timeline, where they started to "group" within the timeline indicating the mentioned periods The research further focuses on a period from 1989 up to the present day. Further, the role of infrastructure within different concepts of transformation in the architectural composition will be determined following the models of: flexibility, performativity and process model. The above mentioned concepts are elaborated through the procedures of critical analysis of the primary and secondary sources. Furthermore in an overview based on the method of logical argumentation connections are established between infrastructure and the process of transformation and changes that infrastructure enables within the architectural composition. The overview is supplemented by observations related to the ways that different transformation models are implemented within the evolving approaches to the design process.

Second Segment - Infrastructural tenets and case studies (Chapter 2)

The second segment of the research determines the potentials of programmatic transformation and ability to facilitate mixed use as the main design principle of the architectural composition in the 21century. To achieve this a method of typological and morphological analysis is applied. First, to determine the infrastructural specificities of program and volumetric typologies. Second, to identify and evaluate the building infrastructures within the cross referenced sets of volume-program typologies using the defined sets of qualitative and quantitative spatial efficiency criteria originating from: project sources (design standards, handbooks), normative sources (zoning laws, urban plans, regulations) and theoretical sources (essays, books).

The case studies were a principle method used to prove the hypothesis and within several other methods were applied. First, methods of similarity and difference are applied to establish the four typological groups of projects (presented in arrays of ascending scale - small to big). Second, method of quantitative analysis is applied to evaluate the spatial efficiency of all the projects. This is performed by measuring and drafting (using AutoCad) over the available project documentations). Third, a method of comparative analysis is applied for typologically similar projects (belonging to the same group), for particular spatial efficiency parameters and the results are presented using the charts. The second step of analysis of the case studies also uses a method of brief quantitative analysis but the primary method is the qualitative analysis as this step focuses on a four intentionally chosen different project cases:

- cubic volume/office and housing (vertical mixed use) - newbuilt

- cubic volume / office - reconstruction

- slab volume (within a city block) / office, mixed use - newbuilt

- slab volume (folded, with an atrium) / housing - transformation (from office)

For each of these cases after the qualitative analysis, the coherence method is applied to define the functionally neutral and mixed use typical plans partially corresponding with the analyzed project but also with other projects previously analyzed. The same method is further used to develop a repository of functionally neutral typical plans (layed out in an array of ascending scale small to big) which will later be used for showcasing the urban automation process. Besides that, the synthesis methods have been applied to summarize the results and set the guidelines for functional neutrality regarding the various aspects of analysis (urban context, economy, program, circulation, structure, mixed use ability, HVAC/MEP and energy).

Third segment - Process based architecture and Urban automation (Chapter 3 and Chapter 4)

The third segment of the research anticipates its possible application by introducing a process based design model which could be implemented through the use of a proposed urban automation software tool. In order to showcase this tool a method of graphical narration and computer simulation is applied. For a case (showcase) study a local urban mixed use city center location is chosen (Block18, Belgrade) and its planning procedures have been analyzed using the method of critical review of the planning documentation and zoning laws. After the critical review a quantitative capacity analysis have been performed on a typical block from different planning stages (including the anticipated typical block). Then, a computer simulation and graphical narration have been used as methods to showcase the urban automation procedure and the implementation of functionally neutral plans[25]. Through the procedures of computer simulation and graphical narration, an array of solutions was generated (to test the optimal block size for the location), then an experience based selection method is used to extract and showcase the massing configurations that have the largest degree of functional neutrality and spatial efficiency and promise the sustainable land use for the location. The chosen solutions are visualized and quantified using the methods of capacity analysis and showing the possibility of evaluation of the plot profitability through an experience based model[26], and suggesting that Building Information Modelling could be applied for the implementation of design supported cost model.

Conclusion (Chapter 5)

The logical argumentation method summarizes and systematizes the obtained results from all stages of the research (related to the hypothesis and theoretical framework), and formulates contributions with suggestions for their practical application.

25 ...from the previously developed repository (Chapter 3)

26 In his PHD thesis Danilo Furundžić developed an experiential model for plot profitability for the business-residential zones in Belgrade which is used here, Danilo S. Furundžić, "Defining model of profitability evaluation for planned urban parameters of residential-business zones in Belgrade." PhD diss., University of Belgrade, 2016, 221.

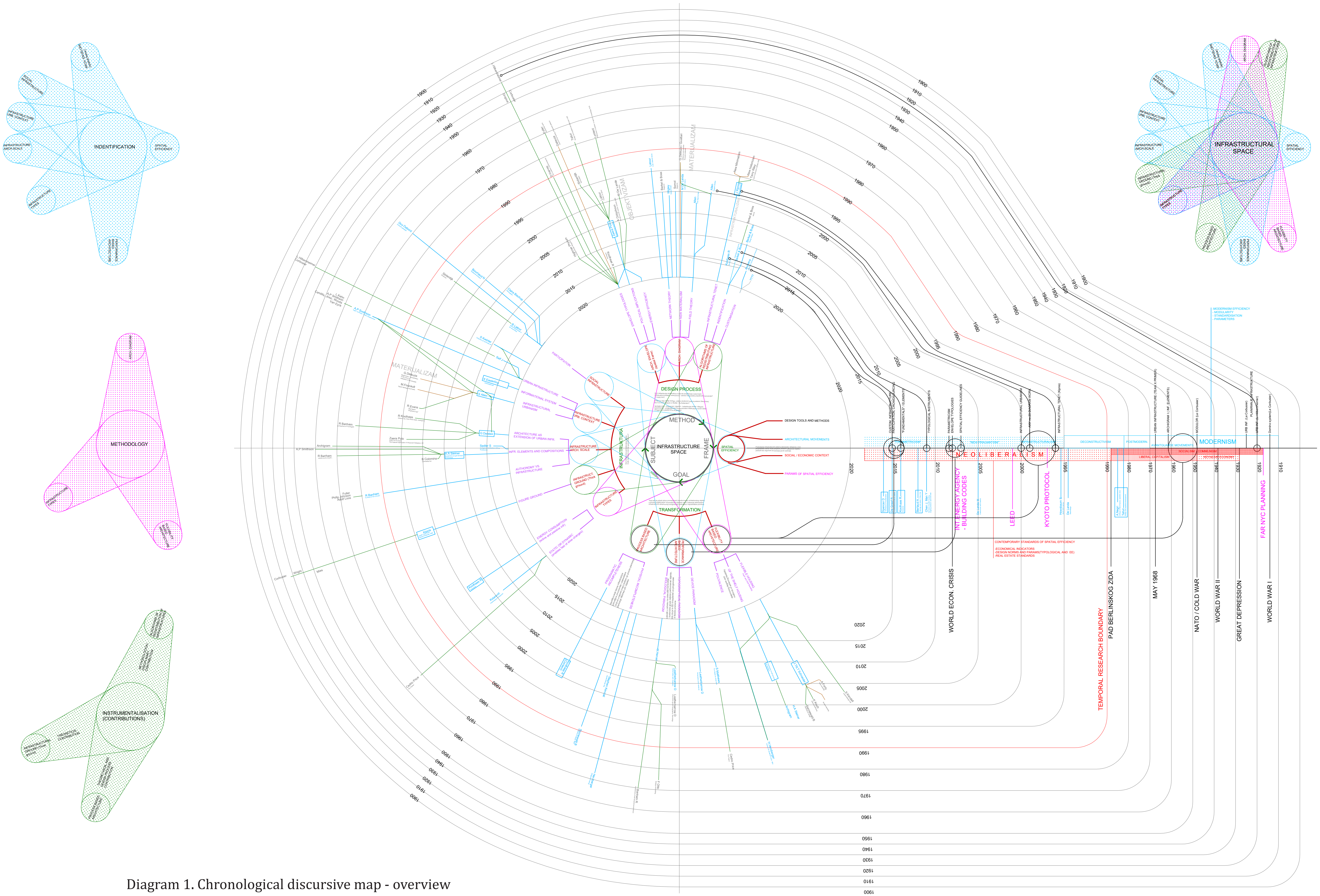

Diagram 1. Chronological discursive map - overview

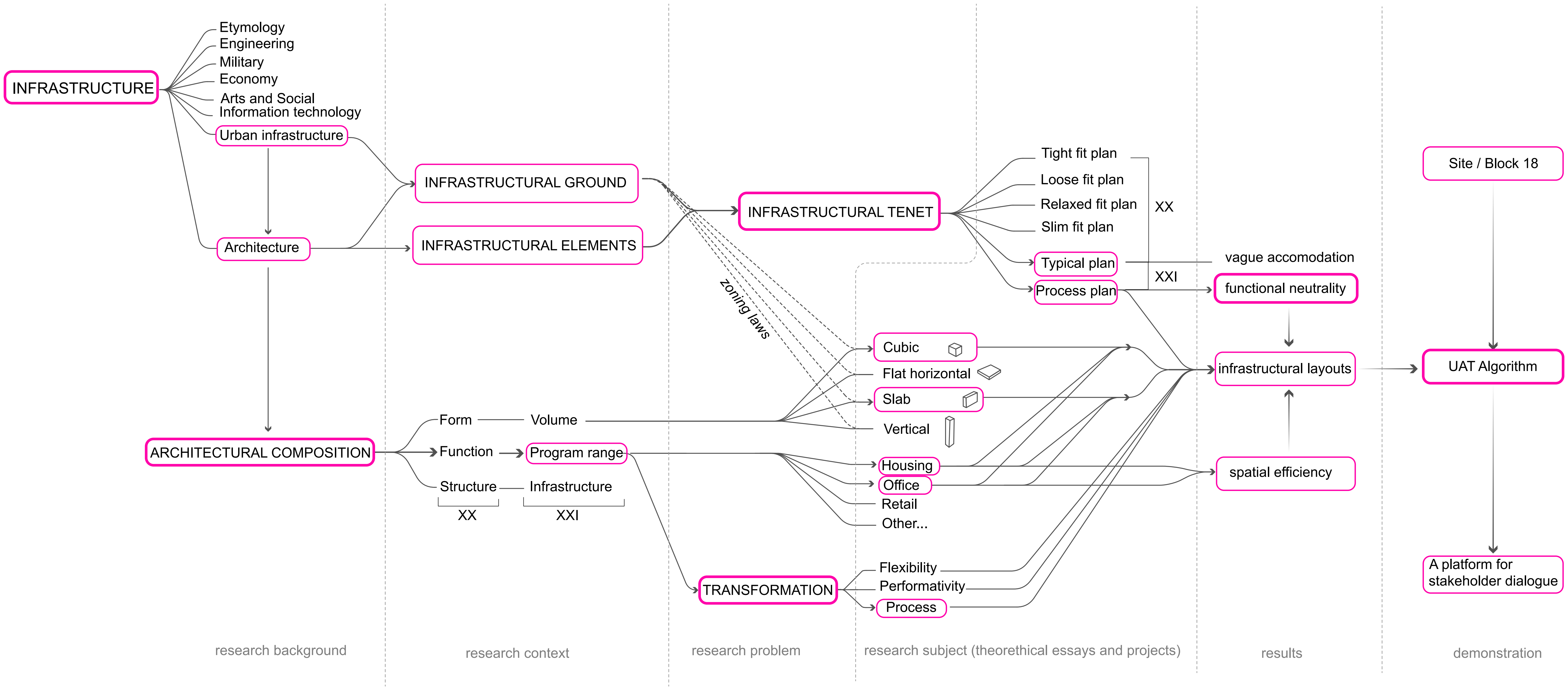

Diagram 2. Methodological flowchart of the research

EXPECTED RESULTS AND POSSIBLE APPLICATION

One of the principal theoretic contribution is related to establishing the topic of infrastructure within the field of architectural design and the scale of an architectural object through defining the clear hierarchical relations with the current understandings of infrastructure in urban and spatial planning. This is realized by defining a new term *infrastructural ground* as a contemporary predominant figure ground condition which establishes connections between the theoretical positions of of Allen (field conditions)[27] and Kipnis (about evolving *figure-ground* relation).[28] By introducing the term of infrastructure into the field of architectural design a term *infrastructural tenet* (Kipnis, 1996) is reestablished since it determines the relations of infrastructural elements within architectural compositions determined with a typological relation of program and volume.

The expected result of the research is: formulating the methodological apparatus for identification and distribution of the key infrastructures within volume and program typologies by establishing the qualitative and quantitative criteria and parameters that determine spatial efficiency of the architectural compositions.

The practical contribution relates to:

1) Improvement of the methodology of the design process through infrastructure planning by including qualitative and quantitative evaluation criteria taking into account the needs and potentials of changing the program segment of the architectural composition

2) Formation of algorithmic procedures as a basis for the creation of design tools that can evaluate the fields of action of infrastructure elements on the spatial efficiency of the architectural composition and determine the possibilities of its changes

The development potentials of the topic would be directed in two spheres:

- Through relations with institutions - improvement and suggestions for more flexible interpretation of design norms and urban parameters

- Towards developing software tools and platforms that more closely integrate architectural practices with the real estate industry, local community and end users

27 Stan Allen, "Field conditions", *Points Lines: Diagrams and Projects for the City* (New York: Princeton Architectural Press, 1999), 92-103.
28 Jeffrey Kipnis, " Recent Koolhaas", *El Croquis,* No. 83, 1996, 32.

1. POSITIONING THE TOPIC OF INFRASTRUCTURE INTO THE FIELD OF ARCHITECTURAL DESIGN

The first chapter aims to provide an overview of understanding the topic of infrastructure in all the different fields and then position it within the field of architectural and urban design in the 21st-century context. Once the topic has been positioned in the field of this research, it is important to understand the scales of infrastructure and further focus on the architectural scale – the scale of a building. The second part of the chapter explores the development of infrastructural tenets as methodological procedures within the fields of architectural and urban design and introducing the term infrastructural ground as a term that connects the two scales of design. The development of infrastructural tenets is further explored through four key periods from 20th till 21st century by drawing the relationships between infrastructure, architectural movement and the design process methodologies on the one hand, and the impact that social-economic circumstances towards developing rules, regulations, spatial and energy efficiency guidelines, on the other. In the Fourth section, infrastructures on a scale of an architectural composition are related to different conceptions of transformation such as: flexibility, performative and process strategies. The last section offers a systematization of the previous findings and focuses the research towards determining the role of infrastructure within the architectural compositions of the 21st century using several volume typologies to investigate the possibilities for functionally neutral architectural compositions.

1.1 INTERPRETATIONS OF THE CONCEPT OF INFRASTRUCTURE IN ARCHITECTURE, URBANISM AND ADJACENT FIELDS

> "By 'infrastructure,' one means every aspect of the technology of rational administration that routinizes life, action, and property within larger (ultimately global) organizations. Today, it can be argued that infrastructures own a little part of everything. Infrastructure includes the systemic expression of capital, of deregulated currency, interest rates, credit instruments, trade treaties, market forces, and institutions that enforce them; it includes water, fuel, and electrical reservoirs, routes, and rates of supply; it encompasses demographic mutations and migrations, satellite networks and lotteries, logistics and supply coefficients, traffic computers, airports and distribution hubs, cadastral techniques, juridical routines, telephone systems, business district self-regulation mechanisms, evacuation and disaster mobilization protocols, prisons, and subways and freeways with their articulated connections; it includes libraries and weather-monitoring apparatuses, trash removal and recycling networks, sports stadiums and the managerial and delivery facilities for the data they generate, parking garages, gas pipelines and meters, hotels, public toilets, postal and park utilities and management, school systems and ATM machines; it covers celebrity, advertising and identity engineering, rail nodes and networks, television programming, interstate systems, entry ports and the public goods and agencies associated with them (Immigration and Naturalization Service, National Security Agency, Internal Revenue Service, Food and Drug Administration, Bureau of Alcohol Tobacco and Firearms); it comprises sewers and alarms, the multi-tiered military-entertainment apparatus, decision engineering pools, wetlands and water basins, civil structure maintenance schedules, epidemiological algorithms, cable delivery systems, police enforcement matrices, licensing bylaws, green-markets, medical-pharmaceutical complexes, Internet scaffolds, handgun regulations, granaries and water towers, military deployment procedures, and street and highway illumination schemes; in short, infrastructure concerns regimens of technical calculation of any and all kinds." [29]

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20 Sanford Kwinter, "Urbanism an archivist's art?", in *Requiem for a city at the end of the millennium,* (Barcelona: Actar, 2010) 59-60.

The “definition” by Sanford Kwinter shows that infrastructure is ubiquitous in our environment in every aspect of our lives nowadays. The concept of infrastructure is complex since it is used to describe a multitude of things in the 21st century. It has become part of the everyday language of economists, IT and traffic engineers, politicians, non-governmental organizations (NGOs), journalists and the media, so it is almost impossible to watch the evening news without this term being mentioned at least once. In his essay *Urbanism – An Archivist's Art?*, Kwinter explains this almost overall inclusion of urban life aspects into a network of infrastructure through the existence of four forces shaping today's cities, and these are: “(1) automatic data processing, (2) the rise of a vast densely knit global image culture, (3) the democratization of access to the public sphere and the demise of the mass culture, and (4) the rise of the “market model” social organization.”[30]

To introduce the term into further research, this section aims to determine its possible meanings first by deconstructing it into several disciplinary aspects: architecture and urbanism, economics and engineering, military, art, and IT sciences. By looking at each of them through a diachronic process relevant to the concept of infrastructure, a semiological scope relevant to architecture as a material practice will be determined.

Over the last decade, architecture has shown a tendency to distance itself from the current philosophical and theoretical discourses (postmodernism, deconstruction, objectivism, and new materialism), thus aiming to re-establish itself as a material practice. As Joel McKim[31] elaborates, there are, however, two more contemporary philosophical schools that hold views on infrastructure: materialist and objectivist.

McKim shares the views of Allen (1999) and Somol (2002) regarding the need to bring back the topic of infrastructure into architectural practice. However, he emphasizes the importance of philosophy as an accompanying discipline that conceptualizes the notion of infrastructure through a world of non-human objects, systems, and processes. According to McKim, followers of the School of New Materialism understand infrastructure as a potential for the development of ecology of space and time, which treats all forces (both people and objects) and agents within an urban field, considering them parts of a continuous network of inter-relationships. While the objectivist position moves further away from the preceding anthropocentric approaches, stating that people display a desire to connect with objects such as infrastructural flows of resources by which they connect natural, cultural, and industrial ecologies into productive totalities. They additionally suggest that it must be understood that objects in nature are often reluctant to become objects of such manipulations and have their established relations independently on such human factors, which paradoxically become aware of the complexity of relations between objects only when these cease to function in the service of infrastructure.[32]

> “Like new materialism and object-oriented philosophy, infrastructural architecture is firmly committed to ecological perspectives, considerations of the non-human, and cultivating sensitivity towards the thingness of the world...Pragmatism is not the only possible mode of exchange between philosophy and design. Materialism and object-oriented approaches may provoke a different form of encounter, one based on rethinking rather than instrumentalizing infrastructural assumptions.”[33]

While McKim predominantly advocates an objectivist position in the domain of architectural and urban design, Keller Easterling and Kwinter (within the sphere of urbanism and urban theory – theory of the city) are concerned with the impact of radical changes brought about by

30 Ibid., 61.
31 Joel McKim “Radical Infrastructure? A New Realism and Materialism in Philosophy and Architecture” in *Radical Philosophy and Architecture: The Missed Encounter.* Ed. Nadir Lahiji, (London: Bloomsbury Publishing, 2014) 1-30.
32 Ibid., 1-30.
33 Ibid., 28.

the digital era, as well as with the attitude of architects towards the infrastructure of the global city. The discussion within this section will aim to direct the field of research towards the instrumentalization of infrastructure, envisioning it as a key component of architecture and not exclusively urbanism, which infrastructure is often traditionally associated with. It seems that much more drastic influences were achieved by technological accomplishments which shaped and amended architecture in accordance with the current socio-political circumstances and created new relationships within the built environment, whereas disciplinary encounters with current philosophical movements had only sporadic impacts.

Therefore, the concept of infrastructure will be discussed in parallel, first as a part of a disciplinary context of technical and technological sciences where architecture and urbanism belong to a certain extent, and then in relation to the social context and other important contexts such as economic, military and others.

1.1.1 Etymology of infrastructure as a term

It is interesting and indicative to view the notion of infrastructure etymologically. As such, it is inseparable from events that have shaped history and hence borrowed from the French, as a term used by the French engineers who designed railways at the beginning of the 19th century and who used it to describe tunnels, bridges, and railroads as an infrastructure network of the French Railways. This term, however, came into general use only after the Second World War, when it appeared as a part of the internal jargon of the NATO military alliance, this time denoting "fixed installations necessary for armed forces operations, as well as capital investments inevitable to ensure the safety of Europe."[34] The concept of infrastructure has been introduced into architecture and urban planning theory by Allison and Peter Smithson in their *Team 10 Primer* in 1968.

1.1.2 Infrastructure as an engineering term

Until the end of the 17th century, the term *infrastructure* implied systems of roads and canals and, above all, was used to assure the transport of goods as well as irrigation. When it came to maritime transport, "infrastructure" meant ports and lighthouses. Only some of the more developed towns had water supply systems for aqueducts, whereas only those most developed ones had sewage systems. However, before the second half of the 18th century, no term would unify all the above-mentioned technical systems. Infrastructure became a matter of national importance in the second half of the 18th century, during a period of substantial works of improvements in the transport network of the Western European colonial countries. In England, ownership of the road network has emerged out from land ownership, and some roads were even built upon the model of concessions. The School of Bridges and Roads (*Ecole de Ponts Chausses*) was founded in France in 1747. Yet, the term itself came into existence almost a century later, after the Industrial Revolution and the invention of the steam engine. In 1875, within an era of significant expansion of the rail network in France[35], which was used exclusively in the mining industry until 1842, infrastructure, according to the French engineering terminology, designated soil substrate upon which a railway or road was embedded.

The era of industrialization led to the further development of the European transport network, primarily through the use of new materials and technologies, first of all, steel and then later reinforced concrete. A series of international exhibitions enabled the spreading and sharing of technological achievements, which marked the 19th-century accomplishments which were crowned by the construction of the Eiffel Tower in 1889. It was kind of a shock to the public

34 Stephen Lewis, "The Etymology of Infrastructure and the Infrastructure of the Internet," Hak Pak Sak, September 22, 2008, https://hakpaksak.wordpress.com/2008/09/22/the-etymology-of-infrastructure-and-the-infrastructure-of-the-internet/)

35 During the rule of Napoleon III concessions for the railways were given for a period of 99 years until 1930 when the socialist government nationalized all the railroads.

taste of the time as an uncompromisingly bare structure in the heart of Paris, by which French engineering, mostly developed through infrastructure objects such as bridges, railway stations, and exhibition halls, has created its permanent, iconic hallmark.[36]

1.1.3 Infrastructure in a military context

Having been taken over from French, it was not long before the term *infrastructure* acquired a military connotation (1885), as: "installations that form the basis for any operation or system." [37] Although the use of construction skills for military and defense purposes dates back to ancient times, it is worth mentioning that urban infrastructure had already been subject to military exploitation before the term was actually coined through the urban planning of the Haussmann's renovation of Paris 1859–1870. According to several contemporary critics of Haussmann, rebuilding the city through improved traffic and city hygiene was not the only motive. Many of them stated that the wide boulevards were designed to allow easier movements of the army. An American critic, Lewis Mumford, also claimed that such urbanism allowed for better control over the city, as well as military maneuvers, reducing the possibilities of barricades in narrow streets and thus enabling the use of artillery in the city, bearing in mind that there had been four uprisings in Paris in the 19th century before this renovation commenced.[38] To support his project-related intentions, Haussmann claimed that applying military logistics was a good way to obtain a larger budget for the reconstruction and that its goals were not politically oriented to protect the ruler (Napoleon III, at the time) but that members of the capitalist bourgeoisie themselves asked for such planning to enhance the safety of their own property. One such historical upheaval, which was prevented as a result of Haussmann's renovation, was the quelled Paris Commune in 1871. This model of planning can similarly be interpreted within the local context of Belgrade if we take as an example The Boulevard of King Alexander, which was constructed in 1892 and also customized to accommodate the width of the royal cavalry battalion.

The term *infrastructure* became widespread only after the Second World War when it found its way into military doctrine and terminology through the Infrastructure Investment Committee formation in 1951.[39]In NATO terminology, the term *infrastructure* refers to fixed installations necessary for armed forces operations, as well as capital investments inevitable to ensure the safety of Europe. Soft Power was the primary means of combating the spread of communism in a post-war period. The post-war development was facilitated by large capital investments, donations or loans, and has generated the loyalty and obedience of recipient countries for decades.[40] Should any country attempt opposition, there were several available scenarios, from internal regime change to violent changes imposed from the outside, which could be seen during the Cold War in, for example, South America and the Far East, where military infrastructure installations, such as military bases and ports, or the positioning of aircraft carriers, served as potential launch-points for specific military operations. The first intervention took place in South Korea during 1951–1953. Ten years later, the USA sent troops to Vietnam during 1965–1975, which meant establishing a geopolitical doctrine that remained in place until today.

Regardless of planning specific military installations at the geopolitical level, military doctrine is still, as with Haussmann, part of urban planning and architecture, which is exemplified by Israel's colonization of the West Coast of Palestine. According to Eyal Weizman, urban plan-

36 Siegfried Gideon, *Prostor Vreme Arhitektura*, (Belgrade: Građevinska knjiga, 1969.)195-200.

37 infrastructure. (n.d.). *Online Etymology Dictionary*. Retrieved July 05, 2016 from Dictionary.com website: http://www.dictionary.com/browse/infrastructure

38 Lewis Mumford, *The City in History: Its Origins, Its Transformations, and Its Prospects* (New York: Harcourt, Brace & World, 1961).418-460

39 "50 Years of Infrastructure, NATO Security Investment Programme," www.nato.int (NATO), accessed January 5, 2020, https://www.nato.int/structur/intrastruc/50-years.pdf)

40 Larry Elliot, " As the Berlin Wall fell, checks on capitalism crumbled", (*The Guardian*, 2. November 2014.) 3.

ning for settlements on the West Coast is directly subordinated to strategic and military goals. This process began shortly after the state of Israel was formed in 1948, in accordance with the plan of Arieh Sharon, who was Walter Gropius's student from the Bauhaus School. His plan implied top-down planning, aimed at establishing and consolidating the border of the newly formed state. According to the plan, all new settlements were positioned at the top of hills and other strategically significant points to be able to easily defend themselves in case of conflicts that were smoldering since the Six-Day War. Besides, the settlements were positioned to form a chain and fence to encircle the territory. Even after Sharon's plan had been implemented and settlements built, the practice continued in a way that these settlements today do not form a fixed chain border but an elastic one.[41]

> "Whereas in the 1950 and early 1960s state planning was undertaken by professional architects and planners, after the 1967 war, it was mainly undertaken by politicians, generals and ideological activists. While the Arieh Sharon plan regarded the borders as fixed, post-1967 efforts, in which Ariel Sharon played a major role, saw the territoriality of the Occupied Territories as elastic and up for grabs.'' [42]

Military doctrine has also influenced architectural expression in a way that almost all houses in new settlements have red tile roofs, which is a deviation from the architectural tradition of the region, interpreted by Weizman as a means of identification in case of air operations [43]. When it comes to erecting new settlements, it is also worth mentioning that, for the most part, there is no legal cause for their construction, but instead, they are formed to maintain or expand certain regional infrastructures. Examples include the Migron settlement (Figure 1), which was formed around a mobile telephony base station, or the Ma'ale Adumum settlement (Figure 2), positioned next to a military base to protect inhabitants. A simple conclusion can be derived in this case: population settlements follow the needs of infrastructure only when they fit into strategic and military plans to become part of military and political infrastructure.

Figure 1. Migron settlement.[44]

Figure 2. Ma'ale Adumim [45]

41 Eyal Weizman, *Hollow Land: Israel's Architecture of Occupation*, (New York: Verso, 2007) 80-89.
42 Ibid., 88.
43 Ibid., 80-89.
44 "Migron settlement,"Reuters, 2012, https://sevenmonthsintelaviv.com/tag/migron/.
45 "Israeli settlement of Ma'ale Adumim (Jerusalem Governorate): 35,673 inhabitants, established in 1975, 1,759 acres," , 2015, http://www.uncubemagazine.com/blog/15801995jpg.

1.1.4 Economy – infrastructure as a tool of capital

Other than the initial function of supporting production and transport of goods, infrastructure has had diverse capital connections throughout history. For example, first roads and bridges were funded through concessions and soon became means of financial turnover and, along with rapid industrialization, became too important an investment to remain in private property; hence, in the first half of the 20th century, roads and railways were nationalized in most of Europe.

In Marxist theory, human society is deemed to consist of two parts: the base and the superstructure. Marx's notion of the Base, which was outlined in A Contribution to the Critique of Political Economy (1859), can be interpreted utilizing today's notion of infrastructure in the broadest sense of the word. Marx talks about the relationship between the base (infrastructure), which articulates relations in the process of production, the technical division of labor, ownership relations, as well as relations between employers and employees – and the superstructure of society, which includes culture, institutions, power structures, etc. The base determines the conditions of its superstructure. Their relationship, however, is not strictly unidirectional, as occasionally the superstructure can affect its related base; nevertheless, according to Marx, the influence of the base is dominant.[46] Marx's theory did not specifically refer to any type of infrastructure, in material or technical terms, but it observes it as a mechanism standing behind and regulating socio-economic relations.

At around the same time when Marx was writing his masterpiece, *Capital (Das Kapital)*, in neighboring France, specifically Paris – a metropolis destined to be at the center of world geo-politics, works of urban infrastructure were carried out, which was also supposed to regulate socio-economic relations through the security system enabled by new urban planning. Such planning would protect the old class order, that of the capitalist bourgeoisie and governors, from one side (those who asked for the master plan to be subordinated to military doctrine) and of the proletariat, on another side. The proletariat – who attempted a series of upheavals in the 19th century, the ultimate of which being Paris Commune of 1871 that was bloodily suppressed in the just-renewed Paris and which was also described in *The Civil War in France*, by Marx as a chronicler of this time:

> "Working men's Paris, with its Commune, will be forever celebrated as the glorious harbinger of a new society. Its martyrs are enshrined in the great heart of the working class. Its exterminators' history has already nailed to that eternal pillory from which all the prayers of their priest will not avail to redeem them."[47]

However, after an era of industrialization and limited rise of the middle class, and after the First World War, the initial foothold of capitalism in the 19th century had been confronted by an alternative in the form of a socialist, Bolshevik Russia and, with the hammer-blow of the Great Depression, was further constrained to change, which was witnessed by the sociologist, Toni Negri[48], as follows:

> "1929 swept away even residual nostalgia for the values that 1917 had destroyed. The Wall Street crash of "Black Thursday" 1929 destroyed the political and state mythologies of a century of bourgeois domination. It marked the historic end of the "state of

46 "Base and superstructure," Wikipedia, https://en.wikipedia.org/w/index.php?title=Base_and_superstructure&oldid=921606254 (accessed January 6, 2020).

47 Karl Marx, *The Civil War in France*, English Edition of 1871, 38.

48 Toni Negri, *Revolution Retrieved: Writings on Marx, Keynes, Capitalist Crisis and New Social Subjects* (1967-83) (London: Red Notes, 1988), 7.

Right," understood as an apparatus of state power aimed at formally protecting individual rights through the bourgeois safeguards of "due process," a state power established to guarantee bourgeois hegemony on the basis of citizenship: the final burial of the classic liberal myth of the separation of state and market, the end of laissez-faire.'' [49]

In Keynesian economics[50] the term infrastructure is used exclusively to designate public finance employed to stimulate manufacture and not private capital, which would otherwise be used for the same purpose. The end of then liberal capitalism marked the beginning of a new era of Keynesian economic discourse which, according to Manfredo Tafuri, shared ideological roots with modern architecture:

> ''It is significant that almost all the economic objectives formulated by Keynes in his General Theory, Can be found in purely ideological form, at the basis of the poetics of modern architecture… And in strictly political sense this also underlines the urban planning theories of Corbusier... Le Corbusier notes the reality of the class in the modern city and takes conflict to a higher level, giving shape to the most advanced plan for integrating the public, whom he involves as operator and active user of the urban mechanism of development now rendered "organically" human.'' [51]

Therefore, the proposals of urban schemes by Le Corbusier,[52] which were considered, were harmonized to Keynesian economic discourse, which meant that the development of infrastructure was under central state control and ownership.

After World War II and the formation of NATO in 1951, the term infrastructure was widespread in the *coterie* of international development agencies, due to which it absorbed a Cold War ideological connotation. The best way to combat the expansion of communism, as was often elaborated, was to ensure local prosperity and economic stability but, noticeably, excluding equal distribution of wealth, which could have been achieved most effectively through infrastructure. All the essentials needed by a society (water and energy supplies, roads, transport, etc.) had been acquired by means of large capital investments and development projects funded by grants or loans meant to ensure the loyalty and obedience of recipient countries over the decades.[53] Such loans were accompanied by investments and economic colonialism, and sporadic military interventions. As suggested recently, "The fear that workers could "go red" meant they had to be kept happy. The proceeds of growth were shared. Welfare benefits were generous. Investment in public infrastructure was high.'' [54]

As the threat subsided coinciding with the break-up of the Soviet Union, so did the need for such generosity. Liberal economy emerged in the 1970s, but it was not before 1990 that the free-market power became entirely prevalent. The free market expanded even to the poorer parts of the world where it could not reach previously, encompassing the global workforce, which consequently brought even cheaper goods and created even stronger pressure to reduce earnings. Moreover, the drive to control and suppress this inevitable process has ceased to exist. Big companies have since been allowed to make even bigger profits, as workers no longer had a choice – another place they could go. Although they perhaps would not have liked the wealth

49 Ibid., 7.

50 John M. Keynes, *The General Theory of Employment, Interest, and Money* (Natrona Heights, Pennsylvania: General Press, 2019), xx.

51 Manfredo Tafuri, *Theories and History of Architecture*. (New York: Harper & Row, 1980), 68.

52 Le Corbusier developed several urban plans in the 20's Ville Contemporaine(1922), Plan Voisin (1925), Ville Radieuse (1933.)

53 Stephen Lewis, "The Etymology of Infrastructure and the Infrastructure of the Internet," Hak Pak Sak, September 22, 2008, https://hakpaksak.wordpress.com/2008/09/22/the-etymology-of-infrastructure-and-the-infrastructure-of-the-internet/)

54 Larry Elliot, As the Berlin Wall fell, checks on capitalism crumbled, *The Guardian*, (2. November 2014): 3.

redistribution reform, they had to accept it unconditionally.[55] The unwilling consensus has finally been achieved (Figure 3).

> "The breakdown of the Soviet model was a confirmation of an existing preconception held by advocates of the capitalist model that no economy could function without the stock market, while the collapse of the ultra-liberal model has convinced socialist that the problems of a society and economy are too significant to be left to chance – to the free-market." [56]

Figure 3. A global yes to capitalism [57]

55 Ibid., 4.

56 Erik Hobsbawm, *Age of Extremes 1914-1991,* (London: Abacus, 1994) *563-564.*

57 OMA/AMO, "A global yes to capitalism," oma.eu, 2010, http://superproductive.blogspot.com/2010/04/omaamo.html.

1.1.5 Infrastructure within the arts and social discourse

Infrastructure, as an element of construction in the arts, has long contributed to scenery and has been a motif in presenting landscapes since ancient times. The attitude and vision of modernization of social life by artists is very interesting, so in the second half of the 19th century, a frequent motif in Impressionist painting in Paris was Haussmann's modernist city reconstruction (Figure 4). It was at that time when Paris became a world metropolis following the orders given by Napoleon III. The impressionists recorded in their paintings specific moments in which Paris, as we know it today, was constructed, and they saw the nascence of wide boulevards, bridges, railway stations, and other pillars of infrastructure. [58]

In the era of analytical Cubism (1909–1912), Georges Braque and Picasso observed the form of objects as geometric structures (Figure 5). Those forms do not have fixed characteristics of firm objects but are made of a series of planes and surfaces which point to the outer and inner boundaries of shapes, thus forming an infrastructure of a painting[59] that provides the basis for unrestricted manipulation of shape, regardless of the laws of perspective. The infrastructure here is a methodological tool of abstract painting and has an entirely new connotation.

In the Cold War, infrastructure was often used as a motive in social realism, painting, and graphic design as a motive of collective effort (Figure 6, Figure 7).

Participatory art has evolved since the 1960s and 1970s, allowing the audience to be actively included in the creative process as a co-author instead of being solely an observer. In today's crisis of institutions, a work of art does not exist without an audience as participants who constitute the social infrastructure – as a new and unique institution of culture. This can be exemplified with the project of Tomas Saraceno, *Museo Aero Solar,* a collective installation-performance where participants are co-authors of a museum as an art institution made of recycled plastic bags flying with solar-heated air inside (Figure 8, Figure 9).

The participatory model, including social infrastructure, has been transferred in recent years from the domain of art into architecture and urbanism through official, systematically organized flows, as well as through the NGO sector, public-private partnerships and other types of initiatives (social housing projects of Alejandro Aravena in Chile being a current example).

Figure 4. *Le Pont de l'Europe* [60]

Figure 5. *Girl with the mandolin* [61]

58 Emma Fallone, "Art as a Window into the Past Impressionist Views of Haussman's Paris," *Historical Review,* accessed January 6, 2020, http://historicalreview.yale.edu/sites/default/files/files/Fallone.pdf)
59 Pepe Karmel and Kirk Varnedoe, *Jackson Pollock: Interviews, Articles, and Reviews* (New York: Museum of Modern Art, 1999) 159-160
60 Gustave Cailleboute, "Le Pont de l'Europe," , n.d.https://en.wikipedia.org/wiki/Le_Pont_de_l%27Europe.
61 Pablo Picasso, "Girl with the mandolin" , 1910, https://www.pablopicasso.org/girl-with-mandolin.jsp.

Figure 6. *Donbass* [62]

Figure 7. *Prva petoletka* [63]

Figure 8. *Museo Aero Solar* [64]

Figure 9. *Museo Aero Solar* [65]

1.1.6 Information technology infrastructure

One of the important understandings of the multitude of the meaning of the term infrastructure is the IT Infrastructure, a software/hardware system that harnesses various information flows so ubiquitous in the 21st century. According to Pironti (2006), information infrastructure comprises all of the people, processes, procedures, tools, facilities, and technology that support the creation, use, transport, storage, and destruction of information.[66]

Information technology infrastructure is defined broadly as a set of information technology (IT) components that are the foundation of an IT service; typically physical components (computer and networking hardware and facilities), but also various software and network components.[67] The fields of IT management and IT service management rely on IT infrastructure, and the ITIL framework was developed as a set of best practices with regard to IT infrastructure. The rise of IT infrastructure and information based society were one of the key cataliyzators for

62 Aleksandar Deneika, "Donbass," , 1925, http://www.tg-m.ru/catalog/en/picture/17163.

63 Matija Zlamalik, "Prva petoletka," , 1954, http://www.supervizuelna.com/monitor-politicki-prostori-umetnosti-1929-1950-borbeni-realizam-i-socijalisticki-realizam/.

64 Tomas Saraceno, "Museo Aero Solar," https://studiotomassaraceno.org/, 2007, https://aerocene.org/buildit/.

65 Tomas Saraceno, "Museo Aero Solar," https://studiotomassaraceno.org/, 2007, https://aerocene.org/buildit/.

66 John P Pironti, "Key Elements of a Threat and Vulnerability Management Program," ISACA 3 (2006): xx, https://iparchitects.com/wp-content/uploads/2016/07/Key-Elements-of-a-Threat-and-Vulnerability-Management-Program-ISACA-Member-Journal-May-2006.pdf.

67 Errol Simon, *Distributed Information Systems: From Client/server to Distributed Multimedia* (New York: McGraw-Hill Companies, 1996) xx.

the forming the global cities considered according to Sassen, (2005) as the nodes in the interconnected networked system of information and finance.[68] Sassen stresses that the information flows are no longer bound to national boundaries and systems of regulation which is a claim still being discussed by theorists like Benjamin Bratton, who claim that the powers of cloud computation have long overgrown the sovereignty of a state.[69]

1.1.7 Infrastructure as an evolving topic - back and forward from technical to social

> "'For four hundred years, architectural values have arisen from the same humanist wellspring. Today these must change,' Eisenman argues, 'Because of fundamental new insights achieved by philosophy.' 'Today, these are fundamentally changed.' Koolhaas argues. 'Because of the elevator.'"[70]

This brief conversation and the brutally pragmatic response of Koolhaas on the verge of banality also tends to illustrate my point of view – technologies and, in a broader sense of meaning, infrastructures, are the material trigger which has changed the most and continues to change our discipline. Koolhaas does not believe that the notion of infrastructure should be interpreted by means of philosophy; even so, at times, philosophy has had an advantageous influence on architecture compared to technology. This overview, however, has shown that the concept of infrastructure is rich in its additional (con)textual meanings, many of which define culture and context in which architecture emerges, and the context itself determines whether and to what extent certain solutions will be applied.

Networked economy and information technologies are the fields that nowadays have the greatest influence on the architectural practice directly through constantly redefining the supply/demand relation that influence how they are being used, and indirectly through their influence on urbanization and shaping the cities and the global culture and eventually on the practice of urban planning urban and architectural design.

As the construction industry is relatively slow and epochal technological steps such as inventions of domino system or elevators and escalator are not happening so often, the current physical, technological innovations are mostly oriented towards improving the material performance and manufacturing processes. However, innovations in information technology announce the digitalization of infrastructure using BIM, big data, cloud computing and analytics, which are changing the way infrastructure is planned, designed, built and managed. Today, software developers are promoting BIM technologies as something that will connect people better to processes and ideas to build more resilient and sustainable infrastructure.[71]

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68 Saskia Sassen, *The Global City: New York, London, Tokyo* (Princeton: Princeton University Press, 2013), 168-176.
69 Benjamin Bratton, "The Black Stack," *e-flux* 3/2014 (n.d.), xx, https://www.e-flux.com/journal/53/59883/the-black-stack/.
70 Jeffrey Kipnis, "Recent Koolhaas," *El Croquis*, No 83, 1996, 26.
71 "BIM for Civil Engineering | BIM for Infrastructure | Autodesk," Autodesk | 3D Design, Engineering & Construction Software, accessed January 2, 2021, https://www.autodesk.com/solutions/bim/infrastructure.

1.2 SCALES OF INFRASTRUCTURE – FROM URBAN TOWARDS ARCHITECTURAL COMPOSITION

The term of infrastructure as a global phenomenon in urban space is theorized by Sanford Kwinter,[72] who considers infrastructure as ''every aspect of technology and rational administration which regulates life''. Keller Easterling, in her book *Extrastatecraft*: *the power of infrastructure space,* discusses the infrastructure space on a global, territorial, and city scale. In her opinion, infrastructure space is an information medium – an operating system that shapes the city. Easterling claims that space-active forms in infrastructure have substituted the aesthetical ones, and the design of the infrastructure space is based on the disposition determined by the actor himself. For her, architecture is dead and without influence since a long time ago, but it could be reincarnated with disposing and managing the information within the infrastructure space of the global city.[73]

The question of infrastructure in the field of urban design was not a subject of theoretical discussion until the big interventions on the reconstruction of European cities such as Barcelona (1858, Cerda) or Paris (1870, Haussman). After the period of industrialization, infrastructure became an important factor in the urban planning of modern cities, which can be illustrated by the urban proposals of Le Corbusier and Hilbersheimer.

In the late modern after-war period in 1958, Yona Friedman with the GEAM group presented the concept of spatial urbanism, aiming to realize the maximum freedom of inhabitants within a stable infrastructure. Friedman's theories have been partially addressed towards shifting the role of an architect from the process of environmental design and the traditional "shaping" role towards a new focus on designing infrastructure [74].

A decade later urban *infrastructure* as a term in the architectural theory was discussed through *TEAM X Primer*[75] from 1968, a publication edited by Alison and Peter Smithson. In one of the chapters of the publication titled *Urban Infrastructure,* the Smithsons offer a set of recommendations through six points from which some consider new – infrastructural approaches both for urban and architectural design: "to develop the road and communications systems as the urban infrastructure and to realize the implication of flow and movement in the architecture itself," "rethink accepted density patterns and location of functions in relation to the new means of communication," to understand and use the possibilities offered by "throw-away" technology, to create a new sort of environment with different cycles of change for different functions, employing the industry of mass-produced building elements to enable different lifestyles through a flexible plan which would follow the changing needs of families and users. The chapter ends with a quote from Van Eyck`s, which will later be taken over by Stan Allen: "…The time has come to conceive of architecture urbanistically and urbanism architecturally [76].

Many of the TEAM 10 recommendations and speculations of Archigram, Archizoom, Metabolists, and others who worked towards mobility and flexibility were modified and partly integrated into the architectural practice. As time passed, buildings became more complex and technologically better equipped, while the infrastructures within the architectural composition started to integrate both program and structure.

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72 Sanford Kwinter, *S M L XL: OMA* (New York: Evergreen, 2000),500.

73 Keller Easterling, *Extrastatecraft: The Power of Infrastructure Space* (New York: Verso, 2016). 9–52.

74 Larry Busbea, *Topologies: The Urban Utopia in France, 1960-1970* (Cambridge, MA: MIT Press, 2007), 61-65.

75 Alison Smithson, Peter Smithson "Urban infrastructure" in: *Team 10 Primer*, ed. Alison Smithson, (Cambridge: MIT Press, 1968), 48-73.

76 The sentence taken by Allen (1999) to end his essay "Infrastructural urbanism".

Hence Rayner Banham famously asked if we actually need buildings or just the systems of service infrastructure[77]. With the shift of paradigm and the rise of post-modernism, infrastructure has been temporarily pushed out from the discourse of architectural design, while in the sphere of urban planning, the design of infrastructure has been taken out of the hands of architects and urban planners in favor of politicians, engineers, and private developers. Stan Allen's essay "Infrastructural Urbanism" starts with the standpoints of Van Eyck and TEAM 10, aiming to re-establish infrastructure as a subject of an architectural design. Allen sees infrastructure as a possible way to instrumentalize the diagram as a methodological tool[78] in which an architectural object was considered a transformable category, both throughout the design process and during its use:

> "Infrastructures are flexible and anticipatory. They work with time and are open to change. By specifying what must be fixed and what is subject to change, they can be precise and indeterminate at the same time. They work through management and cultivation, changing slowly to adjust to changing conditions. They do not progress toward a predetermined state *(as with planning strategies)*, but are always evolving within a loose envelope of constraints." [79]

The book *Go with the flow – Architecture, infrastructure and everyday experience of mobility* by Gilles Delalex, architect and theorist, supports Allen's findings and suggests the next step through establishing a direct connection between urban and architectural scale. He sees architecture as an extension of urban infrastructures that also contains infrastructural elements in itself.[80]

The observations that Delalex presented in his book are useful to formulate a new term that establishes a scalar connection between urban and architectural scale – an *infrastructural ground* – a place of transition between urban and architectural infrastructures, but also an old/new *figure-ground* condition which can be connected with Allen's understanding of field intensities – *a thick 2d.* By including and appropriating the urban flows and infrastructures, the infrastructural ground[81] becomes an expanded ground zone – much more than a ground level, a zone that multiplies the flows and intensities of use, not just a simply multiplied ground surface. The ground level is economically a most valuable space. Therefore, *the infrastructural ground* can be considered the only remaining figure-ground condition that integrates all the preceding ones.[82] *The infrastructural ground* is the space where the capacities of urban infrastructures are provided by the city converge into the architectural composition determining its potentials and boundaries, including the scopes of its possible future transformations.

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77 'When your house contains such a complex of piping, flues, ducts, wires, lights, inlets, outlets, ovens, sinks, refuse disposers, hi-fi reverberators, antennae, conduits, freezers, heaters - when it contains so many services that the hardware could stand up by itself without any assistance from the house, why have a house to hold it up?', Reyner Banham, "A home is not a house," *Art in America*, New York, 2/1965, 70-79.

78 Which he was writing about in his essays from the `90s.

79 Stan Allen, *Points and Lines: Diagrams and Projects for the City* (New York: Princeton Architectural Press, 1999), 55.

80 "'...buildings, as much as they are infrastructures, none of them exists by itself. They are all connected to the series of technical networks, and involve forces that take shape on a much larger scale than the building site itself. What the logic of flows changes for architecture, in my opinion, is that any building, no matter what its scale or size is, necessitates to be regarded as an extension of one or many existing infrastructures.'' Gilles Delalex, *Go with the flow – Architecture, infrastructure and everyday experience of mobility*, (University of Art and Design, Helsinki, 2006), p. 267.

81 see: section 1.5

82 According to Kipnis there are three principles of figure ground conditions developed in modernism present untill today : appropriation, staging, and liberated ground. These conditions originate from three canonical modernist houses Fallingwater house by Wright, Farnsworth house by Mies and Villa Savoye by Le Crobusier; Jeffrey Kipnis, " Recent Koolhaas", *El Croquis,* br. 83, 1996, 32.

The impact of infrastructure is well illustrated by Rem Koolhaas in the essay *Junkspace* in which he claims that capitalism has appropriated all the scientific, technological, and design achievements of modern architecture. According to Koolhaas, it is the infrastructure that enabled junkspace – "…a product of the encounter of escalator and air-conditioning," an enclosed space of consummation based on a hidden structure and infrastructure, and exposed decoration and finish.[83] Jeffrey Kipnis is maybe the first Koolhaas's critic to understand the intention to liberate architecture from all the unnecessary ingredients (style, language, decoration, appearance) and to welcome the intention that architecture should be completely based on its performativity and the elements that support it: space, structure, and infrastructure. In the essay *Recent Koolhaas* published in *El Croquis* 79 in 1996, Kipnis observes that Koolhaas imported urban infrastructure inside his buildings in a set of projects (Tate, Jussieu, Miami, Cardiff opera, etc.).

Kipnis characterizes the OMA practice as driven with an *infrastructural tenet*[84]. He even goes a step beyond, claiming the existence of *infrastructuralism* as a left-wing architectural agenda that tries to maximize and provide accessibility to the *event structure* for the maximum amount of people. Contrary to this, he talks about the other – right-wing stream – *new minimalism* whose reductivist approach to design seeks for the best visual and sensory effects of architecture that can often be seen in architectural photography where no people are present.

After the Venice Bienalle in 2014 (*Fundamentals*), curated by Koolhaas, he published *Elements of architecture*[85], where almost all the elaborated elements of architecture were essentially infrastructural elements (Figure 10, Figure 11). The publication intended to remind us that in the epoch of permanent crisis and growing social inequality, we can rely only on proven achievements, and many of them were not adequately incorporated into the architectural theory and have radically been changing architectural practice for a long time. The fun fact is that a catalog of architectural/infrastructural elements was the first time published half a century before by Archigram at the time of the crisis of Modernism (Figure 12).

Figure 10. Fundamentals exhibition - fireplace [86] Figure 11. Fundamentals exhibition - ceiling [87]

83 Rem Koolhaas "Junkspace" *in Content*, ed. Rem Koolhaas (Koln: Tashen, 2004),162-163.
84 Jeffrey Kipnis, "Recent Koolhaas", *El Croquis,* No. 83, 1996, 32.
85 Rem Koolhaas et al., *Elements of Architecture* (Taschen, 2018), xx.
86 OMA, "Fundamentals exhibition," , 2014, http://www.continuum.com.au/raia/courses.php?o=list&c=19.
87 OMA, "Fundamentals exhibition - ceiling," , n.d.https://www.labiennale.org/en/architecture/2014/biennale-architettura-2014.

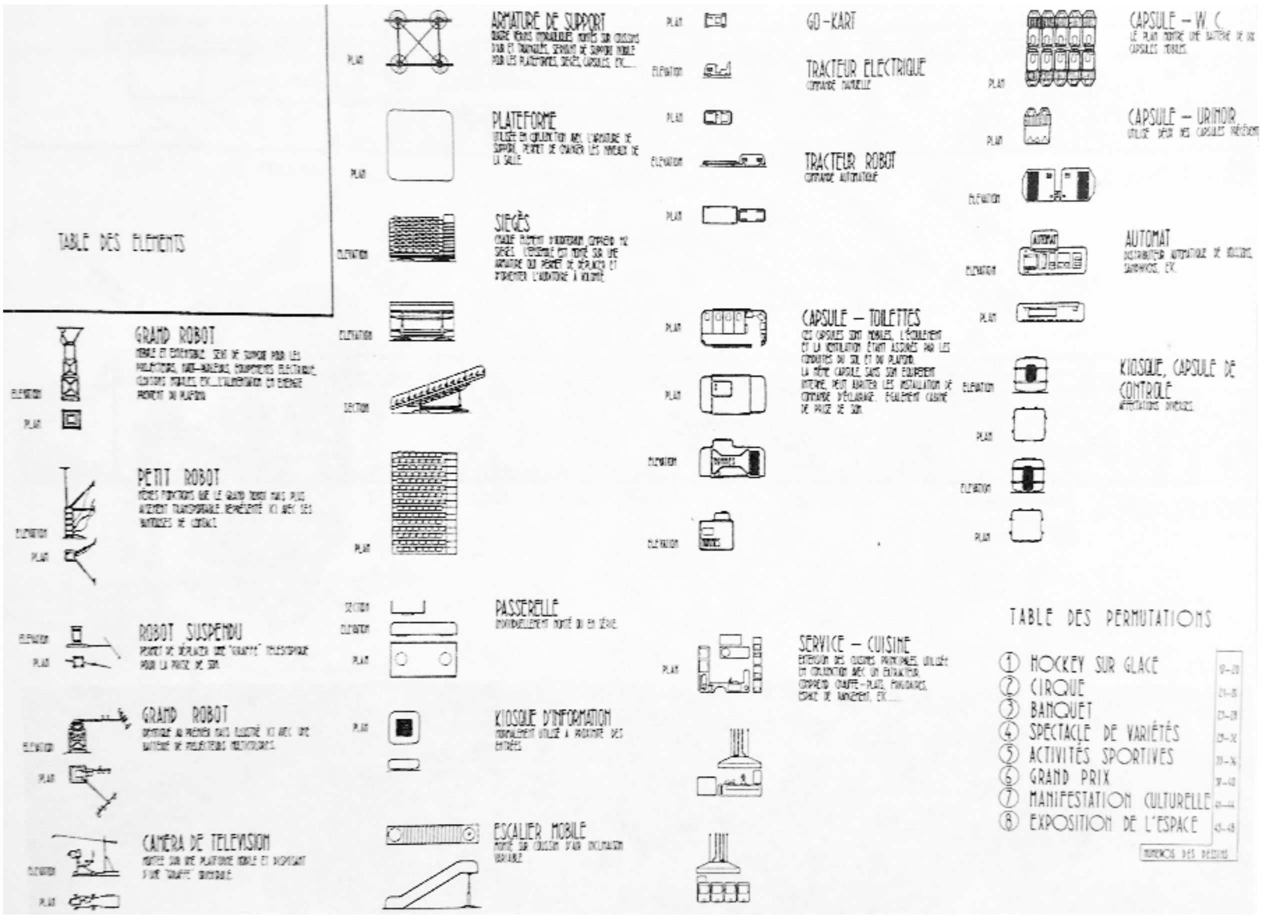

Figure 12. Archigram, Monaco Entertainment center, catalogue of elements [88]

88 Archigram, Monaco Entertainment center 1969, catalogue of elements (source: Simon Sadler, *Archigram: Architecture without Architecture.* (Cambridge, MA: MIT Press, 2005) 176.)

1.3. DEVELOPMENT OF THE INFRASTRUCTURAL TENETS WITHIN THE DESIGN PROCESS

This section elaborates on the four historical periods and the interconnected relationships between infrastructure, architectural movement, and the design process methodologies on the one hand and the impact that socio-economic circumstances towards developing rules, regulations, spatial and energy efficiency guidelines on the other (Diagram 3).

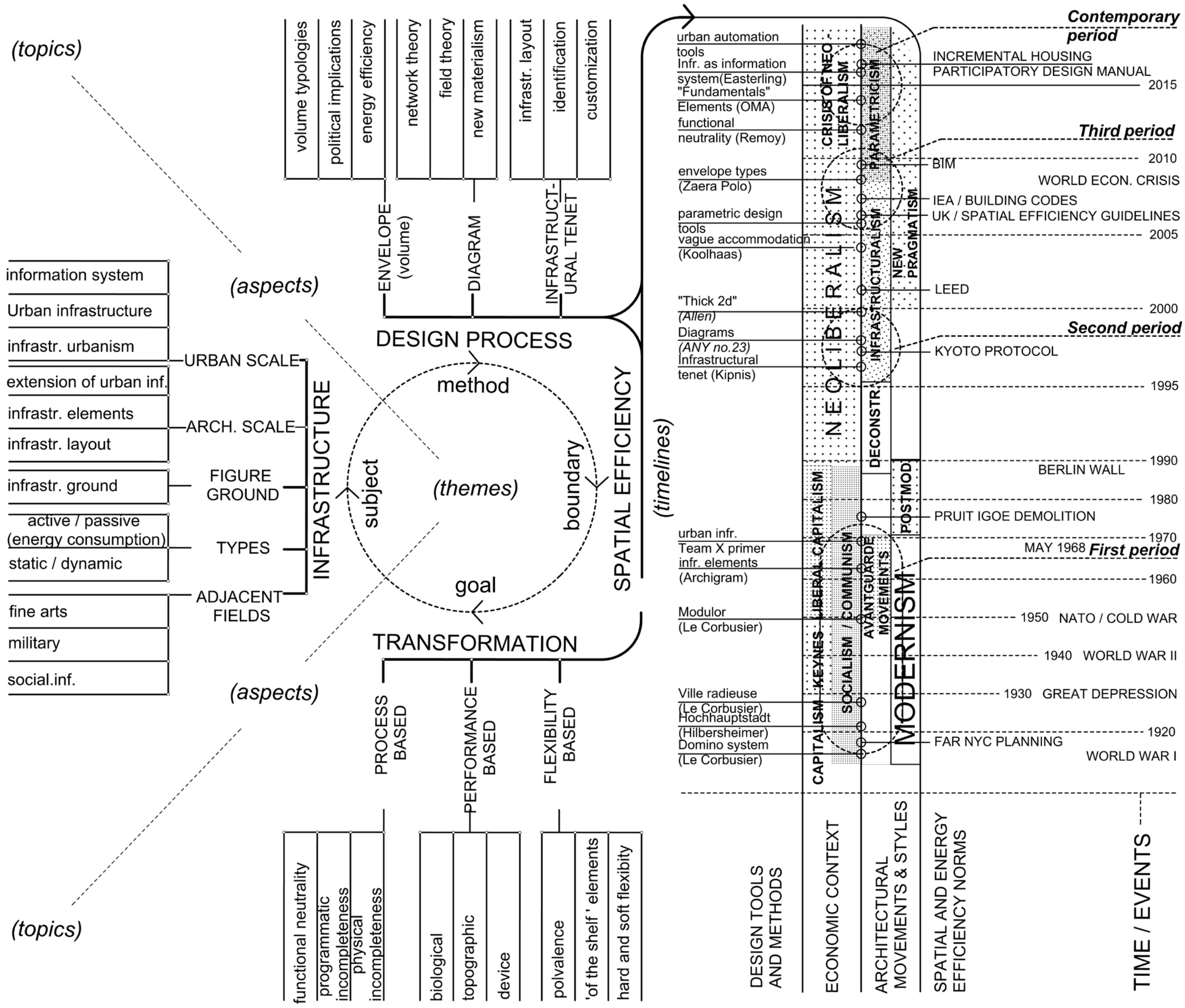

Diagram 3. Chronological discursive map - central zone and time-line

1.3.1 I Prehistory: The rise of liberal capitalism: Modern movement and the tight-fit plan

In 1914 and 1915, Le Corbusier presented the system Domino (based on the skeletal system previously developed within the Chicago school), which has established itself as a tool that has, together with the mass implementation of the automatic elevator, boosted the start of mass production of multi-story buildings. Not long afterward in New York in 1917, a new urbanistic parameter has been set – FAR (floor area ratio), by regulating the maximum build-up as the perception of Manhattan had changed, almost as depicted in the drawings of Hugh Ferris from 1919, promoted by Koolhaas in *Delirious New York.* [89]

89 Rem Koolhaas, *Delirious New York: A Retroactive Manifesto for Manhattan* (New York: The Monacelli Press, LLC, 2014), 109-116.

The FAR parameter combined with plot occupancy is still today the starting criteria in real estate investment. The fast implementation of the Skeletal frame system through the western metropolitan cities in the post-war reconstruction period launched new solutions in urban design throughout the plans of Le Corbusier and Hilbersheimer. The period after the Great Depression was marked by the Keynesian economic discourse, which had, according to Manfredo Tafuri, the same ideological roots as modern architecture.[90] In *Ville Contemporaine* (1925) Le Corbusier anticipates a programmatic division: City, Industrial City and Garden City[91], while in Hilbersheimer's Hochhauptstadt from 1924, this division does not exist, and the city is considered to be developed programmatically heterogeneous through the interaction of urban infrastructure that supports the non-typological generic block. In the time of mass production, it was Corbusier's model that prevailed, with typologically zoned, top-down design process and the tight-fit model of spatial efficiency, which did not leave a lot of possibilities for transformation within the architectural composition.

After the Second World War, Le Corbusier published *Modulor* as a base for the new upcoming period of regeneration and mass-produced housing, which was followed by the prefab technologies and the regulation which standardized most of the typologically determined building elements.[92] At the beginning of the `60s, the mass architectural production became over-saturated, so the new avant-garde groups like Archigram protested that new architecture still aimed towards durability and suggested an ephemeral and disposable concept which used "off-the-shelf elements," which followed the current tendencies in the rise of the consumerist society in the liberal capitalist countries.[93] In the previously mentioned publication *Team X primer,* many of Archigram's ideas were systematized. Not long after, Archigram published a project for an amusement center in Monte Carlo in 1969, with the first catalog of infrastructural components, which aimed to be a tool to achieve maximum flexibility, transformability, and vitality of the project, which was the first step towards conceiving an infrastructure supported transformable space.

1.3.2 II 1989-2000 The fall of the Berlin Wall: New pragmatism / Diagrams and Loose-fit plan/

As the Berlin Wall fell down, the victorious euphoria of the neo-liberal economic model brought the expansion of worldwide construction and a boom in the real estate market at first, but also the first environmental consequences manifested by global warming. So, it was the first limitation that followed the massive expansion in 1997 after the Kyoto protocol had been adopted.[94] For architecture, that implied a big turn towards optimization of buildings on the one hand, whereas, on the other, it implied fast changes in the society caused by the rapid development in information technologies which created a necessity to introduce transformable potential into buildings. A discourse that considered the inclusion of new information flows into architectural

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90 "It is significant that almost all economical goals formulated by Keynes in his *General theory* can be found in their purest ideological shape in the base poetics of modern architecture… In a strictly political sense this emphasizes Corbusier's theories of urban planning… Corbusier notes the reality of a class society in a modern city, and brings this conflict to a higher level, shaping the most advanced plan of social integration, which is integrated as an operator and active user of the mechanisms of urban development envisioned as organic and human." Manfredo Tafuri, *Theories and History of Architecture* (New York: Harper & Row, 1980), p. 68.

91 Le Corbusier, *The City of Tomorrow and Its Planning*. (London: Architectural Press, 1971), 338.

92 After publishing Modulor, Corbusier met in New York an American industrialist Henry Kaiser – a shipbuilder from the times of the Second World War, and they have seriously considered building 10,000 houses a day. Kaiser afterwards changed his mind and decided to build cars instead. (Source Wikipedia, keyword *Modulor*)

93 Hadas A. Steiner, "The architecture of the well-serviced environment," *Architectural Research Quarterly* 9, no. 2 (2005): 133, doi:10.1017/s1359135505000175.

94 By establishing the Kyoto protocol a strategy and guidelines were defined towards reducing the energy consumption in buildings, which were consuming about 40% of world's energy at the time. Kyoto protocol followed the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro 1992.

design began in the early `90s and culminated in 1998 in a series of essays published in *ANY* magazine no. 23 titled "Data Mechanics for a topological age," which was almost entirely dedicated to diagrams[95] as new design tools. [96] Allen's approach to diagram work builds a base in the book *A thousand Plateaus* by Gilles Deleuse & Felix Guatarri, who considered a diagram an "abstract machine which does not function to represent something real but rather constructs a reality that is yet to come, a new type of reality." [97] Allen explains that in the context of an architectural object, the performativity effects are just as important as its permanent existence and that the diagram, therefore, represents a "graphical assemblage that specifies relationships between activity and form, organizing the structure and distribution of functions". [98] Allen characterizes the diagrammatic architecture as a loose-fit relation of program and form channeled but not constrained by the architectural envelope. From a critical time distance and the market already over-saturated with different interpretations of diagrams, morphogenesis and topological forms, Bruno Latour and Albena Yaneva in the essay *Give me a gun and I'll make all the buildings move* highlight that the information communicated throughout the graphic space, using contemporary computational 3D tools is not essentially richer than the Renaissance perspective. They consider an architectural object as a project on the move, , a process with transformative potentials, which we are aware of but unable to predict or manage. They raised a question of incorporating the ever-changing and complex social, economic, political, and other relations into the graphic space, which they considered to be a "space in which buildings are drawn on paper but not the environment in which buildings are built – and even less the world in which they are lived."[99] They recognized that a large part of the architectural production is driven by parameters that imply movements and changes during the design process. Still, a final result often remains only the frozen image of that process.[100]

In the essay "Field Conditions," Allen analyses the changes within architectural objects together with the changes in the urban context as a wider field, suggesting the city's infrastructures organized and shaped as open networks, which are the most obvious examples of such a field. Allen defines a field condition as "…any formal or spatial matrix capable of unifying diverse elements while respecting the identity of each…" Field conditions are bottom-up phenomena, defined not by overarching geometrical schemes but by intricate local connections. Interval, repetition, and seriality are key concepts.[101] He illustrates this approach with comparative examples from minimalist and post-minimalist art of the `60s and architectural examples (Cordoba Mosque, Le Corbusier's Venice Hospital) based on careful addition and repetition. Although Allen does not mention it directly, it is obvious that the method he illustrates contains some of Deleuze's *difference and repetition* concept, which he does not use to explain the formal configurations but rath-

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95 Two decades later Pauline Lefebvre characterized this discourse as a post-critical one, naming it *a new pragmatism* Lefebvre. P. (2017) What differences could pragmatism have made? From Architectural effects to Architecture`s consequences, *FOOTPRINT*, pp. 23-36.

96 Several authors are discussing diagrams: Stan Allen, Van Berkel i Bos, Robert Somol, Peter Eisenman. In the same volume Manuel De Landa published "Deleuze, diagrams, and the genesis of form" as a theoretical essay, and Greg Lynn publishes "Embryological Housing" as an elaboration on the previous one through a practical experiment offered as a product – a generic objects developed through series – capable to be adjusted to any context. Both essays mentioned will have a large influence on the architectural theory and practice in the following period.

97 Gilles Deleuze, *A Thousand Plateaus: Capitalism and Schizophrenia* (Minneapolis: University of Minnesota Press, 1987),141-142.

98 Stan Allen, "Diagram matter," *ANY*, AnyCorp, New York 23 (1998):17

99 This claim is illustrated with a comparison of a life of one architectural project with a bird flight, exemplifying with "Photographic Gun" an art experiment performed by Etienne Jules Marey where one photo of a bird does not say much about its flight, and that for its true exploration we would need a series of photos, just like Marey have made.

100 Bruno Latour and Albena Yaneva, "Give Me a Gun and I Will Make All Buildings Move: An ANT's View of Architecture," *Architectural Theories of the Environment*, 2013, 117-124, doi:10.4324/9780203084274-13.

101 Stan Allen, *Points and Lines: Diagrams and Projects for the City* (New York: Princeton Architectural Press, 1999),92.

er to explain the composition through sets of relations: understanding and directing the flows, intricate local connections and the series of events. Allen offers several guidelines which we can understand through the examples from architectural practice. First, using the field example, he redefines the figure-ground relation, translating it through punctual and regional changes of densities and intensities, which result in a thickened surface (thick 2d). Second, he rejects the Modernist concepts of transparency as democratic values of institutional architecture. He rejects the possibilities of non-hierarchical compositions claiming that they cannot guarantee equality and an open society. [102] The organizational principles which Allen proposes suggest re-defining the *parts* and alternative ways of understanding their inter-relationships in the design context, which means that if we design within a "directed field condition connected to the city or the landscape, space is left for the tactical improvisation for future users, therefore a *loose fit* is proposed between activity and enclosing envelope.[103]

Diagrams were established as design models that promised to be the main tool that organizes the architectural composition: regulating activity – form relation through organizing structure and function (Allen), organizing the infrastructure that supports a loose-fit plan promising transformative capacities. However, the architectural production that followed this model proved to be quite static in most of the cases (Latour and Yaneva), since a loose-fit is possible only within a field condition (and a lot of available space in a plan), and therefore, not applicable for most typologies emerging in cities.

1.3.3 III World economic crisis 2008–2012: Parametricism, integral planning and spatial efficiency – typical plan

After the real estate boom and intensive construction in the `90s, architecture developed with the aid of advanced CAD tools and parametric design. The world economic crisis dramatically reduced hopes about the mass-market driven productions of space financed by loans and unlimited expenditure of money, goods, and energy. The consciousness about energy consumption which had already previously been institutionalized, first through *LEED* standards before the crisis, was confirmed with *Energy efficiency requirements in building codes, energy efficiency policies for new buildings*[104](2008) which influenced the optimization of the overall planning approach by introducing the new concept of integral planning enabled by the emerging network society.[105] Energy efficiency standards have been followed up by the standards of spatial efficiency[106] which support Koolhaas's claim that "in the free market architecture equals real estate".[107]

In 2008, the first year of the crisis, Patrick Schumacher published an essay to promote a new style – *Parametricism* [108] which is based on the premise that treats all the elements of design as parametrically changeable and mutually adjustable, claiming that this approach can be applied on all scales – from the city to furniture. In his later essay, *Free market urbanism,* Schumacher

102 Michael Foucault claims the existence of architecture of limitation and restriction but for him there is no specific liberating architecture. Michel Foucault – "Nitsche Geneology and History", *Foucault Reader,* ed Paul Rabinow (New York, Pantheon 1984), 87.
103 Stan Allen, *Points Lines: Diagrams and Projects for the City* (New York: Princeton Architectural Press, 1999), 102.
104 Published by International Energy Agency (IEA).
105 Integral approach to design implies incorporating methods and tools which encourage and enable the experts from different fields to work together to produce an integrated project. Serge Tichkiewitch, and Daniel Brissaud, *Methods and Tools for Co-operative and Integrated Design* (Berlin: Springer Science & Business Media, 2013).
106 Space Management Group, *Promoting Spatial Efficiency in Building design*, (UK: UK Higher Education Space Management project, 2006), https://www.researchgate.net/publication/307571226_Promoting_space_eff
107 Rem Koolhaas, "Beijing Manifesto," *Wired* 6 (2003): 120–129.
108 Patrik Schumacher, "Parametricism: A New Global Style for Architecture and Urban Design," *Architectural Design* 79, no. 4 (2009): xx, doi:10.1002/ad.912.

draws a connection between a parametricist design methodology and the free market principles, whose self-organizing principles should define the most productive mixtures, maximize value, and the use of land. Douglas Spencer compares Schumacher's standpoint on the social order with the natural processes of selection and self-organization, so to him, the function of architecture that follows this standpoint is a "production of endlessly flexible environments for infinitely adaptable subjects."[109] According to Spencer, flexible space in neo-liberalism obtains new meaning by erasing borders between work, living, rest, education and entrepreneurship, consuming culture and products, which results in the return of the typical plan[110] which emerged in the `70s office buildings in the US which becomes trans-typological in the new context.

In the essay *The Politics of the Envelope: a political critique to materialism (2008),* Alejandro Zaera Polo examines the relations between activities and the envelope typologies by elaborating their typical plans in a new neo-liberal context. Zaera Polo creates a polygon in which relations are drawn between architectural technologies at one side and their social, economic, and political implications at the other. By classifying and analyzing the architectural envelope types, expected infrastructural elements are suggested according to the envelope typology, depending on the technical and political implications of its proportions, context, and environmental characteristics. Zaera Polo sets four types of volumes which can be (but not necessarily) read programmatically: *flat horizontal X=Y>Z (malls, factories – loose-fit); spherical X=Y=Z (HQs, public buildings-relaxed fit); flat vertical – tight-fit X=Z<Y (housing slabs); vertical slim fit Z>X=Y (office high-rise*).[111] This classification will later serve as a framework for the case studies because it is expected that each type will bear its own specificities in the distribution of infrastructure. In further research, this envelope typology classification will be renamed to *volume typology* as volume is more relevant to the overall research (Figure 13).

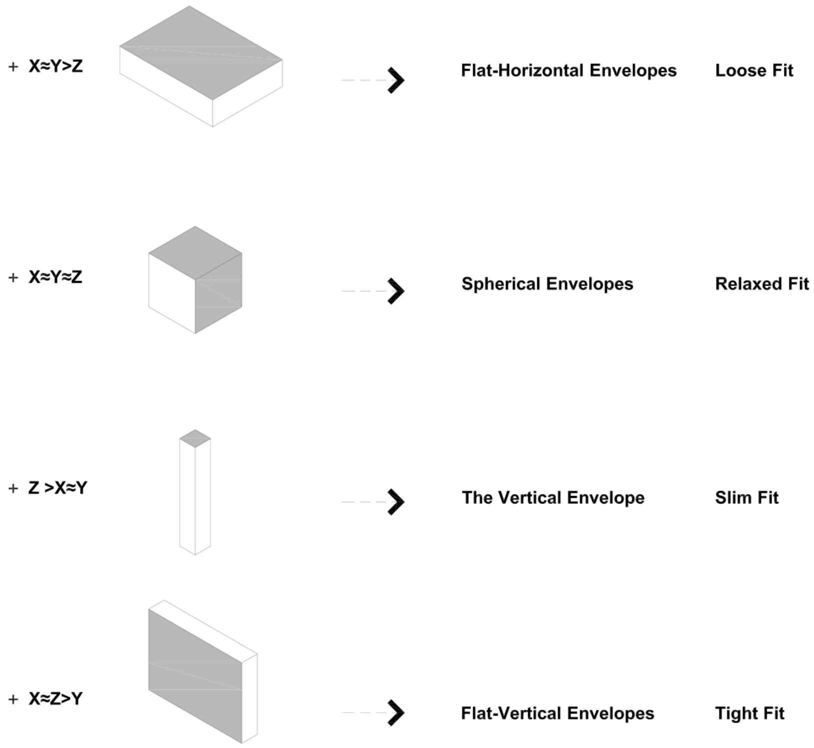


Figure 13. Envelope / volume typologies[112]

109 Douglas Spencer, *The Architecture of Neo-liberalism* (New York: Bloomsbury publishing, 2016), 4.
110 Rem Koolhaas, *Typical plan* in *SMLXL*, (Koln: Evergreen, 1997), 335-350.
111 Alejandro Zaera-Polo, "The Politics of The Envelope." *Log*, no. 13/14 (2008): 193-207. Accessed January 2, 2021. http://www.jstor.org/stable/41765249.
112 Image acquied in: Zaera-Polo, Alejandro. "The Politics of The Envelope." *Log*, no. 13/14 (2008): 193-207. Accessed January 2, 2021. http://www.jstor.org/stable/41765249.

With the omnipresent free-market urbanism (Schumacher) where architecture equals real estate (Koolhaas), the necessity for program flexibility culminates as borders are being erased between human activities (Spencer). In the free market, the necessity for spatial efficiency and the constraints of zoning laws determine the envelope (volume) typologies resulting in the return of typical plans related to them (Zaera Polo). This proves that the building environment is not 'endlessly flexible' as proposed by Schumacher, but with respect to its volume typology and capacity of related infrastructures – it has a scope of flexibility.

1.3.4 IV Contemporary period: Process based architecture – bottom-up plan

The three previous sections elaborated on the evolution of typical architectural plans. Tight-fit plans can be related to the mass production of modernist cities where the infrastructural elements were prefabricated and often over-rationalized in focusing on a single function (housing, office, industry) and therefore could not offer a degree of flexibility and adjustment. This has lead to a lot of buildings being abandoned or demolished or underused due to the inability to satisfy the demands of the market-driven land use evolution. Loose and relaxed fit plans came as a reaction to the rigidity of the modern approach after misleading postmodern attempts to do so. They were characterized by bigger depths and higher plot coverages, and a larger reconfiguration potential, but also demanded a large degree of active technical infrastructure support, HVAC systems primarily, which have lead to environmental concerns in terms of the energy consumption and well-being of the users, in that sense the relaxed-fit plan is more favorable than the loose-fit one. The slim-fit plan has existed since the first conceptions of high-rise buildings and skyscrapers; whose existence can be connected with the high-density urban contexts and high land price. In Modernism, the high-rises were used to provide mass accommodation and leave a lot of green and public spaces on the ground. But in practice, buildings that use the slim-fit plan either are very tall and expensive, built on very expensive land, or most of the time have a very thick and highly occupied ground level and a podium on it, as the efficiency of the slim fit plan decreases with the height due to the increasing amount of structure and necessary vertical transport infrastructures. However, the slim-fit plan is an extreme that brought in new efficiencies in terms of space and energy.

Since the `60s and `70s, participative art has been developing, inspired by the writings of Walter Benjamin and promoted by Guy Debord and the Situationist International, who envisioned the audience to be actively engaged in the creative process as a co-author and not merely an observer.[113] The participative model with the empowered social infrastructure has lately been moved from the artistic circles towards architecture and urbanism through official government channels, the NGO sector, PPPs, and other types of initiatives. According to Spencer, the architecture of neoliberalism does include participation which relieves us from isolation but has nothing to do with Foucault's production of subjectivity considering the fact that "already existing technologies and techniques of the self are broken down and recomposed – dehumanized as Lyotard would say – into hybrid figures: the cultural consumer, the citizen consumer, the student entrepreneur."[114] In the architectural production of neoliberalism, participation represents a method that gives the system necessary and important feedback information, such as customer feedback in online sales. It is more optimization than innovation, which can be illustrated through co-working and co-living concepts currently being developed worldwide by *WeWork*[115] corporation, for example. Still, the method of collaborative design and bottom-up design approach have developed new concepts. An example is the incremental housing projects by Alejandro Aravena – based on the redistribution of urban infrastructure and the careful planning of the house infrastructure with respect to future needs and expansion plans of the end-users – in-

113 "Introduction" by Claire Bishop in: Roland Barthes, *Participation: Documents of Contemporary art*, ed. Claire Bishop (Cambridge: Mit Press, 2006), 9-10.
114 Douglas Spencer, *The Architecture of Neo-liberalism* (New York: Bloomsbury publishing, 2016), 162.
115 https://www.wework.com/

vestors.[116] It is assumed that the collaborative and bottom-up design approach can be based on the infrastructural tenets, which include several methodological steps: identification, customization, infrastructure layouts guided by the projective plan of its functioning (that includes the possible transformations it enables). For this approach to be applied in universal practice, it would probably be necessary to enable flexible reading of existing norms, regulations, legislations, and urban parameters.

1.4. CONCEPTIONS OF TRANSFORMATION OF THE ARCHITECTURAL COMPOSITION: FLEXIBILITY, PERFORMATIVITY, PROCESS

This theoretical segment gathers the transformational concepts defined in architectural theory, aiming to show the ways the concept of transformation has been evolving and determine the role of infrastructure in the presented concepts.

1.4.1 Transformational strategies - flexibility

The flexibility concept is usually discussed together with adaptability. Both terms were set back in 1974 by Rabeneck, Sheppard and Town[117] who criticized the housing practice, which was at the time based on tight-fit functionalism and stressing the importance of careful choices of structure and building techniques and the distribution of services and installations. The previously mentioned distribution of services towards achieving flexibility was a subject decades earlier through the work of Archigram, as discussed in the essay *Architecture of Well Service environment,* by Hadas Steiner in 2005. The essay offers a critical analysis of *Archigram magazine* no. 3, titled *Expandability*. Archigram group promotes leaving the traditions of durable architecture by presenting an array of service (infrastructural) elements developed through projects of the epoch (Fuller, Smithsons,…) for which they believed that could enable the individual autonomy of movement and spatial arrangements. Stainer starts with identifying Archigram's key elements presented in the ascending scale: service cores (*Bathrooms*), parts of the prefabricated houses (*Bubbles*), and *Systems*. Then she discusses the projects where these elements were implemented in the context of flexibility and adaptability. Steiner concludes that using the technologically sophisticated service elements did not have lots of impacts since the construction and the systematic prefabrications of the late Modernism have integrated the services into cores as a kind of a compositional typology, which was since then even more connected to the permanent and fixed urban infrastructure of supply and disposal.[118] Herman Hertzberger, in his book *Lessons for Archtecture students*[119] criticizes the existing takes on flexibility, claiming that "flexibility signifies – since there is no single solution that is preferable to all others – the absolute denial of the fixed, clearcut standpoint." Instead of flexibility, Hertzberger offers a term – *polyvalence*. For him, changes are not a subject of uncertainty on which most of the existing concepts were based; he considers the process of change as a permanent – static factor that implies a polyvalent form, which can be subordinated with different uses without changing the form itself. He votes for a generic, archetypal form, relieved from all meanings – one which can receive and support new ones which can be read as one of the basic principles of functional neutrality. Schneider and Till's proposal is set around the theme of flexible housing and discusses the concept of flexibility from several aspects: Modernism, finance, participation, sustainability, and technology. They determine flexibility in two ways: "…as a built-in possibility for adaptation…" where the house is equipped for different social uses, or "…flexibility which

116 Alejandro Aravena, Andreas Iacobelli, *Elemental - incremental housing and participatory design manual*, (Ostfildern: Hatje Cantz, 2016), 20-65.

117 Rabeneck Andrew, David Sheppard, and Peter Town. "Housing Flexibility/ Adaptability." *Architectural Design*, Feb. 1974, 43- 44, 86.

118 Hadas A. Steiner, "The architecture of the well-serviced environment," *Architectural Research Quarterly* 9, no. 2 (2005): 133, doi:10.1017/s1359135505000175. 140-142.

119 Hertzberger, H. (1991). *Lessons For Students In Architecture*. (I. Rike, Trans.) 010 Publishers, Rotterdam

anticipates different physical configurations." The 20th-century housing projects are discussed from the viewpoint of *determined and undetermined design,* identifying the usage of *hard and soft systems*. Soft systems allow uncertainty and freedom for users[120], Just as classifying the design approach systems, the authors classify flexible housing technologies as hard and soft. The first ones are programmed to enable flexibility, such as skeletal structures with a provisional filling of the *open building*[121] movement. Soft technologies enable flexibility in ways that are not entirely under the control of the building techniques; they are secondary infrastructure systems such as the small service cores that enable movement of bathrooms and kitchens within a certain radius.[122]

Till and Schneider are more supportive towards using soft systems and technologies during the design of flexible housing and conclude that it is possible to use them on different scales of a room, apartment, or a building, so in most cases, the solution is not a technocratic one, but is largely dependant on the design strategy and manipulating the infrastructural elements in the design phase.[123]

Following the evolution of the flexibility concept, it can be observed that the main problem is not the lack of determination of what design aims to achieve but the scale of transformation it promises and its technological dependency. Therefore, flexibility as a transformative strategy uses several standpoints that complement each other and are mainly design-related: polyvalence offers static flexibility as much as possible (Hertzberger) as a basepoint, carefully planned structure as a framework (Rabeneck et al.) with provisional infill (Till and Schneider) and the use of soft systems (Till and Schneider) is directed towards particular operations.

1.4.2 Transformational strategies - performativity

After the turn of the millennium, and as digital technologies became omnipresent in architectural design, a discourse about performative architecture has emerged in the architectural theory, relying on the discourse of algorithmic and parametric design, which dominated the `90s. Performativity is the central subjects in the book *Performative architecture beyond instrumentality* by Branko Kolarevic, and we can understand it by using the two paradigms offered by David Leatherbarrow[124]:

Device paradigm – anticipates an object with movable parts (mechanically or manually operated); the position and the time lapse between usages are defining the role of a certain device. The success of this paradigm depends on the capacities and possibilities to adjust the device with relation to foreseen and unforeseen circumstances. The adaptability strategy is judged to be the first step towards performative architecture.[125]

Topographical paradigm – focuses on the parts of the building that provide its static equilibrium, such as structural, thermal, or material stability. The work that a building performs is measured with the effort needed to sustain the economy of the achieved balance while performing its role.

120 Examples: Mies Van Der Rohe in Weissenhof (1927), Letna block in Prague by Eugen Rosenberg (1935) and Helmutstrasse in Zurich by ADP (1991).
121 Example: Adelaide Road, London - PSSHAK (1979)
122 Examples: Genterstrasse Munchen - Otto Steidle (1972), Diagoon houses Delft – Herman Hetrzberger (1971)
123 A quote from Jeremy Till and Tatjana Schneider, "Flexible housing: the means to the end," *ARQ*, 2005, 295 : "At whatever scale, it is clear that flexible housing can be achieved through a careful consideration of use and technology and without significant, if any, additional cost; it does not rely on an overt display of formal or technological gymnastics."'
124 David Leatherbarrow, *Performative architecture beyond instrumentality* (ed. Kolarević.B) (New York. Spoon Press, 2005), 18
125 Ibid,18.

The change, in this case, does not anticipate the change of position but rather the change of condition. The relation between action and reaction results in a change in the physical body of the building, which demonstrates its capacities to react to different ambient conditions.[126]

After Kolarevic and Leatherbarrow, it was Michael Hensel[127] who suggested a new biological paradigm on performativity. He elaborates Frei Otto's work as a pioneer in considering the biological influence of the environment on architectural objects. Hensel's work also relies on the writings of Rayner Banham, who proposes a thesis that the interior space of the object is inseparable from the environment where the object is located since, for him, the environment is considered an active agent rather than a passive context, claiming that performative architecture could be positioned in the intersection of the four domains: subject (inhabitant), environment, and complexes of spatial and material organization. Hensel embraces the work of Leatherbarrow, agreeing that the principles of performativity must be sought within the boundaries of the interaction of an object and the environment, rejecting the device paradigm as too technology-dependent. He interprets the topographic paradigm to integrate the environmental influences in a building as a material object that does not fight against the environment. Instead, it blends with it, taking the changes in environmental conditions as permanent (just as in the polyvalent spaces of Hertzberger). As an example, Hensel offers the achievement of a locally specific architectural tradition like *Mashrabya* - islamic wall panels which regulate the flow of light, air, and privacy, transmitting at the same time information about the cultural identity of the region. As the directions for further research to follow the biological paradigm, Hensel suggests: analyzing the passive approach to the environment that develops throughout the architecture of the pre-industrial times, and the old/new design methods such as form-finding and the material behavior influence of biology and ecology.[128]

The relation between object and the environment, which Leatherbarrow and Hensel talked about, can be interpreted through the prism of the neoliberal context in Koolhaas' *Junkspace*. For Koolhaas, infrastructure is a performative instrument that generates a new separate environment:

> "Junkspace exploits any invention that enables expansion, deploys the infrastructure of seamlessness: escalator, air-conditioning, sprinkler, fire shutter, hot-air curtain... Because it costs money, is no longer free, conditioned space inevitably becomes conditional space; sooner or later all conditional space turns into Junkspace..."[129]

The latter claim indirectly but very clearly suggests the possible classification of infrastructure systems, elements as tools for interaction with the environment (or against it).

- Passive – do not spend energy and money; these are one-off costs during construction, such as staircases, corridors, atria, light catchers, natural ventilation systems. These are applied mainly in the public zones of the building (the ones which do not generate profit).
- Active systems – spend energy and money; moreover, their constant activity includes constant energy spending, so they are mostly introduced in the spaces for lease that can provide

126 A quote from: David Leatherbarrow, *Performative architecture beyond instrumentality* (ed. Kolarević.B) (New York. Spoon Press, 2005), 18: "At the outset I distinguished between two kinds of understanding in the theory of architectural performativity: the kind that can be exact and unfailing in its prediction of outcomes, and the kind that anticipates what is likely, given the circumstantial contingencies of built work. The first sort is technical and productive, the second contextual and projective. There is no need to rank these two within a theory of architectural performativity; important, instead, is grasping their reciprocity and their joint necessity."

127 Michael U. Hensel, "Performance-oriented Architecture: Towards a Biological Paradigm for Architectural Design and the Built Environment," *FormAkademisk 3*, no. 1 (2010): 36-56, doi:10.7577/formakademisk.138.

128 Ibid., 36-56.

129 Rem Koolhaas, "Junkspace," in Content (Koln: Taschen, 2003), 162-163.

direct or indirect income – no matter whether public, private, or privatized, these can be: HVAC system, lifts, escalators, travelators, air-curtains…

Unlike the other two other strategies presented in this chapter, performativity does not deal with any physical and programmatic transformation; instead, it deals with infrastructure that mediates the changing relations mainly between the building and the environment (outside) or user comfort (inside). Therefore, Koolhaas's statement can be understood in a sense that all three paradigms need to complement each other with respect to the particular program section of the building using an active or passive approach.

1.4.3 Transformational strategies – unfinished architecture, a *process strategy*

A significant portion of architectural objects which were built since the beginning of the Third millennium is in a way only partly finished. After being built, their program or physical structure changes in time. When presenting "Innertnes modified" (1997) as a part of the *Universal modernization patents,* in the publication *Content*, Koolhaas suggests that today's production of space, enabled by the domino system, is a homogenous structure able to receive non-specific and variable programs which implied flexibility even before being first deployed.[130]

The expression *vague accommodation*[131] which works together with the typical plan, represents an important term suggesting unfinishedness and non-specificity because, in the context of neoliberalism, free market spaces are less often defined by the architect, but by the clients, operators, and tenants, who complete most of the interior spaces by themselves by doing so-called 'fit-outs.' In housing projects, finished apartments are less and less popular and are being replaced by infrastructurally equipped volumes. Public and communal spaces have been left over to be designed by the architect. While the private/leasable areas are defined only as the infrastructure layouts and often redirected towards the consulting engineers (Figure 14). In the context of infrastructure, we can identify this situation as a type of programmatic incompleteness that anticipates developing a technical infrastructure system that can cover multiple (often similar) programs that (although not determined yet) can be supported.

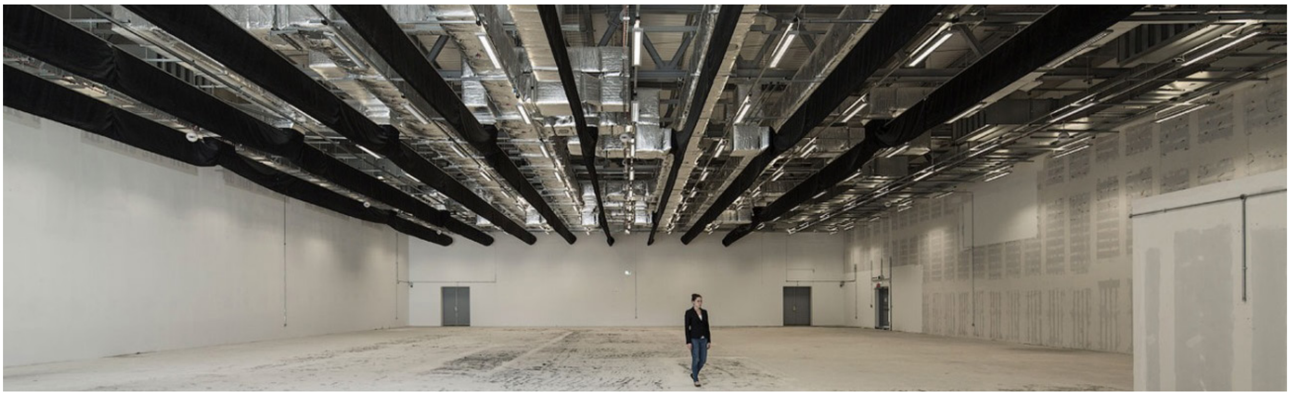


Figure 14.[132] Infrastructure and fit outs

The second type of incompleteness is a physical one and anticipates the possibility of a physical change and expansion of the structure by forming new additional volumes. This type already existed in the `60s through conceptual projects such as the *Plugin city* and *Spatial city,*

130 A quote by: Rem Koolhaas, *Content* (Koln: Taschen, 2003), 83. 'Now when the buildings have become vague accommodations which enable anybody to do anything with whomever in ways that do not exclude new uses in the imminent future.'

131 Ibid., 83.

132 "Plexal Here East innovation center," Sam Shead, n.d.https://sg.finance.yahoo.com/news/plexal-quirky-innovation-centre-high-162400046.html?guccounter=1.

both of which have integrated the expansion principle into the infra-mega structural system. This approach was first realized by Hertzberger for Diagoon housing projects in Delft in 1978, where he offered a naked structure to inhabitants and allowed them to define their apartments themselves and partially to participate in the architectural design process as well. Besides the character of the open structure, these houses were not the ones that enabled unlimited combinations but offered a space frame and the indication of the possible configuration – a productive tension between the aim of the architect and the user's control.[133] Aravena's incremental housing projects[134] work on similar principles but through a more advanced process – which can be named *process architecture* based on planning and designing infrastructure with respect to the current and the future needs of the user who is included from the very beginning in the process. The optimal use of space in process architecture is dependent on a multitude of contexts: natural, social, economic, and cultural; hence the activities that the designers claim to predict and plan need infrastructure adapted to the context and the changes performed within.

An overview presented the possible understandings of unfinished architecture in the physical, but more often in a programmatic way, which corresponds to the concepts of vague accommodations and functional neutrality. As all concepts are oriented towards designing a process of building exploitation, unfinished architecture – will be designed using a process strategy based on planning and designing infrastructure with respect to the current and the future needs of the users and clients (individual or corporate), preferably included from the very beginning.

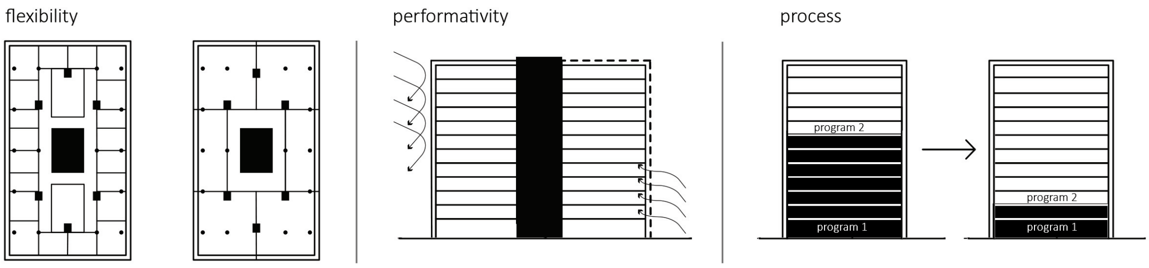


Figure 14a. Transformational strategies - illustration

1.5 INFRASTRUCTURE − FROM A GROUND CONDITION TO A DESIGN TENET

Current research of the theoretical background and framework on the role of infrastructure in an architectural composition has resulted in two findings: a theoretical one – "infrastructural ground" is set as a new term, and a methodological one – "infrastructural tenets." The theoretical one, sums up the understandings of the scale of infrastructure in architectural theory as: planetary, territorial, urban, and architectural scale. As the scope of the architect's work generally revolves around the connections between urban and architectural scale, a new term is set to connect these two scales – an *infrastructural ground.* This term integrates the theoretical positions of Allen, Delalex, and Kipnis: An understanding of the field intensities – a thick 2d (Allen), as an extension of the urban infrastructure into the building (Delalex, Kipnis).

Today, in densely populated cities, the land is a most valuable resource, and maximizing its potential is a must. As an extended area of the building footprint, a plot is saturated with infrastructures[135] densified and intensified to achieve greater performativity and maximize land use potential. The ground level is economically a most valuable space. Therefore *infrastructural ground* can be considered the only remaining figure-ground condition that integrates all its preceding ones (Figure 15).

133 Herman Hertzberger, "Diagoon Houses, Delft," *A&U*, 1991, 66-71.
134 Presented in his book: Alejandro Aravena and Andrés Iacobelli, *Elemental: Incremental Housing and Participatory Design Manual* (2016)
135 ...installations, access routes, garages and retail zones, public spaces and podiums

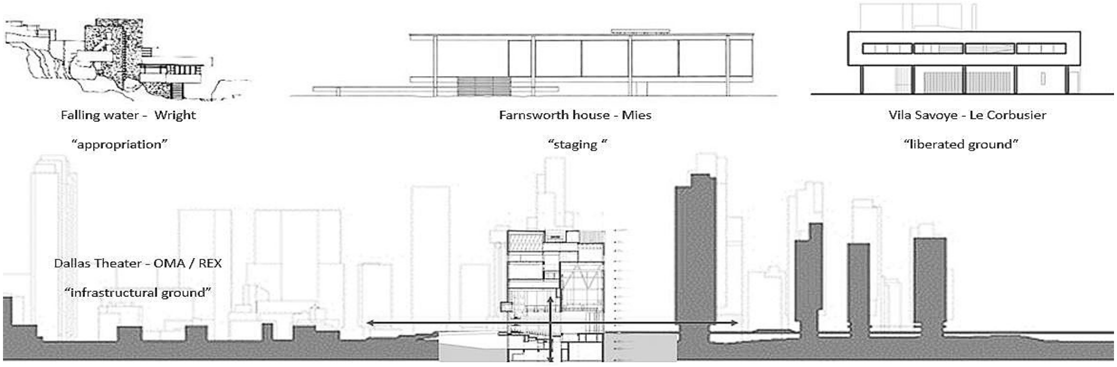


Figure 15. Infrastructural ground[136]

Infrastructural ground is the space where capacities of urban infrastructures provided by the city converge into the architectural composition determining its potentials and boundaries, including the scopes of its possible future transformations.

The land use potential of a plot is dependent of the capacities the larger scale of infrastructures (urban, social, and territorial) indexed through zoning laws and urban regulations. So the developer by using the equipped land agrees to participate in the development of the direct, indirect or remote infrastructural systems or he develops the necessary infrastructures on his own with coordination with the city authorities. The larger the development is, the more infrastructures are allocated both in or outside the plot. This indeed results with indeed thick ground (thick 2d) often hosting multiple underground and overground levels with circulations, services, technical spaces , car parks, lobbies, vertical cores, green spaces and commercial functions, as the urban density is higher the ground is thicker, and the building capacities enlarged. This phenomena reflects the density of the urban context, and therefore the density of needed infrastructures to service the building(s) on site, but has to be understood independently from the term *spatial efficiency* on the scale of a building/ architectural composition (discussed in chapter 2 and 3) which is usually determined by the building/program typologies. The thick 2d infrastructure will eventually service and host one or more compositions with certain degrees of spatial efficiency, but with respect to the theories discussed here belongs to a different discourse.

During the process of research it became evident that infrastructural tenet[137] is actually not a singular methodological procedure as Kipnis presented it. There are actually multiple tenets as sets, aiming towards different transformational outcomes and performative effects. Infrastructural tenets integrate infrastructural ground and infrastructural elements, both in terms of the object on a plot and its ground condition, and in terms of the distribution of infrastructural elements within the architectural envelope that completely determines its architectural composition. Infrastructural tenets are not something essentially new. They have been evolving with the development of the professional technology and economy. Comparative historical analysis shows that each of the historical periods, marked by an economical discourse, have brought new understandings of the architectural plan, not as a reaction to a previous style, but rather to the changes and crises in the socio-economic sphere, followed by changes in normatives and legislation. Changes of architectural plans influence the conception, evaluation, and distribution of infrastructure. This anticipates, as the technology advances, a permanent inclusion of the new and rethinking the existing infrastructural elements (Table 1).

136 A collage created by the author compiling section and elevation drawings of following projects: Falling water House (Wright, 1939), Farnsworth House (Van Der Rohe, 1951), Villa Savoye (Le Corbusier, 1931) and Dee and Charles Wyly Theatre (OMA/REX, 2009)

137 A term originally coined by Kipnis to explain how OMA brings urban infrastructure into the building.

Table 1. Design process evolutionary periods related to infrastructure

Period	Economic context	Norms & Policies	Typical plan
Modern period 1900 -1989	Liberal capitalism Keynesianism	FAR (Floor area ratio)	Tight - fit plan
New pragmatism 1989 - 2000	Neoliberalism	UNFCCC Kyoto protocol LEED	Loose - fit plan
Parametricism 2008 - 2015	World economic crisis	IEA Int.en.effic.build code Spatial efficiency guidelines	Slim - fit
Contemporary period 2015 -	Crisis of neoliberalism	BIM Implemented into building codes	Process plan Functionally neutral plan

The afore-mentioned plans do not necessarily relate to programs. Rather, they relate to envelope typologies, which were used as a framework to define transformational scopes, strategies and capacities and the infrastructural tenets that will organize the composition capable of performing these changes (Table 2).

Table 2. Transformational strategies matrix

Typical plan	Volume Envelope typology	Program related transf.	Transformation strategy
Tight - fit plan	Flat vertical (slab)	Reconfiguration	Flexibility
Relaxed - fit plan Loose - fit plan	Spherical (cube) Flat Horizontal	Reprogramming Intensification	Polivalence, Flexibility
Slim - fit	Vertical	Reprogramming Reconfiguration	Performativity
Process plan Functionally neutral plan	All typologies	Expansion, Reconfig. Reprogram. Intensification	Process strategies Functional neutrality

Both architectural envelope typologies and program typologies anticipate different models of changing its spatial arrangements, such as: reconfiguring, reprogramming, intensifying, expansion, conditioning, sometimes several models associated. With respect to the aimed model of change, design strategies are defined to achieve these changes: flexibility (and polyvalence), performativity, and a process strategy based on unfinishedness, which carries the possibility to integrate the previous ones. The choice of a transformational strategy, with respect to the aimed model of change, program, and envelope typology, could determine the current project's specific infrastructural tenets – configurations of infrastructural elements – which will be a research subject for the case studies (chapters 2.3, 2.4).

Considering the historical background of the infrastructural tenets architectural design process has long since existed, dependent on the socio-economic changes, altering models of the design process, and the spatial and energy efficiency requirements, so connections can be drawn between each of these mutually influencing areas. Models of the design process which co-exist and evolve at the same time as reactions to the remaining freedom frames drawn by mostly economical/logical circumstances are reflected in architectural norms and standards.

Due to the unstable market demands and the ever-changing needs and habits of end-users, both businesses and individuals – inhabitants, the second part of this research concludes with an approach towards greater, but pragmatic, program transformability throughout the design chain, which is based on both the possible programmed palette[138] (and if needed the model of change) and envelope typology defined by the urban parameters. In addition, it is the role of the architect to determine the design process model, strategy of transformation, and last but not least, the infrastructures that will determine the architectural composition of the future building (Diagram 4).

The previously proposed chain is indeed a theoretically based conclusion and needs to be proven through case studies which should result with: 1) creating a methodological apparatus for identification and distribution of the key infrastructures related to envelope (volume) typologies, 2) establishing sets of quantitative and qualitative criteria and parameters (Chapter 2.2) which determine the relations between: the distribution of infrastructure and the spatial efficiency of related to different programs, 3) possibilities for programmatic changes in the architectural composition - examining the potentials for its functional neutrality.

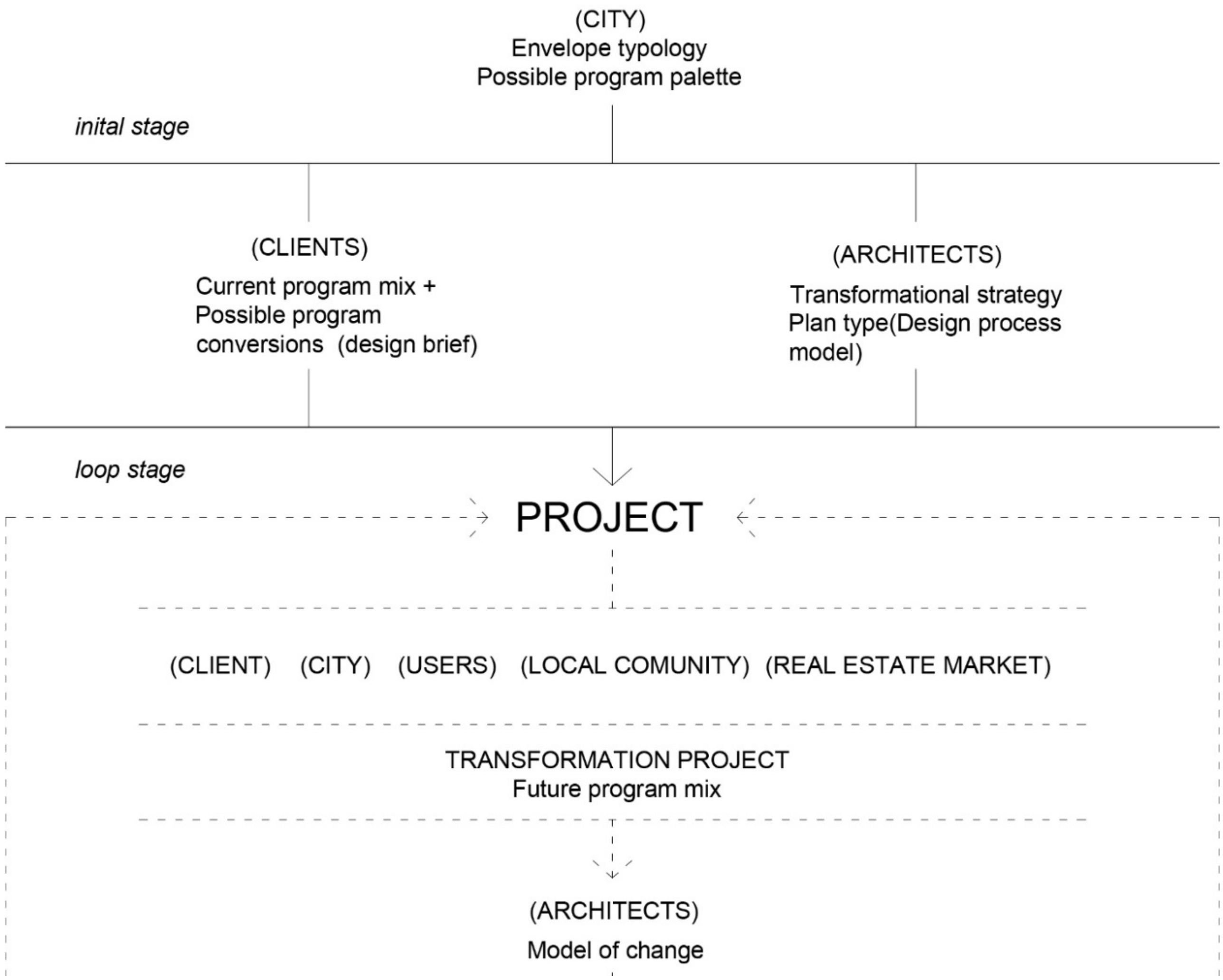


Diagram 4. Speculation on future project flows

138 Possible programs within an envelope, programs with similar infrastructural needs.

2. DETERMINING ARCHITECTURAL COMPOSITIONS THROUGH INFRASTRUCTURAL TENETS

The previous chapter established infrastructure as a driving engine of the contemporary architectural composition oriented towards programmatic transformation. By following the different design models from the tight-fit to the loose-fit, typical, and finally a functionally neutral (process-based) plan. It showed that the role of infrastructure is being customized to the evolving economic and spatial constraints. One of the main conclusions was that all the transformational strategies analyzed are infrastructure-based. As they evolve, they do not substitute the previous but rather expand and become more precise and typology-related. The task of this chapter is to show that the contemporary architectural composition is based on infrastructural tenets - typologically determined with: volume type, possible "program range" and suitable transformational strategies.

2.1 PROGRAMMATIC TRANSFORMATION WITHIN THE CONTEMPORARY ARCHITECTURAL COMPOSITIONS- POSSIBILITIES AND LIMITS

Before we bring in a disciplinary-specific term such as an architectural composition, we need to be reminded who we are designing for. For the people or for the market? It may have started with the first, but for a while now, the second has dominated the architectural production. In the 21st century, the process of rapid urbanization and migration towards the cities has been further intensified with globalization and the influence of the information-based society and electronic communication, which enabled even a further division of labor through outsourcing both physical production and intellectual work. This resulted in various speculations in the booming real estate market – globally, in the cities, it often resulted in shortages or oversupplies of various programs, primarily housing, offices, or retail, as functions which are most present in the city zones.

As neoliberal capitalism further develops and the return of income through accumulated wealth has long surpassed the income obtained through labor (Pikkety, 2013), and most of the wealth is accumulated in the real estate, it is clear that the construction industry will ignore the usual supply/demand ratio and continue producing and deploying wealth through real estate developments (De Graaf, 2019).[139]

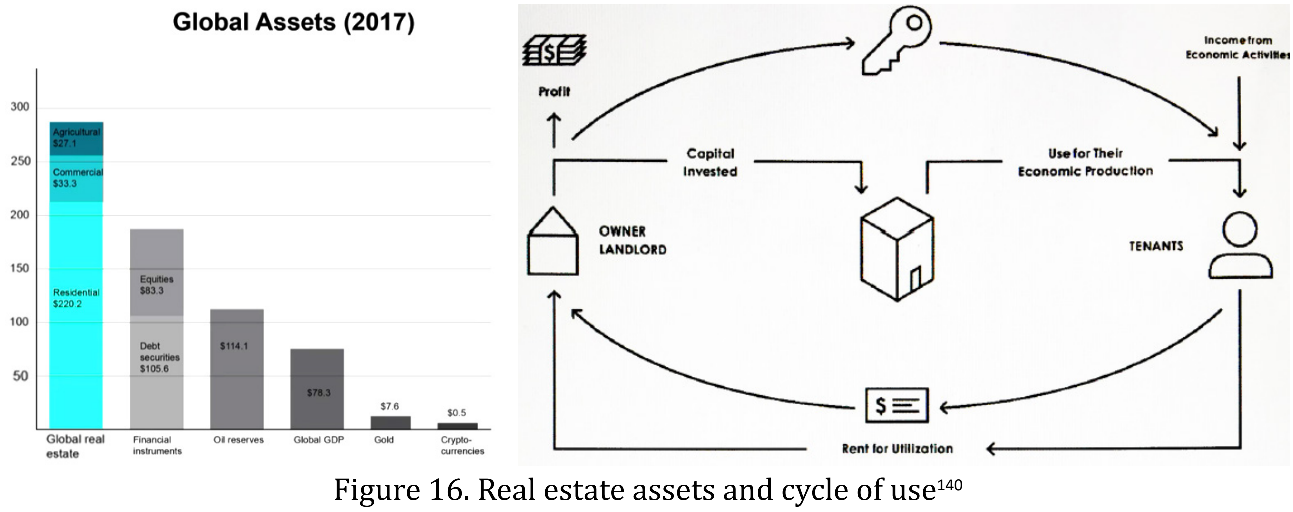


Figure 16. Real estate assets and cycle of use[140]

139 Reinier De Graaf, *Four walls and a roof*, (Cambridge: Harvard University Press, 2017), 415-417
140 A slide from a lecture by: Reinier De Graaf, "Where from here" (lecture, New Zealand Institute of Architects, Auckland, New Zealand, February 13, 2019)

In the already densely built city centers, space is becoming less and less affordable to buy and own. therefore the new-built real estate are becoming increasingly rental (Figure 16).[141] The economic and financial impact may be a dominant component behind a rental real estate concept, but it is not the only one; the second component is the migration of people and businesses (implying non-permanent occupation of space) influenced by the globalized market economy, faster and cheaper travel and transportation of people and goods.

De Graaf sees this as a potential bifurcation in the building use with respect to the intentions of the developer:

- if a developer seeks to obtain the return of the capital annually by receiving rent through its operation, there would be a larger interest in the efficiency of the program, structural integrity and durability, aesthetics, and the good fit within an urban context

- if a building is developed to be immediately sold to a third party, the focus will be more on a market impression that would generate a faster investment return rather than the long-term use.

> "The important variation arises in the proportion of investment return to be received from annual cash flow during its ownership versus the increased price when it's sold. In the global real estate boom of the early 21st century, this latter return – value appreciation – sought by the large and fluid amounts of investment capital circling the globe, all but dominates the formation of cities."[142]

This condition of the real estate market often results in inappropriate land use, such as overdeveloped or underdeveloped areas. The first, often results in vacant or underused buildings which are often not sustainable and not able to adapt to the new market needs or necessities for technological improvements. The second results in the high rental prices and space shortages, expensive land, and fertile grounds for speculations. The economic crisis of 2008 sobered up some of the developers and city governments in Western Europe as they are trying to develop strategies to maintain the land use appropriate and efficient, despite many obstacles which could be technical, functional, legal that altogether result in the economic consequences to the investments.

In the context of constantly maintaining the land use on a high level, it can be anticipated that one of the methods to contribute to that direction is working with the spatially efficient and functionally neutral typologies that are ready to facilitate the future transformations (by upgrading the current or adapt to a new program). From the side of the city authorities, this can be stimulated by the creation of the mixed-use zoning plans, which could give freedom to the developers to follow the market needs more accurately from the beginning. But in return, developers should be stimulated to develop buildings that could benefit future users as well.

2.1.1 Ownership as a prerequisite for transformation

However, there is a problematic point as the cost of integrating the transformation capacities within a building has to be paid by the first owner, which is an investment where the return is uncertain, while the benefit will probably go to future owners. That is why the buildings designed and constructed with the integrated possibility for future transformation might be most attractive to actors that want to own and maintain the building for a long time (such as govern-

141 Reinier De Graaf, "Where from here" (lecture, New Zealand Institute of Architects, Auckland, New Zealand, February 13, 2019)

142 Reinier De Graaf, "Creation, Calculation, Speculation - A short history of Real Estate Development," *BAUMEISTER*, June 2019, 40, https://curated.baumeister.de/en/reinier-de-graaf/#magazine.

mental building agencies, housing association, or pension funds).[143] This process that has already begun in the well-regulated and rich European societies such as Switzerland.[144] According to De Graaf, another issue that is important for transformation, which is related to ownership is the discrepancy between acquiring ownership and the shortening lifetime of contemporary buildings. Apartments, just as most other real estates in European capitals, are no longer affordable to buy (even with the decades-long mortgage agreements), and the building life cycles are becoming shorter and shorter (even shorter than the mortgage periods). The latter statement may be paradoxical, but indirectly it favors the sustainability improvements throughout building transformations by accepting it as a permanent condition in the 21st century's architectural composition in an Anti-Vitruvian manner (Figure 17).[145]

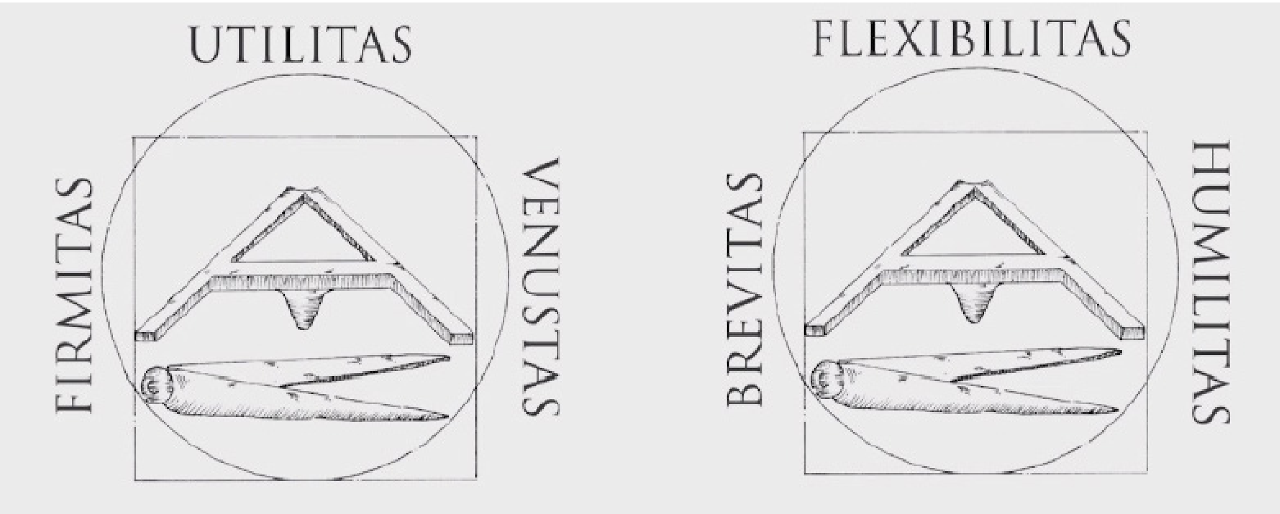


Figure 17.[146] An Anti - Vitruvian architectural composition

The conclusion is that ownership can be one of the main obstacles in order to increase the shortening building lifespans by changing the use of a building through transformation. Basically, transformation is more likely to happen in a rental operation of a building or if a building has one or a small number of owners with the same intentions.

2.1.2 Transformable vs. mixed use buildings

In order to facilitate programmatic transformations, there is a whole set of technical, functional, and legal parameters to be met, which is in a way similar to the situation with a mixed-use program. A programmatic mix is achievable on different scales at first: neighborhood, block, a building. On a scale of a building, the two most common and widely applied models that can be distinguished are a horizontal and vertical mixed-use.

Traditionally, horizontal mixed-use developments have been typically realized because of ease in development, and regulatory and development controls seem to favor this. Nevertheless,

143 Hilde Remoy and Theo Van Der Voord, "SUSTAINABILITY BY ADAPTABLE AND FUNCTIONALLY NEUTRAL BUILDINGS" (Paper presented at SASBE 2009, 3rd CIB International Conference on Smart and Sustainable Built Environments, Delft, May 15, 2014), 8.
144 This can be illustrated by two projects developed in 2019 in Switzerland for Swiss Railway company, mixed use, mid high rise rental projects in Basel by Herzog & de Meuron and Geneve by Lacaton & Vassal. The latter is analyzed as a case study project within the appendix.
145 Reinier De Graaf, "Where from here" (replacing durable, functional and beautiful with temporary, flexible and discrete)
146 Ibid.

mixed-use developments that take on a vertical dimension, or vertical mixed-use (VMU) developments, are also gaining popularity as a feasible compact development model. Vertical mixed-use developments are usually far more complex to develop both from various positions of the stakeholders, design expertise, regulations, and accessibility, and therefore are more expensive from the start. But they are economically interesting, particularly for rental or mixed (rental and sales) income strategy because they are providing more time-resilient income streams to the developer and therefore reduce the investment risks or a small number of owners.[147]

Knowing this division of mixed-use buildings, we can assume that vertically mixed buildings can be considered transformable in most cases when different programs are set on the same floorplan. Horizontally mixed buildings can achieve a variety of programs but more often without transformational potentials (Diagram 5). However, a thing in common for transformable (functionally neutral) and mixed-use buildings is probably the location within the urban context – a densely developed mixed use city center.

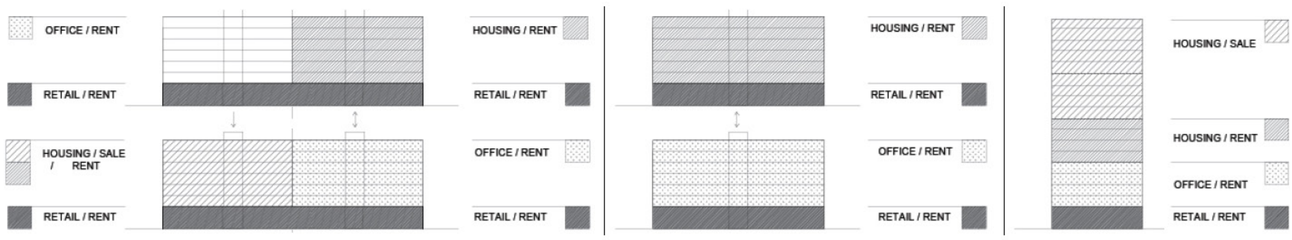


Diagram 5 - Horizontal, functionally neutral and vertical mixed use option

2.1.3 Programmatic transformation within the design process vs. transformations during building lifespan

This discussion could be started with a question: do we need the tools and methodological procedures that can evaluate the transformational or mixed-use potentials in the design process for negotiation and decision making, or do we only need them only to ensure that a finished building can change its program in the future? The answer is both. The first step is to find the right location where the transformative compositions could take place or are likely to happen. The second step is to enable programmatic transformations of architectural compositions during the design and planning phase in order to ensure the minimum obsolescence risk, which should be both in the interest of the investors and city governments and subsequently the end users. The third step is to ensure that the programmatic transformations are possible during the lifespan of buildings, by designing the buildings in such a way to define the physical infrastructures that make the transformations are possible and economically viable. This can be done by defining particular standards for: structure and floor spans, facade system characteristics, particular floor-plan proportions and depth, strategic distribution of horizontal and vertical installation conduits, and distribution of horizontal vertical communications…

The research about this topic has already been conducted by the members of the Department of Real Estate and Housing at TU Delft, they have been researching the realized office to housing conversions and speculating about functionally neutral building as a possible future. They researched a number of cases studies of these types of conversions in the Netherlands and gave several directions for consideration, which will be important for further research. First, these

147 Huston, Simon & Mateo-Babiano, Iderlina. (2013). Vertical mixed-use communities: a solution to urban sustainability? review, audit and developer perspectives. (Paper presented at : 20th Annual European Real Estate Society Conference, Vienna, Austria, July 2013), 6.

are the criteria that enhance the transformation of a building such as: location, appearance, facade, structure, and the installations applied. Second, it is the breakdown of transformation costs showing that the facade is the highest cost, then followed by building interior walls and contractor/building cost (Table 18). [148]

The problem is that the results they have can only be regarded as a guideline and a starting point since the converted office buildings they have studied have not intentionally been designed for such conversions.

Table 1 Criteria that enhance transformation

1. Location	
	Mix of functions Zoning plan permitting future modification e.g. with mixed use including housing No serious health risk (pollution, noise, stench) Noise load on facade < 50 dB, according to Dutch building regulations No serious crime risk (vandalism, burglary, attacks) Facilities nearby, in particular public transport, shops and greenery < 0.5 – 1.0 km View and sunlight not limited by other buildings Sufficient parking space (> one per dwelling) at a distance of preferably < 250 m
2. Building	
Appearance	No "office building look", attractive identity and entrances A high spatial/visual quality issued by the design concept or the materials and colours used
Facade	Replaceable, not load-bearing Daylight admittance at least according to building regulations for housing Opportunity to add balconies Operable windows Acoustic and thermal insulation according to building regulations for housing
Flexibility / adaptability of the structure	Possibility to enlarge the building, horizontally or vertically Acoustic and thermal insulation according to building regulations for housing A structure (grid of columns) that can accommodate floor plans for different target groups (e.g. building depth > 10 m) Preferably no load-bearing walls Access and escape routes (entrances, staircases, elevators) according to building regulations for housing (e.g. including an emergency staircase and at least one elevator if the building counts 4 storeys or more) Free ceiling height > 2.60 m Floor load capacity > 3,5 kN/m2
Installations	No installations integrated in the load-bearing structure Possibility to add service ducts, including the possibility of cutting holes in floors and walls for shafts High energy performance (re-use of heated air)

Table 2 Factors affecting the variation in transformation costs

High costs, high influence	High costs, low influence
Structure	Interior walls
Facade	Ceilings
Mechanical installations	Electro-technical installations
Total contractor costs	Fixed interior
Purchasing costs	
Low costs, high influence	**Low costs, low influence**
Roof	Foundation
Floors	Elevators
Stairs, ramps, railings	Plot

Source: Geraedts and De Vrij, 2004, based on eight projects

Table 4 The three most important cost generators per case

Case name	cost generator *highest*	*second high*	*third high*
Wilhelminastaete	facade	interior walls	contractor costs
Churchill tower	facade	interior walls	contractor costs
PDV building	interior walls	contractor costs	facade
Rijswijkstraat	facade	finishing	contractor costs
AKZO building	facade	interior walls	finishing
Bodelograve	facade	contractor costs	site preparation
J.C. Van Markenlaan	facade	contractor costs	Interior walls
GAK office	facade	interior walls	structure
Putgraaf	facade	interior walls	contractor costs
Roos & Doorn	contractor costs	facade	sanitary equipment
Labdiek	contractor costs	roof	facade
Bakenmonde	facade	interior walls	contractor costs

Source: MacKay, 2008

Figure 18. [149](Tables 1,2,4) Cost based conclusions on the building transformations

148 Hilde Remoy and Theo Van Der Voord, "SUSTAINABILITY BY ADAPTABLE AND FUNCTIONALLY NEUTRAL BUILDINGS" (Paper presented at SASBE 2009, 3rd CIB International Conference on Smart and Sustainable Built Environments, Delft, May 15, 2014), 3-6.
149 Ibid., 3-6.

The focus of this research will also be the relation between housing and office programs, but it will start with the assumption that the building can be designed to be transformable and that today with BIM technologies, we can actually know how and when to propose that kind of buildings, and even how much they could cost. Therefore, this research holds the design standpoint and looks out for the ways how to design "functionally neutral" buildings, in the right place, for the right user, for the foreseeable amount of time, and a rational amount of invested funds. The research to be performed in the following chapters will start with determining the architectural compositions which can be developed as functionally neutral buildings. As that scope might be large, the next step is to provide a quick overview of the infrastructural implications for different the volumetric and program typologies and to choose the ones with the highest potential for functional neutrality, and choose the case studies to explore that scope.

2.2 OVERVIEW OF POSSIBLE CRITERIA FOR DETERMINING THE INFRASTRUCTURES OF AN ARCHITECTURAL COMPOSITIONS

2.2.1 Infrastructural specificities and transformational potentials of volumetric and program typologies

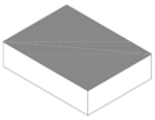
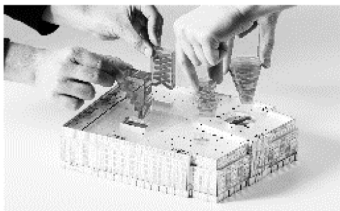
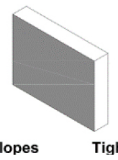
As previously mentioned, Zaera Polo (2008) has elaborated the political, environmental, and infrastructural specificities for each of the four envelope (volumetric) typologies that he proposed in his classification. His thesis studies the tension between the two influences: environmental and political for each type the architectural envelope – which is, for him, the last glimpse of architectural freedom and creativity (Table 3).

This classification is important to structure this research which is more focused on the inside of the envelope (volume) which is in a way "already defined" by the speculative interests of developers and the urban density parameters. In the context of this research, we can argue that there are two types of infrastructure: the internal (the one defined within the GFA-GLA difference) and the external defined through the mediation between the content and the context/environment (façade). This research primarily focuses on the first one but will address the indications about the second as well.

The volume typologies can be programmatically read, but for this research, they will be considered as functionally neutral (having in mind that the most common realized buildings can be described proportionally as A x B x H). Therefore, the next step will examine a degree of their transformational capacities with respect to the selected program range (office and housing).

Another issue posited by Zaera Polo relevant for this research are the design models (plan strategies) related to the volumetric typologies: loose-fit, relaxed-fit, slim-fit, and tight-fit. This issue is important as it determines the kind and scope of possible transformation. The plan-strategies that Zaera Polo proposes do not anticipate the program variability but rather describe the regularities of deployment of a single program with a particular volume boundary.

Table 3. Envelope typologies characteristics according to Zaera Polo's essay [150]

volume / envelope typology	characteristics	visual references (OMA)
1. + X≈Y>Z  Flat-Horizontal Envelopes Loose Fit	- less representation and figural performance - Material flows: traffic, ventilation, daylight, security - Host crowds, enclose public space - Roof, large spans or structural repetition - Horizontal surfaces most important - Vertical surfaces, defensive and ornamental -Atmospheric performance most important - Private (enclosed), public (permeable) - Active boundary strategy (program) integration with context - Renaturalization - Thick ground – bifurcating ground - (gradients of natural and artificial) - High energy consumption	2.KaDeWe, Berlin 
+ X≈Y≈Z  Spherical Envelopes Relaxed Fit	- Lowest ratio surface/volume – ecologic less material - Relative independence envelope/program - Non repetitive - Gradients of publicness - Articulation between wall and roof disappears - Low level of environmental constraints - representational - Insulation and immunizations as a technical problem - Public program compensated with high energy. efficiency	3.Seatle Library 
+ Z >X≈Y  The Vertical Envelope Slim Fit	- Determination and technical complexity -Representative and environmental to the highest level - Densification for economic purposes - Efficiency as a political expression - Re engagement with nature - Patterns of residential qualities - Pyramidal shape, structural stability, domesticity - Larger apartments higher up	4. De Rotterdam 
+ X≈Z>Y  Flat-Vertical Envelopes Tight Fit	-Generated by horizontal displacement of section - Optimized density daylight ventilation - Optimized structure - Large volume of homogeneous program - Facade to facade depth - Facade to core depth - Abandons street alignment and property lines for environmental concerns - Repetition and differentiation doesn't affect the infra.	5.The Interlace, Singapore 

This research will try to address the issue of programmatic transformation both during the planning, design, and development process and the possibility of program transformation after the building is built. As a starting point, a theoretical matrix is set – four volumetric typologies, three dominant programs, and the basic space efficiency parameters to loosely describe their infrastructural layouts. As a theoretical starting point, the directions of possible transformations are drawn between programs and volumes with respect to the possibly similar indications on the spatial efficiency parameters (Diagram 6).

150 Zaera-Polo, Alejandro. "The Politics of The Envelope." *Log,* no. 13/14 (2008): 193-207. Accessed January 2, 2021. http://www.jstor.org/stable/41765249.

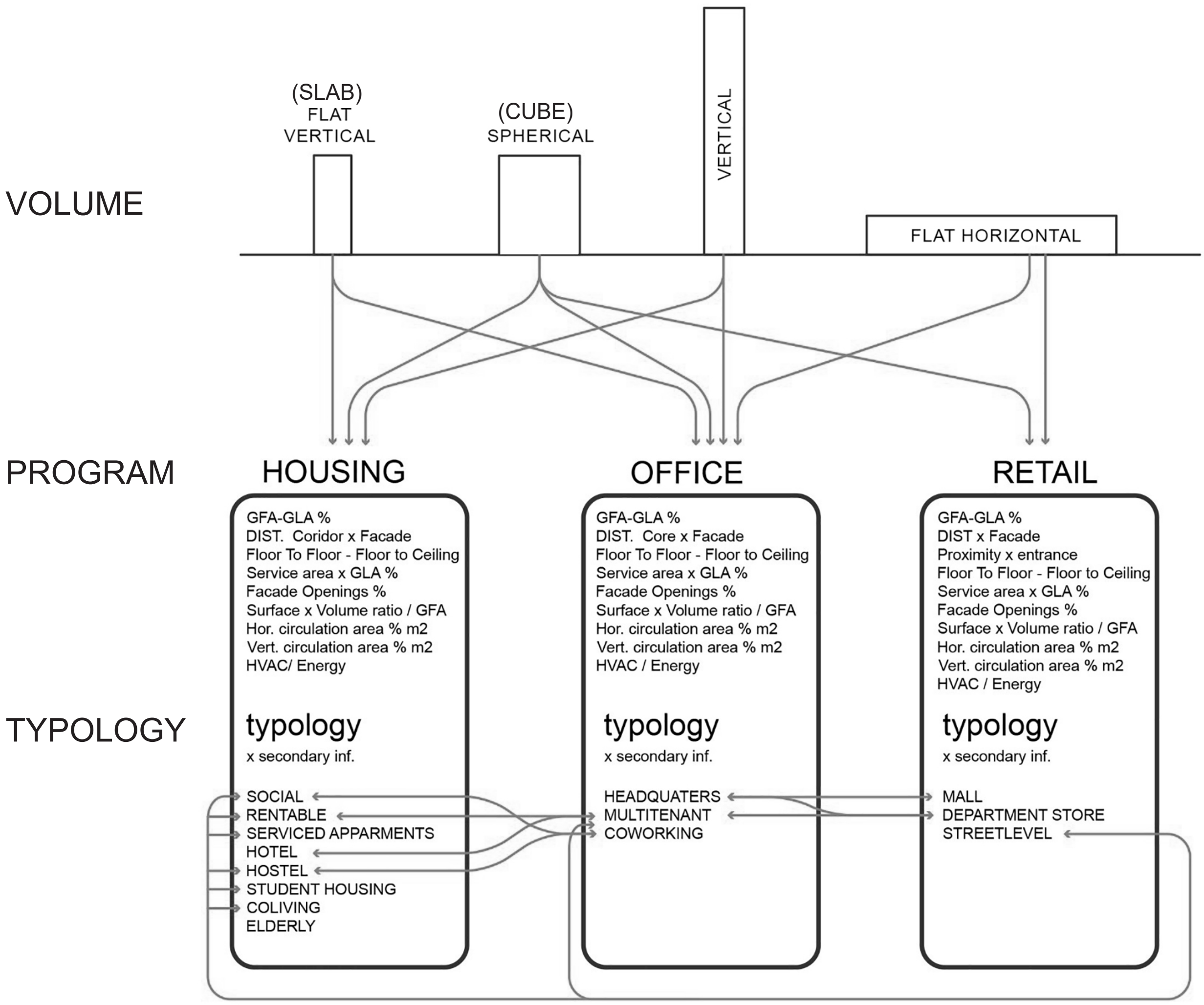


Diagram 6. Program typologies vs. Volume typologies

2.2.2. Architectural scale - Infrastructure and spatial efficiency criteria

Case studies and comparative analysis represent methodological procedures for investigating the infrastructure of a functionally neutral architectural objects. The proposed methods are intended to dissect the architectural project and to identify the links between program segments and the distribution of infrastructure. In order to achieve functional neutrality it is expected that the infrastructure within the architectural composition will be redistributed in towards a new typological framework that may add additional value (excess public space, programmatic changes, spatial efficiency, economic savings...)

The criteria for the analysis were determined from two types of sources that are interrelated and dependent. The first is normative sources consisting of architectural regulations and spatial efficiency parameters that partially define the typology. The second are theoretical/practical sources originating (from the authors from the leading architectural practices) from projects and related publications that help the evolution of regulations, trends and the established conventions.

Infrastructure of an architectural composition from the theoretical position of this research can be defined and located in a simple way – using a basic understanding of spatial efficiency, a difference between Gross Floor Area (GFA) and Gross Leasable Area (GLA). However, we need to locate this difference within the volume as well in order to understand the design logic that determines the architectural composition influenced by a multiplicity of other factors such as:

urban zoning laws, positioning, climate, and economic context, etc. (Diagram 7). The evaluation criteria can be divided into four principal groups (urban and architectural – each of them quantitative and qualitative) to be taken into consideration, which will be applied later to different levels of detail while performing the case studies.

The spatial efficiency of a building does not necessarily reflect the quality of a building and its architecture. This term within the research reflects a different kind of spatiality than that usually referred to by the architects and theorists from the 20th century. Spatial efficiency is related here to the economic or ecologic value, and it doesn't reflect spatiality in terms of the social and architectural value. Instead it is used as a methodological tool - a set of measurable parameters convenient to evaluate the more commercial architectural typologies such as office and housing.

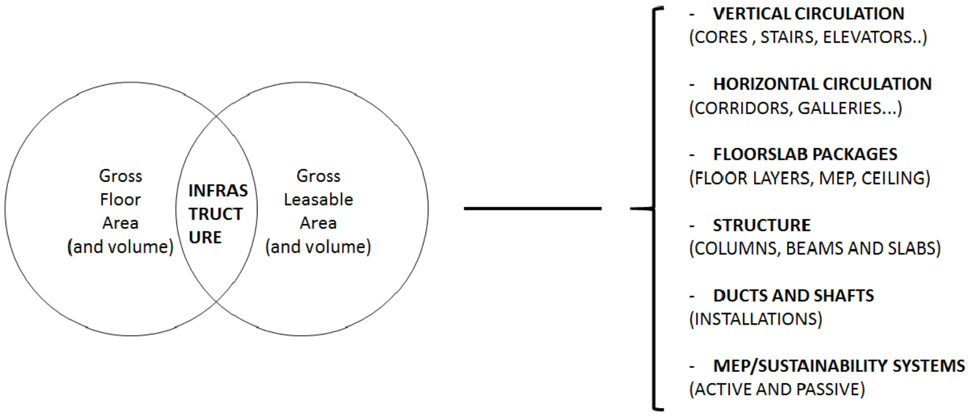


Diagram 7. Locating building infrastructures

2.2.2.1 Quantitative spatial efficiency parameters:

- *GLA % (gross leasable area)/GFA (gross floor area)* – The net/gross ratio is one of the primary spatial efficiency parameters of the architectural composition. This well-known parameter of spatial efficiency does not come from architecture but from real estate industry and consists of two segments: Gross Floor Area (GFA) as a total floor surface of a building, and Gross Leasable Area (GLA, net area) is the amount of building surface area that can be sold or rented – designed for tenants and their exclusive use.[151]

The difference between GFA and GLA surfaces is a field that limits and directs the program structure and internal organization, as well as a field where changes are made in architecture through quality space management, in which the strategic positioning of infrastructure elements plays a key role, both in spatial and economic terms. It is also space where infrastructural components are located. According to Ridzwan Rahmat, one of the indicators of good spatial organization and management is maximizing GLA at the expense of GFA through the creative appropriation of basement galleries and corridors as a space that can generate profit.[152] This, in addition to financial benefits, carries risks to jeopardize the functionality of the building, so this type of appropriation should be taken into account. However, from a slightly more ethical perspective of the architect-designer, the possibility of appropriation of public space (and void) can be overlooked, and at the expense of the economic benefits, it carries offset by better quality semi-public and public content, which will sometimes expand at the expense of the private GLA for mutual benefit. The GFA – GLA optimality standards differ, however, for different types of architectural objects depending on program and volume typology, location and categorization,

151 Space Management Group, Promoting Spatial Efficiency in Building design, (UK: UK Higher Education Space Management project, 2006), https://www.researchgate.net/publication/307571226_Promoting_space_efficiency_in_building_design_UK_Higher_Education_Space_Management_project.
152 Ridzwan Rahmat, "Gross Leasable Area," Reitsweek, December 30, 2012, xx, https://www.reitsweek.com/2012/12/gross-leasable-area.html.

and appropriation opportunities are changing accordingly.

- *FTF (floor to floor height), FTC (floor to ceiling height)* – The two parameters indicate the sectional efficiency of a building, according to the standards and regulations for specific programs. Besides that, they indicate the structural rationality such as floor span and the positioning and space capacity reserved for the horizontal MEP installations together with the material substrates of the total floor package (PACK (thickness of the floor package)=FTF-FTC)
- *Core to Facade distance (CTF)* – Core to facade distance is a parameter that originates from the high-rise building typologies determining the depth of the usable area within a floor plan. However, it is used nowadays in all typologies to regulate the program-specific requirements and standards primarily related to the supply of air and natural light. As CTF is more oriented towards cubic and tower volume typologies, in slab typologies building depth will be measured from corridor to façade.
- *Depth ratio CTF/FTC* – The CTF distance is often related to FTC since to make the depth evaluation more precise in 3d, the larger CTF is, the deeper the floorplan can be. For the slab typologies (flat vertical), total width will be used, and depth will be measured as the corridor to the facade.
- *- Void to Volume ratio %* - Volume-to-void ratio is a significant parameter and analytical tool that complements the previously analyzed parameters pertaining to the area of a building, given that the regulation of many European countries contains cubic meters m^3 as a spatial benchmark for businesses[153] but also for schools, kindergartens, hospitals. In his book *Content*, Koolhaas presents a strategy for forming voids as public spaces, calling it a void strategy (Figure 19). The strategy consists of the method of redistributing the volume of public space in an uneven way instead of the repetition that already exists in the rest of the structure. Koolhaas proposes the formation of more undeveloped void zones that will more effectively animate the built program mass.[154] Voids can be classified as internal and external.

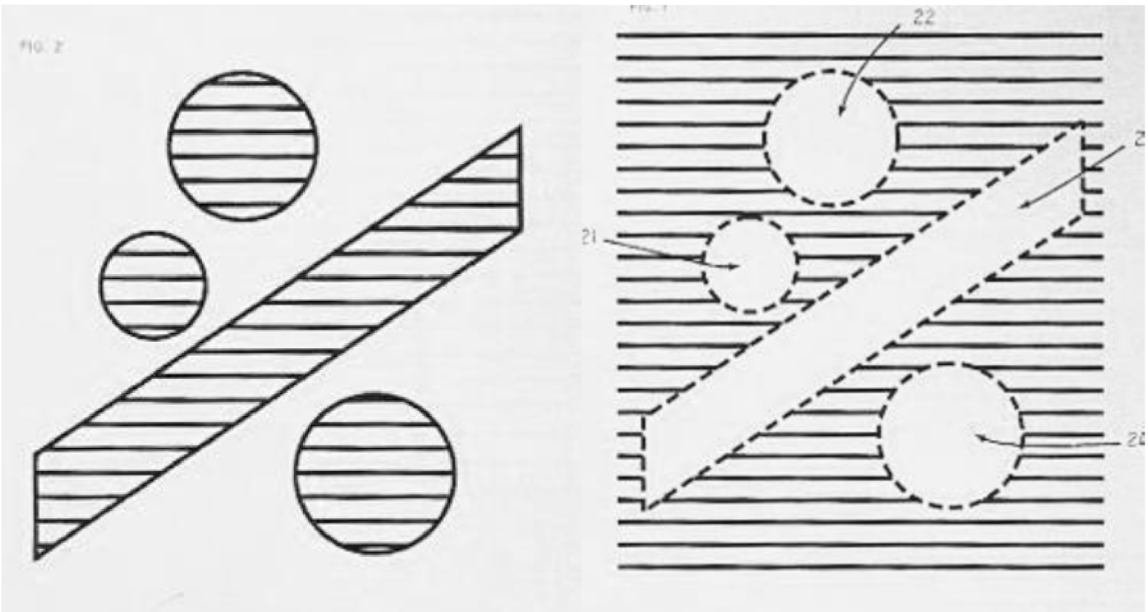


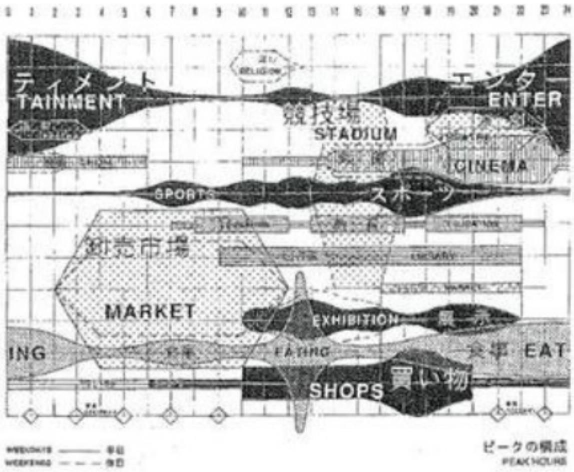
Figure 22. Strategy of the Void II[155]

153 Health and Safety Executive, Workplace health, safety and welfare (Health and Safety Executive, 2007), https://www.hse.gov.uk/pubns/indg244.pdf.
154 Ingrid Böck, *Six Canonical Projects by Rem Koolhaas: Essays on the History of Ideas* (Berin: Jovis, 2015), 266.
155 Rem Koolhaas, "Junkspace," in *Content* (Koln: Taschen, 2004), 77.

2.2.2.2 Qualitative and descriptive evaluation criteria

Program related criteria:

- *Program structure* – refers to the % of different programs within the overall GLA; as most of the analyzed buildings have besides a primary an additional program or have a mixed-use program structure. It is interesting to relate the program structure to the urban density where the project is developed to see how the density affect the development of the mixed use buildings.
- *Program-specific infrastructure* – different programs often require different infrastructures such as circulation, HVAC systems, or specific service areas; therefore, it is important to notice and map those elements
- *The intensity of program use* (hours/day) – The question of the variability of program activities is one of the key issues, which originally concerned situations of the high density of built-up and populated areas when it is impossible to assign an independent spatial framework to each program segment. The programs overlap with different intensities of use, and therefore the supporting infrastructures are laid out according to fixed and temporary programs (Figure 20, Figure 21).



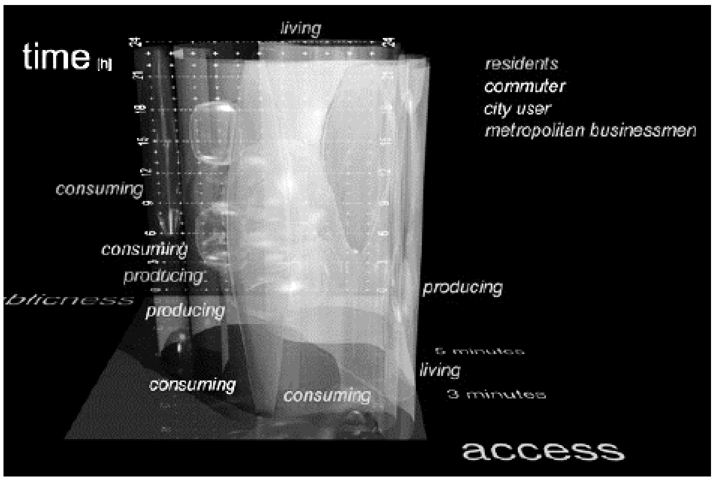


Figure 20. Yokohama Masterplan (OMA)[156] Figure 21. IFCCA 24h cycle (UNStudio)[157]

- *Unfinishedness* - This criterion was formed under the hypothesis that a significant part of architectural objects that have been under construction since the beginning of the new millennium is in a way unfinished. After construction, over time, their programming or physical structure changes without question. Interior becomes a variable category that depends solely on the user, so architects have stopped designing it as an integral part of the building, but rather it depends on the customers and tenants. When constructing commercial buildings, the structure of future users is almost never fully known but partly defined and assumed. In the context of infrastructure, we can characterize this situation as a type of an unfinished program, and it implies the development of conventional technical systems and infrastructure for the whole facility, although it is not completely programmatically defined, but provides the infrastructure that allows it to be programmatically flexible in a certain range. The second type of unfinishedness is physical and involves options for physical alteration and upgrading of the structure, forming new spatial volumes. This type of structure was already popular in the 1960s through Plug-in City, or Spatial City projects, which meant

156 OMA, "Yokohama Masterplan," , 1991, https://oma.eu/projects/yokohama-masterplan.
157 UNStudio, "IFCCA competition diagram," , 1999, https://www.unstudio.com/en/page/12062/ifcca.

upgrading within a defined mega-infrastructure. However, this approach, but on a much smaller scale, was first implemented by Hertzberger (1978 Diagoon housing, Delft); by offering a bare core and slab structure, it allowed residents to define their dwellings partly by architecture (Figure 22). In addition to their openness, these houses are not objects that provide an unlimited number of options; they offered a spatial framework and indications for spatial configurations but also a productive tension between architect intent and user control.[158] The same approach is exploited by Aravena in recent social housing projects in South America, but with a significant social impact.

Figure 22.[159] Herman Hetzberger - Diagoon houses layouts

Circulation

- *Circulation zones % GFA type (horizontal and vertical)* – determines the share of horizontal and vertical circulations within the GFA of a typical plan.
- *Circulation zones layout strategies (horizontal and vertical)* – this criterion can be most often related to building typology (program and volume). Efficient and well-dimensioned circulation is the key prerequisite for the spatial efficiency of a building, but moreover, the good positioning of circulations with respect to the urban flows is the first most important action. Circulation zones also often represent the thick borders between public and private – thick because they very often incorporate a variety of building installations and systems in order to keep the GLA areas that they service maximally unobstructed and efficient.

Structure

- *The type of structural system* – the type of structural system is an important factor and a prerequisite for transformations within the architectural composition. In general, skeletal sys-

158 Herman Hertzberger, "Diagoon Houses, Delft," *A&U*, 1991, 66-71.
159 Herman Hertzberger, "Diagoon houses plans," , 1970, https://archinect.com/news/article/30540087/editor-s-picks-241#&gid=1&pid=1.

tems are more convenient than massive systems, while steel or wood may be more flexible than concrete structures; however, concrete structures are still the most common, durable, and cost-effective, so they will be primarily considered.

- *Typical structural grid* – determines the structural efficiency of the composition together with the flexibility in a plan. The larger spans are, in general, most flexible in a plan, while smaller spans most efficient in section and material-wise. Some grids are also program-related, while others may be used well for different programs.
- *Façade, opening %/program* – Facade/the building envelope is both a qualitative and quantitative criterion for the analysis. Quantitative because the facade typologies can be quantified with transparency (defined as opening %). This ratio can then be related to a certain program (or class of the program, budget constraints, etc.), or an event in a particular context (noisy street, proximity, privacy), or the ecologic context in terms of (orientation – north-south, applied HVAC system, type of ventilation...)

Economy and cost related criteria

Economic facts for different projects are often disclosed information and not accessible to the public; however, if some information is available, it is important to understand the overall economic context of the project or the structure of investment in order to understand why certain design decisions have been made. When project-specific data is not available, statistical publicly available information will be used instead, such as the cost of land, construction cost, average rental, and sales prices for different programs and countries and cities.

- *Cost of land (CL)* – determines the cost of a purchased plot per m^2. Interesting to compare in urban contexts of different densities.
- *Construction cost (CC)* – determines the construction cost per m^2 Cost/m^2 GFA towards determining the total structure of the investment.
- *Investments cost (IC)* – total investment cost (includes land cost, construction cost, taxes, sales cost, financing cost...)
- *Real estate strategy (rent or sales)* – is important for understanding the current and the future ownership structure and if there are differences in infrastructures between the program segments with different ownership.
- Investment return – potential investment return can be calculated by dividing IC - (m^2 sales value x GLAm^2) or IC - (GLAm^2 x rent/m^2 GLA x No. Years)

HVAC MEP & sustainability criteria

- *Service area/GLA* – Since services are an important segment of each program, it is important to locate them within or beyond GLA areas and determine the relation of their size and capacity to the area they are servicing. This is often regulated with standards or guidelines that vary with different program typologies (and classes) but also with different regions where the projects are developed.
- *% ducts/typical floor* – The vertical ducts are important since they are the service points of the architectural floorplans, places where different installations converge vertically; according to Till and Schneider, careful placement of installation ducts acting like small service cores can directly contribute to the increase of flexibility of the plan. Sizing and distribution

of vertical ducts therefore are important prerequisites both for the mixed-use and programmatic transformation.

- *Active and passive infrastructures* – according to the previously elaborated findings from Koolhaas' essay Junkspace, a clear division of infrastructure can be determined in terms of the energy/maintenance performance – infrastructures can be active and passive with respect to the fact that their maintenance is charged only once or it consumes energy and funds continuously. It is interesting to determine their dispositions in the architectural project with respect to the public or private areas they may service.
- *HVAC/Energy consumption* – Environmental concerns have raised the awareness about the energy consumption and carbon footprint each building has during its construction and exploitations. The second is measured with energy efficiency standards (which may vary regionally), but most buildings do have an energy certificate that proves how much energy is spent in the operation costs. The HVAC is the primary consumer in the non-industrial buildings; therefore, the choice of the HVAC systems often significantly influences the greater design decisions with the architectural composition.

2.2.3 Urban scale - parameters and criteria related to the urban infrastructures

Urban parameters and criteria can be divided in two groups as quantitative and descriptive.

2.2.3.1 Quantitative urban parameters

The first set of parameters that indicate the type of infrastructures applied to an architectural composition are the urban parameters that determine the volume (envelope) type of a building:

- *FAR (Floor Area Ratio)* – the basic urban parameter that indexes urban density. It is a coefficient that shows how many times a surface area of a plot can be multiplied to reach the maximum number of gross m^2 (GFA).
- *HEI (height index)* – the maximum number of overground levels a building can reach. According to the site-specific condition, a number of underground levels can be allowed as well. It is often combined with site-related height limit, so it affects the floor-to-floor heights and the design of possible *sous terrain* and attic levels (in most of the countries, the maximum height is based on a limit in meters, for easier comparison in this research, it is expressed in levels, while the FTF height is analyzed separately).
- *Site occupancy %* – the maximum allowed building footprint on the plot of land. Site occupancy varies with urban densities and land value. It can also be regulated differently for the underground levels, which can often take a higher % of the site than over the ground, in order to achieve enough parking and technical spaces for the overground structure. Besides, a minimum % of green space obliged is defined along with this parameter.
- *GFA (Gross Floor Area)* – refers to the total area within the building envelope, including the outer walls, without the roof. (Calculated differently in different countries. It indexes a maximum number of gross m^2 of a building, defined by FAR.)

The site occupancy area, FAR, and HEI are the parameters that define the maximal possible volume of the building. This was well illustrated already in 1919 with the drawings of Hugh Ferris depicting the volumetric potentials limited by the New York zoning laws (Figure 24).[160] About a century later, at the Venice Architecture Bienniale, the exhibition in the Korean pavilion has shown again that the FAR game still lives on (Figure 23):

> "It is true that a clear identity for Korean architecture has been blurred amid the struggle between conflicting agendas: demolition vs. regeneration, privatization vs. nationalization, aesthetics vs. practicality. But underneath all of these considerations, the FAR Game always rages. It is easy to dismiss the FAR Game as a symptom of unscrupulous greed, and perhaps this is why theorists and critics rarely talk about it openly. However, the reality is that, rather than resisting it, architects in Korea must welcome the tension between the desire for maximum floor area and the building rules that restrict it, and use that tension to spark creativity and innovation." [161]

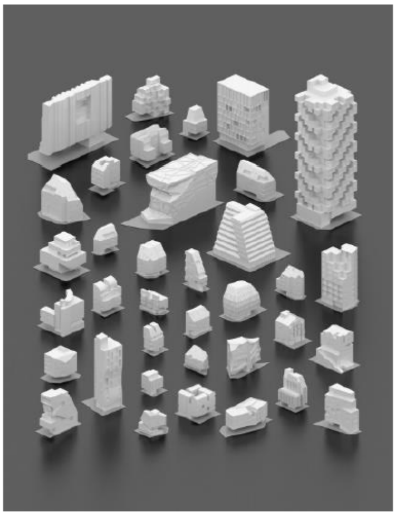


Figure 23. FAR game exhibition[162]   Figure 24. Hugh Ferris' vision of Manhattan[163]

2.2.3.2 Qualitative and descriptive evaluation criteria

- *Appropriation of public spaces* – This phenomenon came into architectural and urban theory by interpreting the views of Henry Lefebvre in the appropriation of public spaces by the capital outlined in the book Production of Space:

> "The sphere of private life ought to be enclosed, and have a finite, or finished, aspect. Public space, by contrast, ought to be an opening outwards. What we see happening is just the opposite."[164]

> "It is therefore in appearance only that the 'private' sphere is organized according to the dictates of the 'public' one. The inverse situation... is the one that actually prevails.[165]

160 Rem Koolhaas, *Delirious New York: A Retroactive Manifesto for Manhattan* (New York: The Monacelli Press, LLC, 2014), 109-116.
161 Kim Sung Hong, "Korean Pavilion exhibition contents" (Paper presented at Venice Architecture Biennale 2014, Venice, 2014). 3.
162 Korean National pavilion, "FAR game exhibition," 2014, 2014, https://www.asiae.co.kr/article/2016031723115653768&mobile=Y.
163 Hugh Ferriss, "Manhattan zoning laws," , 1920, http://words.provolot.com/parallel-dates/38.
164 Henri Lefebvre, *The Production of Space* (Hoboken: Wiley-Blackwell, 1992), 147.
165 Ibid, 375-376.

Appropriation of public spaces occurs at the city level and within the architectural object itself. On the architectural scale, the limits of appropriation go beyond the boundaries of the architectural object[166]. On the urban scale, appropriation can be partially viewed through the quantitative parameter of occupancy, fencing, occupation of space, and here we are referring not only to space within the plot but also to the appropriation of urban flows and activities through urban infrastructure. Guy Debord, in the book Society of Spectacle, even dismisses urbanism, arguing that it is a discipline that determines the *modes of appropriation of the natural and human environment by capitalism*.[167] The OMA's Urban Planning Strategy implies and welcomes appropriation opportunities in urban space, arguing that leaving the space undeveloped offers the possibility of its re-appropriation, in a way implying that public space can only exist as undeveloped and cultivated on account of its counterpart – a private and developed space (Figure 25).

"Given that practically all we build today is disappointing, we invest our hopes in the unbuilt as the last source of the sublime. If we deploy in the unbuilt the powers formerly applied to the built, we can afford to treat the built as we formerly did for nature, and take it for granted."[168]

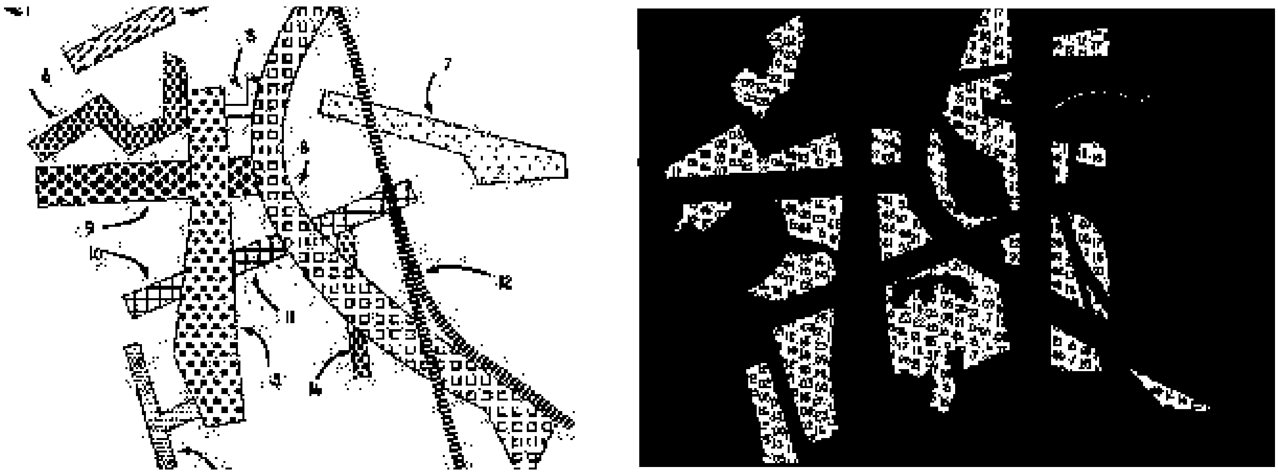


Figure 25. OMA/ *Strategy of the void I*[169]

- *Relation with the urban infrastructures* – In his book *Go with the Flow – Architecture, Infrastructure and Everyday Experience of Mobility*, architect and theorist Gilles Delalex builds on the writings of Stan Allen (elaborated in Chapter 1). Delalex, for the first time, directly links infrastructure on an urban and architectural scale, suggesting that architecture is actually an extension of urban infrastructure and itself contains infrastructure elements. The relation towards urban infrastructure may, on the one hand, be predetermined by cultural (proprietary or urban patterns) and, on the other, may be design-defined so that within the design scope itself, it can define different states that differ in the way of upgrading to urban infrastructure (some of the possible conditions are defined through the observation of examples: multiplication, selective extensions, completion, passing (Diagram 8, Diagram 9). This also implies strategies of introducing flows of urban infrastructure into an architectural object.

166 Appropriation occurs also internally within the space of gross and net difference (GFA-GLA)
167 Guy Debord, *Society of the Spectacle*, Etc. (Second Printing.) (1973), 169.
168 Rem Koolhaas, "Junkspace," in *Content* (Koln: Taschen, 2003), 74.
169 Ibid. (image scanned)

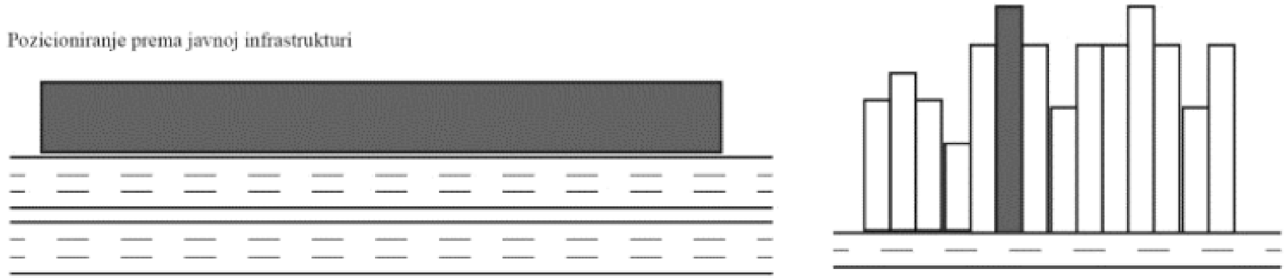


Diagram 8. Positioning of buildings towards public infrastructure: Red Kilometer in Italy (Jean Nouvel) vs. Ho Chi Minh city block

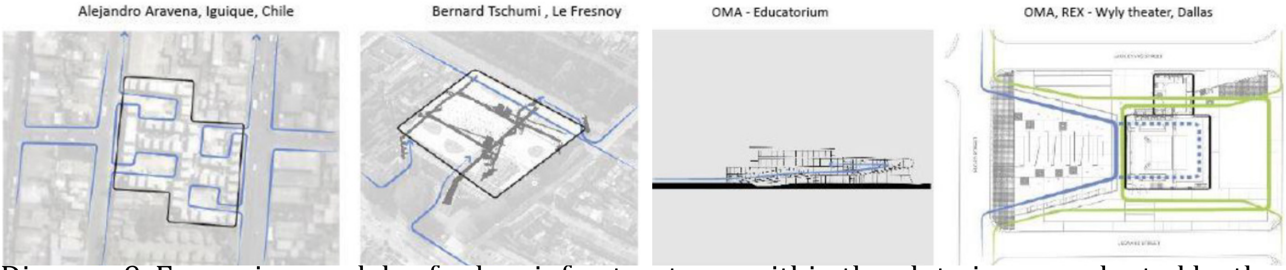


Diagram 9. Expansion models of urban infrastructures within the plot - images adapted by the author (from left to right): multiplication (Aravena), Selective extension (Tschumi), Ending (OMA), Overpassing (OMA, REX)

2.3. CASE STUDIES: DETERMINING THE INFRASTRUCTURAL LAYOUTS OF BUILDINGS WITH RESPECT TO THEIR VOLUME AND PROGRAM TYPOLOGIES

The previously elaborated theoretical model – infrastructural tenet is to be demonstrated through a set of case studies. The set of case studies is used to show how and within which program and volume typologies transformations based on functional neutrality and the mixed-use program can be achieved. The goal of the case studies is to determine a set of infrastructural layouts for the functionally neutral volume typologies that can accommodate multiple programs. Two common programs are chosen for this: the housing and office program, as it is anticipated that an intersecting scope of their spatial requirements may result with a significant overlapping.

The previous theoretical section (Chapter 1) has explained that programmatic transformations can be performed following the models of Flexibility, Performativity, and Process model. Flexibility is understood as a range of acceptable program-related spatial efficiency parameters for the two chosen programs (Step 1). Performativity is a model that is elaborated mainly in a descriptive manner to draw the causally consequential relations between the spatial efficiency and certain technical systems (structure, facade, HVAC, and sustainability systems) applied within the analyzed projects (Step 2). A more detailed performance analysis is not conducted as it would require much more data that is not publicly available and additional expertise to evaluate it. The process model is yet to be established based on the principle of functional neutrality and programmatic incompleteness.

In the previous theoretical section, connections are drawn between the four volume typologies (Slabs, Cubes, flat horizontal, and vertical) and the types of the architectural plan (tight-fit, relaxed-fit, loose-fit, and slim-fit). From the four volumes and their prospective plans, two extremes are excluded (flat horizontal and vertical volumes). The excluded types appear in areas of extremely low or extremely high urban density. Also, flat horizontal volumes are very rarely used to accommodate office and housing programs (Diagram 6) and vertical volumes (tall towers) and require very complex technical systems for their performance which is hard to evaluate (since additional engineering expertise would be needed), compared to other typologies in Europe they are relatively rare and built according to the locally more specific regulation.

A concept of a typical plan (that integrates the tight fit and relaxed fit plans of the chosen volumes) is reintroduced within research to "write" the infrastructural layout of functionally neutral typologies (Step 3). To do that, for the two chosen programs (office and housing) and volume typologies (cubes and slabs), four groups of projects are carefully selected for analysis.

2.3.1 Criteria for choosing the projects for the case studies

In order to compare the projects ("apples with apples and pears with pears"), the following criteria are applied to chose the projects for the case studies:

- Plot parameters / density of the urban setting

The urban parameters, regulations, and plot size and position within the urban context determine the volumetric typology of a building. Research on housing and densities developed by the A+T Research Group in 2018[170] has been used as a reference guide for the curatorial process for the case studies, so the projects developed in the context of similar urban densities can be grouped and evaluated together. It is the urban density that determines the generic volumes of the buildings, and in this research, it is not related to the program typologies being developed but to the overall level of urbanity and urban density (Figure 26, Figure 27).

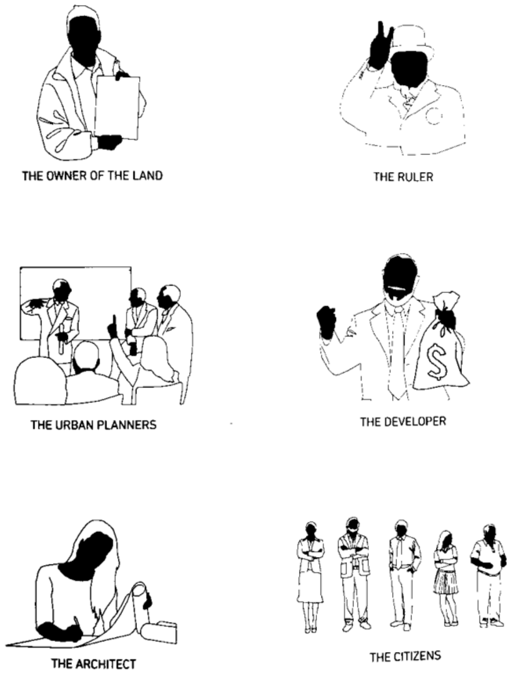


Figure 26. The stakeholders [171]

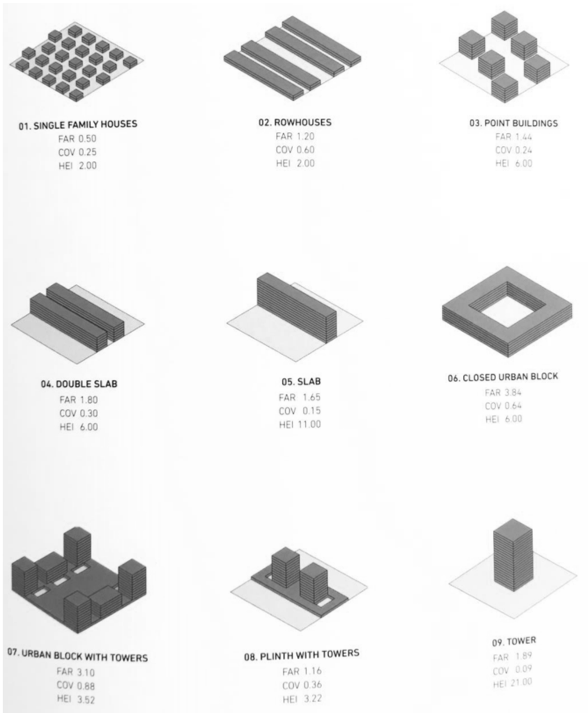


Figure 27. Massing Typologies[172]

- Volumetric typology

As described earlier in the previous chapters, this research is partly guided by Zaera Polo's classifications of buildings to four principal building volumes, which have particular infrastructural characteristics and political implications but also carry certain nuances in terms of the design strategies and methods, and transformational potentials.

For the scope of this research, two principal typologies have been chosen (flat vertical envelope – slab and a spherical envelope – a cube), and two extremes have been excluded (vertical – tower and a flat horizontal slab). The reason for this is that the research will focus on, for instance, the European context of a medium to high-density urban fabric where there is no space for many low-rise buildings, and urban regulations also avoid construction of high-rises (for example, over 20 floors). For the chosen volumetric typologies, gradients are anticipated rather than simplified divisions that Zaera Polo proposes. An enclosed city block can also be consid-

170 A+t research group, *Why density?* (Álava: A+T, 2015)
171 Ibid, 17.
172 Ibid, 59.

ered a slab, sometimes cubes and slabs can be combined, or sometimes a deep cube can have a dominant vertical dimension (10–floors) and still could be taken into consideration for the case studies since it is not conceived as a super tall high-rise and does not yet need all the high-rise technologies.

- Program typology

Most of the European buildings are not entirely programmed homogeneously but are actually mixed-use buildings; however, most of them have dominant programs. The two dominant programs for the case studies are housing and office programs, the ones that deal with a large degree of repetition but also the ones that may have similar infrastructural demands and could possibly be transformed from one to another.

- Transformational potential of the architectural composition (or the change that happened)

The chosen project should, in a certain way, imply a certain degree of transformational potential. This potential does not have to imply a change from program to program; it also counts in the possible transformation between the categories of a single program. In terms of housing, these are social housing, rentable housing, temporary housing, serviced apartments, hotel, co-living, etc. And in terms of office program that could be: traditional office, HQ, co-working space… The second criterion related to the transformational potential is the architectural composition itself, whether it carries a certain degree of flexibility or if a project is a reconstruction, so the change has already happened, meaning a transformation is already proven to be feasible.

- Repetition

Projects chosen for the case studies should have a large degree of repetition of both functional and structural/spatial units; therefore, they could be easily measured in terms of their spatial performances and efficiency. So both the functional units and the infrastructural zones can be easily identified, analyzed, quantified, and classified. In those terms, the buildings chosen for the case studies should be considered to be high-quality architecture but also generic architecture in terms of form and typology.

- High degree of spatial efficiency of the architectural composition

In terms of spatial efficiency and land use, the chosen examples should be highly efficient with respect to the urban regulation FAR and land occupancy, but also inside the building in terms of the GLA/GFA ratios and the efficient use of buildings infrastructural elements.

- Structural system

In order to be able to compare better the chosen examples, a criterion related to the building structure is added, so the technology does not make too much difference throughout the chosen projects. The chosen structure is, therefore, primarily a skeletal concrete structure or combined with steel or wood as a secondary structure or addition.

- Period of design and construction

As stated in the title of the thesis, the case studies will use the projects designed and built in the 21st century. However, for the larger matrix, which will be developed as a first step of the case studies, four precedents (prototypical buildings) from earlier periods (such as modern architecture will be chosen, i.e., Aalto, Le Corbusier, Otto Heinrich Senn, Foster…)

- Project locations – European and local

Following the previous criteria, four groups of projects for the case studies will be distinguished. Each of these groups will have one prototypical modern example no matter the location. As well, each of the two chosen programs will have one local project developed in Serbia. Most of the projects are chosen from the EU zone, most of which within the central-European climate zone and cultural context where Serbia also belongs.

2.3.2 A three step analytical procedure - applied parameters and criteria

The previous section have provided a list of possible criteria and parameters for evaluation the infrastructures within the architectural compositions of the chosen case study buildings. However only a limited number of parameters is applied within the proposed scope of the case studies (limited to cubes and slabs as a volumetric typology and housing and office as program typology). Tasks performed on the case studies can be divided in three steps, and each steps uses a selection of parameters and criteria listed below.

Step 1 - Identification and valorization of the infrastructural layouts in terms of the spatial efficiency parameters – spherical and flat-vertical volume typology / office and housing programs (22 buildings) – quantitative analysis (see Diagram 8)

The collected number of 22 projects are sorted into four groups are a subject of first step:

1) Housing - Slabs

2) Housing – Cubes

3) Office - Slabs

4) Office - Cubes

Parameters for the infrastructure /spatial efficiency analysis of the architectural compositions can be classified in two groups:

Urban:

- FAR - land use (quantitative)
- COV - Site occupancy % (footprint allowed) / (quantitative)
- HEI (height index, number of levels) / (quantitative)

Efficiency:

- GFA (gross floor area) / (quantitative)
- GLA (gross leasable area) GLA % GFA / (quantitative)
- Circulation zones % (horizontal and vertical) / (quantitative)
- FTF (floor to floor height) FTC (floor to ceiling height) / (quantitative)
- PACK % (FTF-FTC) x height (floor/ceiling package thickness) / (quantitative)
- Core to Façade distance (CTF), Depth ratio CTF / FTC (quantitative)
- % and m2 ducts / typical floor (quantitative)
- Façade opening % / program (quantitative)
- Size of a typical structural grid (quantitative)

There is a part of previously collected parameters (Chapter 2.2) which have not been used (or not fully used) in this step of the analysis for following reasons:

- Program structure and program specific infrastructure - as most of the analyzed buildings are mono-functional or have a dominant program (apart for the ground levels) it was not necessary to elaborate this criteria in this step.
- Intensity of program use h/day- is the parameter that can be only anticipated for example for housing it would be 24h/day, or for offices 10-12h/day. This parameter would be more relevant for more complex mixed use buildings.
- Unfinishedness - a qualitative parameter not used since all the chosen example are physically finished, programatically - it is possible that office building examples or apartment compartments in housing projects could be qualified as unfinished and waiting for a fit-out but there is not enough publicly available data.
- Circulation % and strategies - this parameter have been explained graphically but not fully quantified (Only as a part of GFA-GLA) and analyzed in detail
- Structural systems - analysis is limited to measuring the typical grid size
- Economy and cost related criteria - not performed because the necessary data is not available for most of the chosen projects.
- HVAC, MEP and sustainability - not performed because the necessary data is not available for most of the chosen projects.

Step 2

Qualitative and quantitative analysis of four projects (2 transformation, 2 mixed use newbuilds) towards understanding the conditions of undertaking transformation or mixed use with the context of the densely populated urban centers. (Diagram 8)

The four projects selected from initial scope for the second step are:

1) Housing / slabs /TRANSFORMATION /Schubertsingel - Houben & Van Meirlo, Den Bosch, 2018.

2) Mixed use / cubes /NEWBUILT / Tour Opale - Lacaton & Vassal, Geneve, 2019.

3) Office / slabs /NEWBUILT / Aufbauhaus 84 - Barkow & Leibinger, Berlin, 2015.

4) Office /cube /RECONSTRUCTION / Roaming HQ - Biro Via, Belgrade, 2018.

Each of the case study projects is analyzed using the following groups of criteria and parameters:

1)Urban:

- Plot size (quantitative)
- Site Occupancy% (quantitative)
- FAR (quantitative)
- Population density (quantitative)
- HEI (quantitative)
- Parking perspective (descriptive)

2)Spatial efficiency (observations based on quantitative and descriptive criteria)

- GFA (gross floor area) / (quantitative)
- GLA (gross leasable area) GLA % GFA / (quantitative)
- Circulation zones % (horizontal and vertical)/ (quantitative)
- FTF (floor to floor height) FTC (floor to ceiling height)/ (quantitative)
- PACK % (FTF-FTC) x height (floor/ceiling package thickness)/ (quantitative)
- Core to Façade distance (CTF), (total width, and corridor to facade, for flat vertical volumes)/ (quantitative)
- Depth ratio CTF / FTC (quantitative)
- % and m2 ducts / typical floor (quantitative)
- Façade opening % / program (quantitative)
- Void to Volume % (quantitative)

3)Economy:

- Client / Developer (descriptive)
- Investment Value /m2 (where data is available) / (quantitative)
- Real estate prices for office and housing program per m2: rental and sales (based on statistical data from www.statista.com and www.globalpropertyguide.com) / (quantitative)
- Land value (descriptive low-mid-high)

4) Program (Observations

- Main programs share %/ GFA (quantitative)
- Additional program share %/GFA (quantitative)
- Number of units/ program (quantitative,,per typical floor)
- Facilities and service areas (descriptive)
- Tenants (descriptive)

5) Structure

- Type (descriptive)
- Cores (descriptive)
- Typical grid size (quantitative)
- Floorslab type (descriptive)
- Facade type (descriptive)

6) Sustainability (observations based on quantitative and descriptive criteria)

- Passive systems (descriptive)
- HVAC type (descriptive)

- Active systems (descriptive)
- Ducts %GFA/typical floor and technical spaces (quantitative)

7) Circulation (observations based on quantitative and descriptive criteria and circulation diagrams drawn or used from the project documentation)

- Access (descriptive)
- Lobbies m2 (quantitative)
- Horizontal circulation (quantitative)
- Vertical circulation: Stairs and elevators (quantitative)

There is a part of previously collected parameters (Chapter 2.2) which have not been used (or not fully used) in this step of the analysis for following reasons:

- Appropriation of public spaces - not performed because the necessary data is not available the chosen projects.
- Relation to urban infrastructures - not fully performed, limited to the analysis of the site plan and zone of the plot because the necessary data is not available for the chosen projects.
- Unfinishedness - a qualitative parameter not used since all the chosen example are physically finished, programatically - it is possible that office building examples or apartment compartments in housing projects could be qualified as unfinished and waiting for a fit-out but there is not enough publicly available data.
- Intensity of program use h/day- is the parameter that can be only anticipated for example for housing it would be 24h/day, or for offices 10-12h/day. This parameter would be more relevant for more complex mixed use buildings.
- Structural systems - analysis is limited to measuring the typical grid size
- Economy and cost related criteria - is performed partially since the data is not available publicly or confidential, so the statistics for the urban context have been used to substitute some of the unavailable data.
- HVAC, MEP and sustainibility - performed only on a descriptive level because the necessary data is not available for most of the chosen projects.

Step 3 / synthesis

The third step uses the findings from Step 1 and Step 2 (see Diagram 10) to achieve two things:

1) Generating a library of functionally neutral typical plans abducted from the case studies contextualized with typologically similar projects analyzed in Step 1 following the infrastructural tenets of:

- Vertical mixed use (Tour Opale, Aufbauhaus) / (design based)
- Programmatic transformation (Schubertsingel, Roaming HQ) / (design based)

Since the four volumetrically different projects are already mixed use, or have changed its program in a reconstruction process, it is expected that already have functionally neutral typical plans. By comparing with the other analyzed housing or office projects of similar proportions it will be possible to generate the functionally neutral typical plans using their infrastructural layouts. A set of four functionally neutral typical plans of different volume proportions and typologies will be established as a base to generate a larger gradient of typologies presented as a repository of functionally neutral plans.

2) Determining a boundary of urban, economic conditions and spatial efficiency parameters which enable successful program transformations or erecting the mixed use of functionally neutral buildings uses previously listed groups of indicators

- Urban indicators
- Spatial efficiency indicators for functionally neutral buildings
- Economic indicators
- Structure
- Facade
- Sustainability indicators (HVAC, MEP, Energy)
- Mixed use strategies
- Functionally neutral / Infrastructural layout indicators

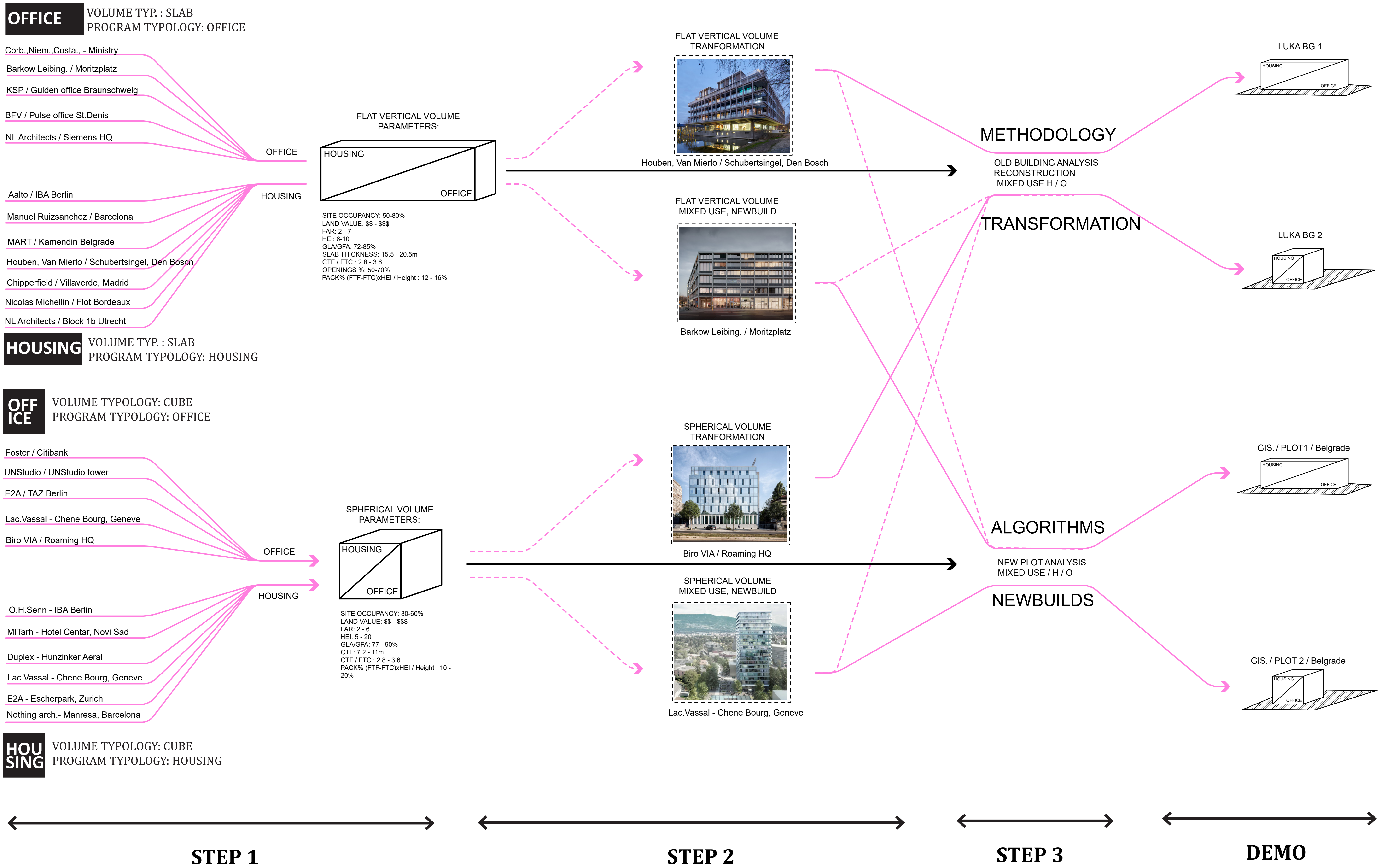


Diagram 10. - A step by step work-flow for the from the case study analysis (APPENDIX1) towards the demostration of its results and possible application (CHAPTER 3 and CHAPTER 4)

2.3.3 Step 1 - Identification and valorization of the infrastructural layouts using the spatial efficiency parameters - Quantitative analysis

The work on the case studies starts with selection of 22 projects divided into four groups according to the volumetric and program typologies. Each group starts with a “modern” archetype from the 20th century, while the rest are from 21st century. The work on the case studies is elaborated and documented in section 6.APPENDIX.

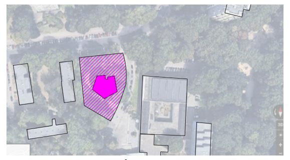
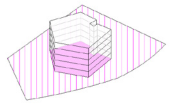
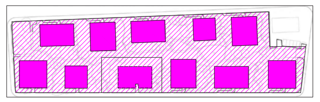
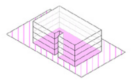
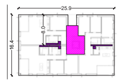
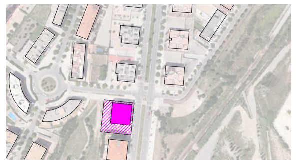
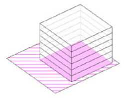
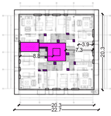
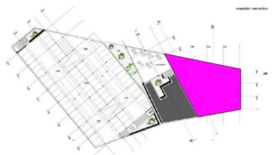
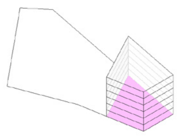
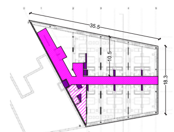
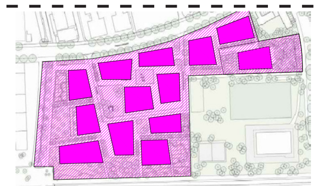
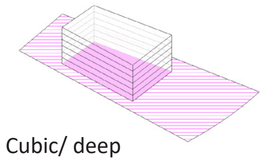
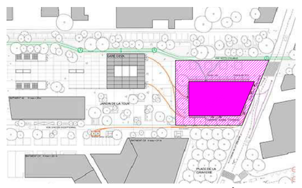
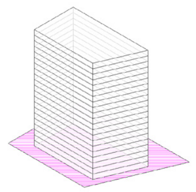
The four groups are analyzed using a set of spatial efficiency parameters and indicators, by measuring the efficiency on several levels: land use (urban scale), typical plan, and section. The graphical research material such as plans, sections,elevations, site-plans etc. (and when available numerical data) is mainly obtained from the architects websites or other public sources, then retraced in AutoCad and measured, calculated and presented in matrices (Table 4, 5, 6, 7). The results are presented in charts (see Appendix 6.) and then the charts for office and housing project groups are overlapped within the framework of mutual typology and so the spatial efficiency indicators are extracted to determine the infrastructural layouts for the possible mixed and functionally neutral typologies. (Diagram 11.)

This step is performed as a quantitative analysis with a degree of comparability. The findings of the first step of analyzing the case studies can be divided into two segments:

The first segment clarifies the urban contexts where mixed use buildings and functionally neutral buildings are being developed. It is the context of the mixed use city centers, characterized with high land value, high density city areas or CBDs indexed with high FAR parameter (usually 2 and higher), and a high site coverage percentage usually 30-60% sometimes until 100%. This is usually followed with mixed use zoning with moderate to high retail potential. with the HEI index usually allowing minimum 6 levels till 20 levels allowing moderately high high-rises.

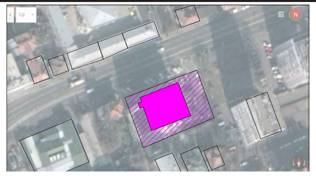
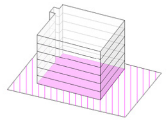
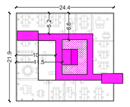
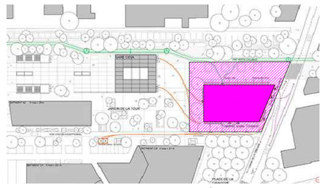
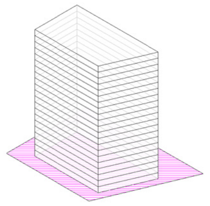
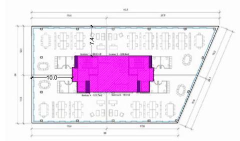
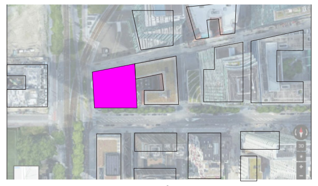
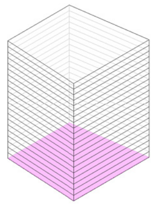
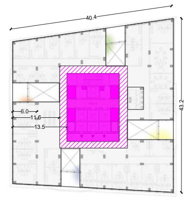
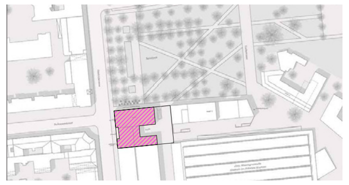
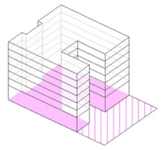
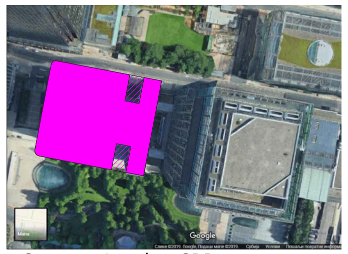
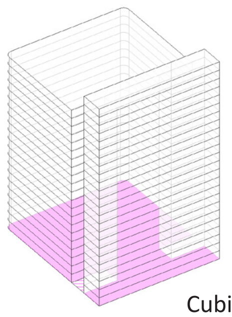
The second segment have clarified the overlapping spatial efficiency indicators for housing and office buildings and determined a set of spatial parameters which can cover both typologies within the same volume which is one of the prerequisites for designing functionally neutral buildings or designing horizontally or vertically mixed programs.

Table 4. Housing / cubes – overview of urban and compositional spatial efficiency indicators

Project / Name/ Year Architect / Location		Site / Situation / Dencity		Volume typology description	Typical plan / void and infra. distribution	Spatial efficiency parameters	FTF , FTC, structure, vertical ducts
	**IBA / 1957**	 Context: IBA / Hansaviertel Density: Land value:$	Plot size: 2870m2 GFA:1925m2 Footprint: 0.15 FAR: 0.69 Cost:/	 Cubic / point building	 no voids / centralized infra.	Typical Plan GFA: 403m2 Typical Plan GLA:370 GLA % GFA : 90% HEI: 5 HEIGHT:15.6m ENERGY EF.LEVEL: / HVAC: gas HOR+VERT CIRC= 32m2	FTF: 3.1m FTC: 2.8m PACK(FTF-FTC):0.3m BASIC GRID: 7.4x 3.4m CTF depth : 7.2m CTF / FTC index: 2.93 (PACK % x HEI):14.1 % DUCTS / GFA: 1%
	**Escherpark / 2014** **E2A / Zurich**	 Context: Zurich outskirts Density: Land value:$$	Plot size: 13008m2 GFA:17935 Footprint: 0.34 FAR: 1.38	 Cubic/ point building	 no voids / centralized infras.	Typical Plan GFA: 416m2 Typical Plan GLA: 377m2 GLA % GFA : 90% HEI: 4 HEIGHT:11.6m ENERGY EF.LEVEL: / HVAC: floor.gas HOR+VERT CIRC= 33m2	FTF: 2.9m FTC: 2.45m PACK(FTF-FTC):0.45m BASIC GRID: 8 x 4m CTF depth : 8m CTF / FTC index: 3.26 (PACK % x HEI):15.5% % DUCTS / GFA: 1.3%
	**Manresa Housing / 2008** **Nothing Architects / Barcelona**	 Context: Barcelona satellite town Density: Land value:$$	Plot size: 1232m2 GFA:2418 Footprint: 0.33 FAR: 2	 Cubic/ point building	 no voids / distribut. infrastructure	Typical Plan GFA: 412m2 Typical Plan GLA: 368.5m2 GLA % GFA : 91.5% HEI: 6 HEIGHT:21.9m ENERGY EF.LEVEL: / HVAC: heat pumps	FTF: 2.9m FTC: 2.6m PACK(FTF-FTC):0.3m(0.65 service) BASIC GRID: 5.4x5.4m CTF depth : 7.2m CTF / FTC index: 2.93 (PACK % x HEI):14.1% % DUCTS / GFA: 1.3%
	**Hotel Centar / 2015** **MITarh / Novi Sad**	 Context: City core Density: Land value:$$$	Plot size: 625m2 GFA:3750m2 Footprint: 1 FAR: 6	 Cubic / block corner	 excentric voids / linear infra.	Typical Plan GFA: 625m2 Typical Plan GLA: 368.5m2 GLA % GFA : 76% HEI: 6 HEIGHT:21.9m ENERGY EF.LEVEL: / HVAC: /	FTF: 3.3m FTC: 2.6m PACK(FTF-FTC):0.6m BASIC GRID: 8x8m CTF depth : 9m CTF / FTC index: 3.45 (PACK % x HEI): 20% % DUCTS / GFA: 1.6%
	**Hunziker Aeral / 2015** **Duplex Architekten / Zurich**	 Context: Zurich city zone Density: Land value:$$$	Plot size: 40170m2 GFA:75012 Footprint: 0.31 FAR: 1.87	 Cubic/ deep	 centralized voids / ring infras.	Typical Plan GFA: 1030m2 Typical Plan GLA: 368.5m2 GLA % GFA : 84% HEI: 6 HEIGHT:19.4m ENERGY EF.LEVEL: / HVAC: / HOR+VER CIRC = 150m2	FTF: 3m FTC: 2.65m PACK(FTF-FTC):0.35m BASIC GRID: 4.8x4.8m CTF depth : 9.2m CTF / FTC index: 3.28 (PACK % x HEI): 10% % DUCTS / GFA: 1%
	**Halte Ceva, Chene Bourg/ 2019** **Lacaton Vassal / Geneve**	 Context: Geneve city outskirts Density: Land value:$$$	Plot size: 2611m2 GFA:17485m2 Footprint: 0.38 FAR: 6.7	 Cubic extended / tower	 no voids / centralized infra.	Typical Plan GFA: 780m2 Typical Plan GLA: 700m2 GLA % GFA : 90% HEI: 21 HEIGHT:61m ENERGY EF.LEVEL: / HVAC: / HOR+VER CIRC = 80m2	FTF: 2.9m FTC: 2.6m PACK(FTF-FTC):0.3m BASIC GRID: 8.8 x 8.8m CTF depth : 7.5m CTF / FTC index: 3.26 (PACK % x HEI): 10% % DUCTS / GFA: 0.5%

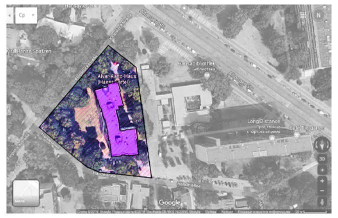
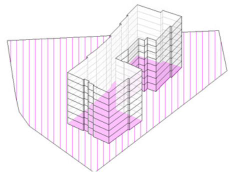
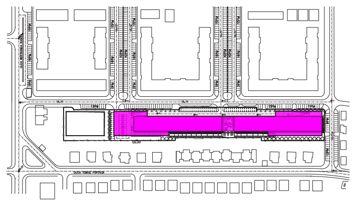
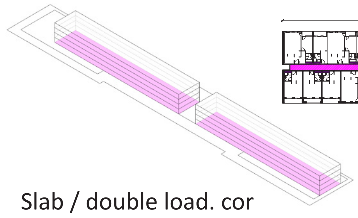
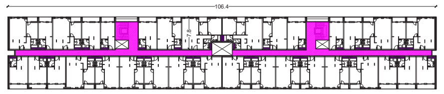
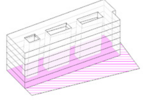
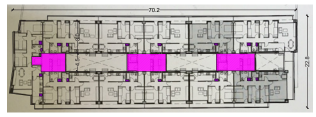
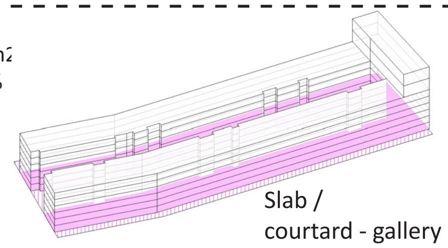
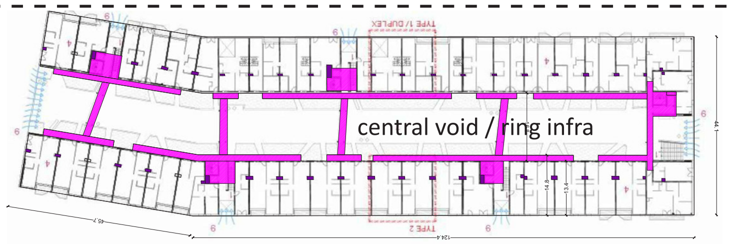
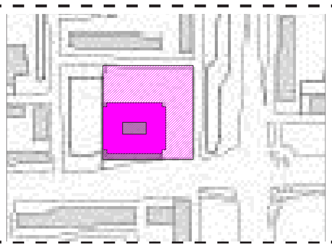
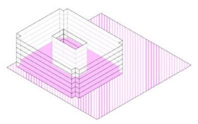
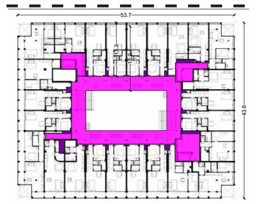
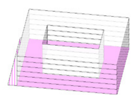
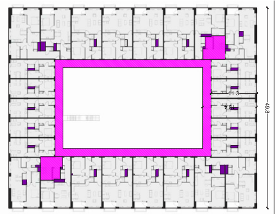
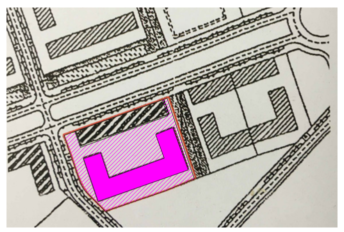
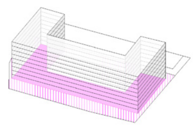
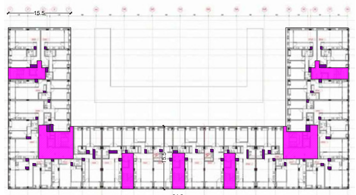
VOLUME TYPOLOGY: CUBE
PROGRAM TYPOLOGY: OFFICE

Table 5. Office / cubes – overview of urban and compositional spatial efficiency indicators

Project / Name/ Year Architect / Location	Site / Situation / Density		Volume typology description	Typical plan / void and infra. distribution	Spatial efficiency parameters	FTF , FTC, structure, vertical ducts
 Roaming HQ/ 2018 Biro VIA /Belgrade	 Context: Belgrade city area Density: Land value:$$	Plot size: 1433m2 Footprint 680m2 Site coverage 47% GFA 4080m2 FAR 2.84 Total cost 7 200 000 e 1764e/m2 Overgr.floor area	 Cubic / point building	 no voids / distribuded infra	Typical plan GFA = 680m2 Typical plan GLA = 1020 m2 GLA % GFA = 79.5% HEI: 6 HEIGHT:24.1m ENERGY EF.LEVEL: C HVAC: Heat pumps HOR+VER CIRC 153m2 Ducts 7.5m2	FTF: 3.6m FTC: 2.9m PACK (FTF-FTC): 0.7m BASIC GRID: CTF depth avg.: 10m CTF/ FTC index = 3.84 %ftf-ftc PACK / HEI = 17.5% % DUCTS / GFA: 1.7
 Tour Opale /2019 Lacaton Vassal / Geneve	 Context: Geneve outskirts Density: Land value:$$	Plot size: 2611m2 GFA:17485m2 Footprint: 0.38 FAR: 6.7 HEI: 21 / HEIGHT:61m	 Cubic extended / tower	 no voids / centralized infras.	Typical Plan GFA: 1000m2 Typical Plan GLA: 838m2 GLA % GFA : 83% ENERGY EF.LEVEL: / HVAC: / HOR+VER CIRC = 172m2	FTF: 2.9m FTC: 2.6m PACK(FTF-FTC):0.3m BASIC GRID: 8.8 x 8.8m CTF depth avg: 9.5m CTF / FTC index: 3.65 (PACK % x HEI): 10% % DUCTS / GFA: 0.5%
 UNStudio tower / 2013 UNStudio/ Amsterdam	 Context: Amsterdam CBD Density: Land value:$$$	Plot size 1569m2 Site coverage 100% GFA 28280m2 FAR 18 HEI: 21 / HEIGHT:85m	 Cubic extended / deep tower	 distribuded voids / centraliz. infra	Typical plan GFA = 1365m2 Typical plan GLA = 1020 m2 GLA % GFA = 74% ENERGY EF.LEVEL:/ HVAC:/ HOR+VER CIRC 345m2 Ducts 24m2	FTF: 3.8 FTC 2.90 FTF-FTC 0.9m BASIC GRID: 5.6x8m CTF depth:12m CTF/ FTC index = 3.96 %ftf-ftc PACK / HEI = 24.7% % DUCTS / GFA: 1.7
 TAZ HQ / 2018 E2A / Berlin	 Context: Berlin city center Density: Land value:$$$	Plot size: 1672m2 Footprint 1017m2 Site coverage 60% GFA 6400m2 FAR 3.8 HEI: 7 / HEIGHT:28.5m	 Cubic	 apropriated voids / distrited infra.	Typical plan GFA = 915m2 Typical plan GLA = 715 m2 GLA % GFA = 78% ENERGY EF.LEVEL:/ HVAC:/ HOR+VER CIRC 96m2 Ducts 6.5m2 Services 40m2	FTF: 3.4m FTC 2.7m FTF-FTC 0.7m BASIC GRID: 13x5m CTF depth avg.: 9.5m CTF/ FTC index = 3.51 %ftf-ftc PACK / HEI = 17% % DUCTS / GFA: 1.7
 Citibank Canary Wharf / 1996 Foster & Partners / London	 Context: London CBD Density: Land value:$$$	Plot size: 4290m2 Site coverage 90% GFA 73600m2 FAR 16 HEI: 24 / HEIGHT:105m	 Cubic XL	 distributed vods / distributed infra.	Typical plan GFA = 4090m2 Typical plan GLA = 715 m2 GLA % GFA = 60% ENERGY EF.LEVEL:/ HVAC:/ HOR+VER CIRC 1000m2 m2 Ducts 70m2 Services 396m2	FTF: 4.1m FTC 3.3m FTF-FTC 0.8m BASIC GRID: 10x14m CTF depth avg.: 9.5m CTF/ FTC index = 3.51 %ftf-ftc PACK / HEI = 18% % DUCTS / GFA: 1.7

HOUSING VOLUME TYPOLOGY: SLAB
PROGRAM TYPOLOGY: HOUSING

Table 6. Housing / slabs – overview of urban and compositional spatial efficiency indicators

Project / Name/ Year Architect / Location	Site / Situation / Density	Volume typology description	Typical plan / void and infra. distribution	Spatial efficiency parameters	FTF , FTC, structure, vertical ducts
 IBA Hansaviertel/ 1957 Alvar Aalto /Berlin	 Plot size: 5655m2 Footprint = 1000m2 Site Coverage 17% GFA= 8000m2 HEI: 8 HEIGHT:25.1m FAR = 1.41	 Slab / merged cubes	 no voids / point infra.	Typical plan GFA = 1002m2 Typical plan GLA = 891 m2 GLA % GFA = 88% ENERGY EF.LEVEL:/ HVAC:/ HOR+VER CIRC 102m2 Ducts 9m2	FTF: 2.9m FTC 2.6m FTF-FTC 0.3m BASIC GRID: CTF depth avg.: 9.6m Total slab thickness: 19.6m CTF/ FTC index = 3.7 %ftf-ftc PACK / HEI = 9.5% % DUCTS / GFA: 0.9%
 Kamendin social housing / 2015 Nemanja Kordic /Belgrade	 Plot size= 9643m2 Footprint = 4242m2 Site Coverage 44% FAR = 1.08 HEI: 4.5 HEIGHT:14.4m GFA= 10438m2	 Slab / double load. cor	 distributed voids / linear infras.	Typical plan GFA = 1900m2 Typical plan GLA = 1670m2 GLA % GFA = 88% ENERGY EF.LEVEL:B HVAC: City heat. / AC HOR+VER CIRC 200m2 Ducts 15m2	FTF: 2.9m FTC 2.6m FTF-FTC 0.3m BASIC GRID: 7.8x5.4 CTF depth avg.: 9.6m Total slab thickness: 19.6m CTF/ FTC index = 3 %ftf-ftc PACK / HEI = 10.4% % DUCTS / GFA: 0.7%
 Gouverment sponsored housing/ 2008 /Manuel Ruiz Sanchez / Barcelona	 Plot size: 2601 Footprint: 1412 Occupancy %: 55 GFA:8472m2 HEI: 6 HEIGHT:26m FAR:3.24	 Slab/ double bay	 distributed voids / distributed infra	Typical plan GFA = 1412m2 Typical plan GLA = 1288m2 GLA % GFA = 91% ENERGY EF.LEVEL: HVAC: / HOR+VER CIRC 116m2 Ducts 15m2	FTF: 2.9m FTC 2.6m FTF-FTC 0.3m BASIC GRID: 8x8m CTF depth avg.: 9.6m Total slab thickness: 22.8m CTF/ FTC index = 3.07 %ftf-ftc PACK / HEI = 2.1 / 18 7.2% % DUCTS / GFA: 0.5%
 Carree de Flot / 2014 /Nicolas Michellin /Bordeaux	 Plot size 6559m2 Footprint =5050 m2 Site Coverage 88% FAR = 3.41 GFA= 22368 m2 HEI = 6 HEIGHT=19.3 m	 Slab / courtard - gallery	 central void / ring infra		Typical plan GFA = 4235m2 Typical plan GLA = 3657m2 GLA % GFA = 86% BASIC GRID:8x7m HOR+VER CIRC 116m2 Ducts 15m2 % DUCTS GFA: 0.35% CTF: 13m Total slab thicness:14.5m FTF: 31.m, FTC: 2.8m FTF-FTC PACK:0.3m %FTF-FTC / HEI: 9.3%
 Schubertsingel / 2019 /Houben Van Mierlo /Den Bosch Reconstruction (office>housing)	 PLOT SIZE 6204m2 Footprint = 2010 m2 Site Coverage 33% FAR = 1.61 GFA= 10000m2 HEI = 6 HEIGHT=21m	 Slab / courtyard - gallery	 central void / ring infra	Typical plan GFA: 2125m2 Typical plan GLA:1945 GLA % GFA = 84% Hor+vert circ 295m2 Ducts= 34m2 COR x FACADE max =13m	FTF: 3.25 FTC 2.75 FTF-FTC 0.5m BASIC GRID: 5.4x5.4m CTF depth: 13.3m Total slab thickness: 16m CTF/ FTC index = 4.83 %ftf-ftc PACK / HEI = 19% % DUCTS / GFA: 1.6%
 Block 1b / 2019/NL Architects/ Utrecht	 PLOT SIZE 3333m2 Footprint = 2360 m2 Coverage 70% FAR = 3.82 GFA= 12750m2 HEI = 6 HEIGHT=2.2 m	 Slab / courtyard -gallery	 central voids / ring infra	Typical plan GFA: 2360m2 Typical plan GLA:1970 GLA % GFA = 83% Hor+vert circ 355m2 Ducts= 34m2	FTF 3.1 FTC 2.7 FTF-FTC avg.: 0.4m BASIC GRID: 6x7.5m CTF depth: 11.3 Total slab depth: 13.5 CTF / FTCavg = 11.3 /2.7=4.18 %ftf-ftc PACK / HEI = 12.6% %DUCTS / GFA: 1.4%
 Villaverde housing / 2014 /Nico-las Michellin /Bordeaux	 Plot size 5233m2 Footprint = 2125 m2 Site Coverage 40% FAR = 2.43 GFA= 12750m2 HEI = 9 HEIGHT=27 m	 Slab / city-block - cores	 centralized voids / point infra	Typical plan GFA= 2071m2 Typical plan GLA= 1785m2 GLA/GFA /typ.floor. = 86% Hor+vert circ 258m2 Ducts= 28.5m2 COR x FACADE max =15.5m	FTF = 3m FTC = 2.6m FTF-FTC pack =0.4m BASIC GRID: 5x5m Total slab depth:15.5m %pack x Height =3.6m /27m=13% %DUCTS/GFA: 1.5%

OFFICE VOLUME TYPOLOGY: SLAB
PROGRAM TYPOLOGY: OFFICE

Table 7. Office / slabs – overview of urban and compositional spatial efficiency indicators

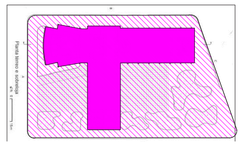
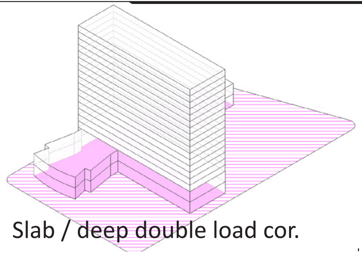
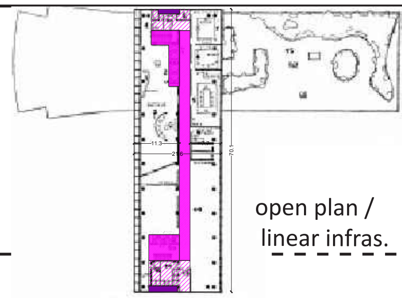
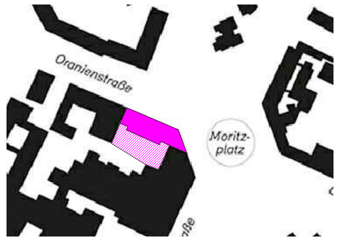
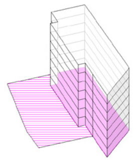
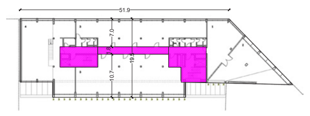
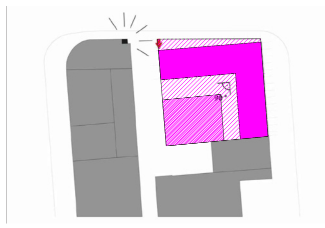
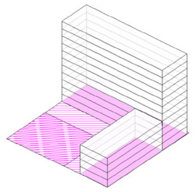
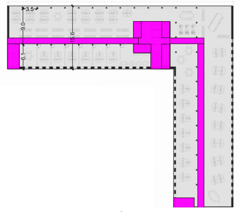
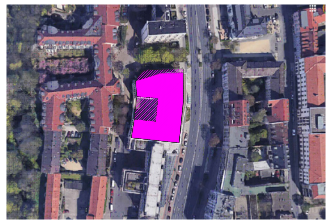
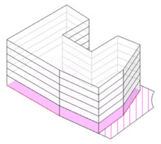
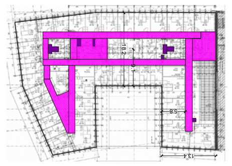
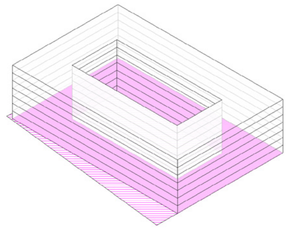
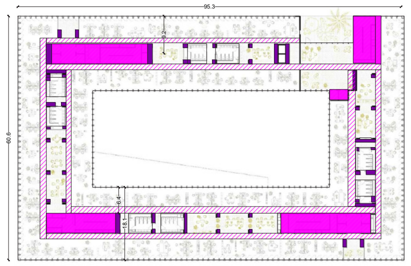
Project / Name/ Year Architect / Location		Site / Situation / Density		Volume typology description	Typical plan / void and infra. distribution	Spatial efficiency parameters	FTF , FTC, structure, vertical ducts
	Ministry od Education / 1943 / Corbusier, Niemeyer, Costa / Rio		Site size 10233 Footprint 3323m2 Site coverage 32% GFA 6646 +21182=27828 m2 FAR 2.71 HEI= 16 / Height: 65m	 Slab / deep double load cor.	 open plan / linear infras.	GFA / typ. floor = 1513m2 GLA / typ.floor = 1245m2 GLA/GFA /typ.floor. =74% Hor+vert circ 252m2 Ducts 16m2 Services 114m2 COR x FACADE = 7,11 m	FTF = 4.5m FTC = 4m FTF-FTC pack =0.5m %pack x Height 15x0.5m=7.5m /64.5m=11.6%
	Aufbauhaus 84 / 2015 /Barkow Leibinger /Berlin		Plot size 1914m2 Building footprint = 958 m2 Site Coverage 50% FAR = 1.61 GFA= 8335m2 HEI = 6.5 / HEIGHT=31m	 Slab / double load. cor	 distributed voids / linear infras.	GFA / typ. floor = 1068m2 GLA / typ.floor = 918m2 GLA/GFA /typ.floor. = 85% Hor+vert circ 150m2 Ducts= 34m2 COR x FACADE max =10.7m	FTF = 4m FTC = 3.4m FTF-FTC pack =0.6m BASIC GRID: 5.4 x 6.8 Total slab thickness: 19.5 %pack / Height 4x0.6m =2.4m /16m=15% (4 office floors)
	Siemens HQ / 2012/NL Archi-tects/Hengelo		Plot size: 2490m2 Footprint 1351m2 Site coverage 70% GFA 5512 +4200=9712 m2 FAR 3.3 HEI= 11 / Height 40.5m	 Slab/ double load. cor.	 distributed vods / distributed infra	Typical floor area= 1378 / 600 m2 GFA / typ. floor = 1378 m2 GLA / typ.floor = 1137m2 GLA/GFA /typ.floor. =82% Total slab thickness:15.6m Hor+vert circ 241/ 69 m2 Services 38 m2 COR x FACADE = 7.8 m	FTF 3.325 FTC 2.80 FTF-FTC 0.525m BASIC GRID:9x3.5, 3.5 x 6 depth/ FTC = 7.8 /2.8 = 2.78 %ftf-ftc / HEI = 5.77 /40.5 = 14%
	Guldenoffice / 2018 /KSP Juergen Engel /Braunschweig		Site size: 1945m2 Footprint 1566m2 Site coverage 80% GFA = 9420 m2 FAR 4.84 HEI= 6 Height: 22.3m	 Slab/ courtard - double bay	 centralized void / double bay	Typical plan GFA= 1317m2 Typical plan GLA= 1245m2 GLA/GFA /typ.floor. = 74% Hor+vert circ 114 m2 Ducts= 16 m2 Services 114m2 COR x FACADE max =9.1m	FTF = 3.4m FTC = 2.8m FTF-FTC PACK. = 0.6m BASIC GRID: 7 x 6.4m Total slab thickness: 18.2m %pack / HEI=15.4%
	Pulse office building / 2019 /BVF Architectes /St.Denis		Plot size 6593m2 Footprint (incl.atrium) 5902m2 Footprint : 4322m2 Site coverage 90% GFA 31834 m2 FAR 2.71 HEI= 4.82 / Height 27.1m	 Slab / courtyard city block	 centralized voids / double bay	Typical plan GFA = 4322m2 Typical plan GLA = 2943m2 GLA/GFA /typ.floor. =72% (68%-ser) Vert circ 392m2 Hor circ. 700m2 Ducts 81.2m2 Services 206m2 COR x FACADE = 9.2 m	FTF 3.50 FTC 2.90 FTF-FTC PACK 0.6m BASIC GRID:8x7m, 8x5m depth/ FTC = 9 /2.9 = 3.1 %ftf-ftc / HEI = 4.2 /27.1 = 15%

Diagram 11. Overlapping spatial efficiency parameters for office and housing projects

2.3.4 Step 2 - Identification and valorization of the infrastructural layouts – Qualitative analysis

The second step of the case studies aims to determine the possibilities for programmatic changes and mixed use ability within the architectural compositions of the four chosen projects / spherical (cubes) and flat-vertical (slabs) volume typology, office and housing.

In this step besides an extended scope of parameters and criteria from Step 1, a qualitative analysis have been used to evaluate methodologically the design procedures behind the four projects that dealt with specific design problems: transformation (reprogramming), reconstruction & extension, vertical mixed use, and a horizontal mixed use in a compact city block.
Based on the typical plans of the analyzed projects a method of abduction have been applied (Diagram 12,13,14,15,16,17) to create the a set of generic functionally neutral plans (Diagram 18). (See Appendix 6, 199-239)

The findings from both steps have been used to establish a typological repository - a library of functionally neutral typical plans that could further be used as a base for design algorithms. (Diagram 19, Diagram 20)

HOU SING OFF ICE

CASE STUDY: 1 TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

POSSIBILITY OF FUNCTIONALLY NEUTRAL COMPOSITION

Office and residential typical plans have been developed on a generic level following the design strategy of Lacaton&Vassal, who achieve the vertically mixed program regulating the depths using the balcony setback. A flexible layout is achieved with a clear and almost column-less core to facade distance and a carefully planned MEP ducts which have enough range to service all the programs without obstructing the layout and flexibility of both typical plans. Both plans remain highly efficient in terms of their GLA, despite the fact that an additional vertical circulation for the office floors is added, extending or shortening this non structural vertical circulation the ratios between office and housing floors could be regulated.

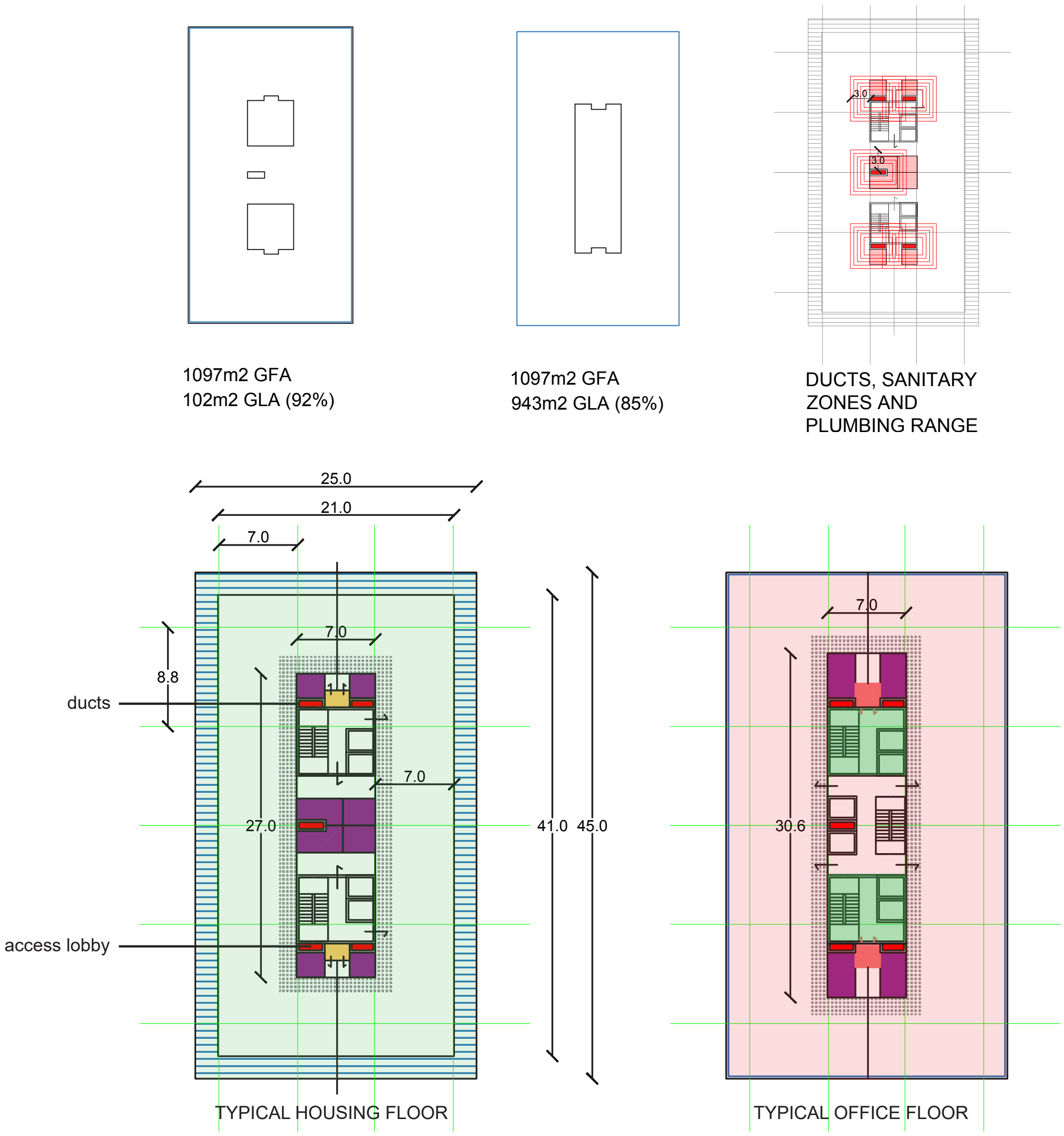


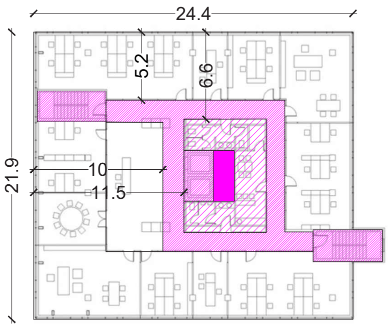
Diagram 12. Tour Opale - developing generic functionally neutral plans

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

POSSIBILITY OF A FUNCTIONALLY NEUTRAL COMPOSITION

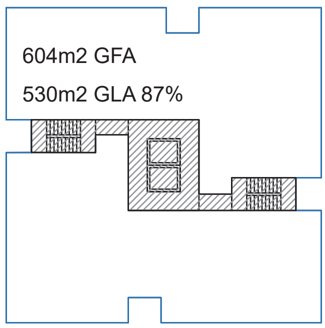
This office building can be related to a housing projects analyzed in the previous step, because of the similar floor-plate size and the similar layout of vertical circulations and services. Since a housing project is a new-built it is more rational in many ways especially in terms of the structure. It can be anticipated with careful planing both programs could work efficiently using the same architectural composition, which implies that the program change could be possible in a building designed in such a way.

Biro VIA / Roaming HQ



Nothing Architects / Manressa Housing

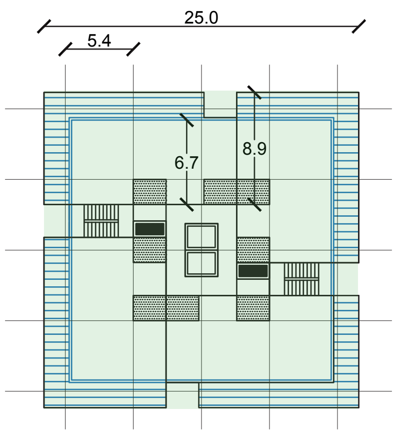
Functionally neutral composition



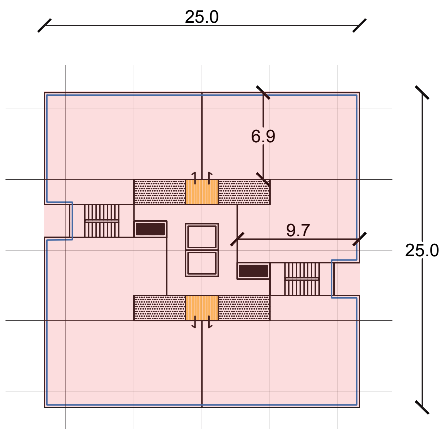
Comparative study with similar housing plan - developing generic functionally neutral plans

POSSIBILITY OF A MIXED USE PROGRAM

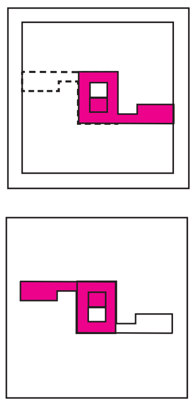
With the approximately 2m average depth difference between office and housing program with the setback strategy elaborated in the previous case study (Tour Opale, Lacaton&Vassal) a typical plan can be developed combining the experiences from the two examples. With the two fire escapes and two elevators, a smaller mixed use building could exist, each with their own vertical access.



housing floorplan



office floorplan



sharing scenario

Developing generic mixed use scenario plans

Diagram 13. Roaming HQ - developing generic mixed use scenario

OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

POSSIBILITY OF FUNCTIONALLY NEUTRAL COMPOSITION

This office building can be related to a housing projects analyzed in the previous step, because of the similar floor-plate size and the similar layout of vertical circulations and services. Since a housing project is a new-built it is more rational in many ways especially in terms of the structure. It can be anticipated with careful planing both programs could work efficiently using the same architectural composition, which implies that the program change could be possible in a building designed in such a way.
Regarding the typical plan the Aufbauhaus building has similar layouts to (NL Architects - Siemens, and Le Corbuser, Niemeyer, Costa - Ministry of education building). Basically it can be compared with central corridor typologies, with vertical cores on one side and office services on the other. It can be anticipated that this composition could be also a housing scheme, by adding ducts / service points more frequently along the corridor on both sides, and recessing the facade to reduce depth and add balconies.

Comparative study with similar housing plan - developing generic functionally neutral plans

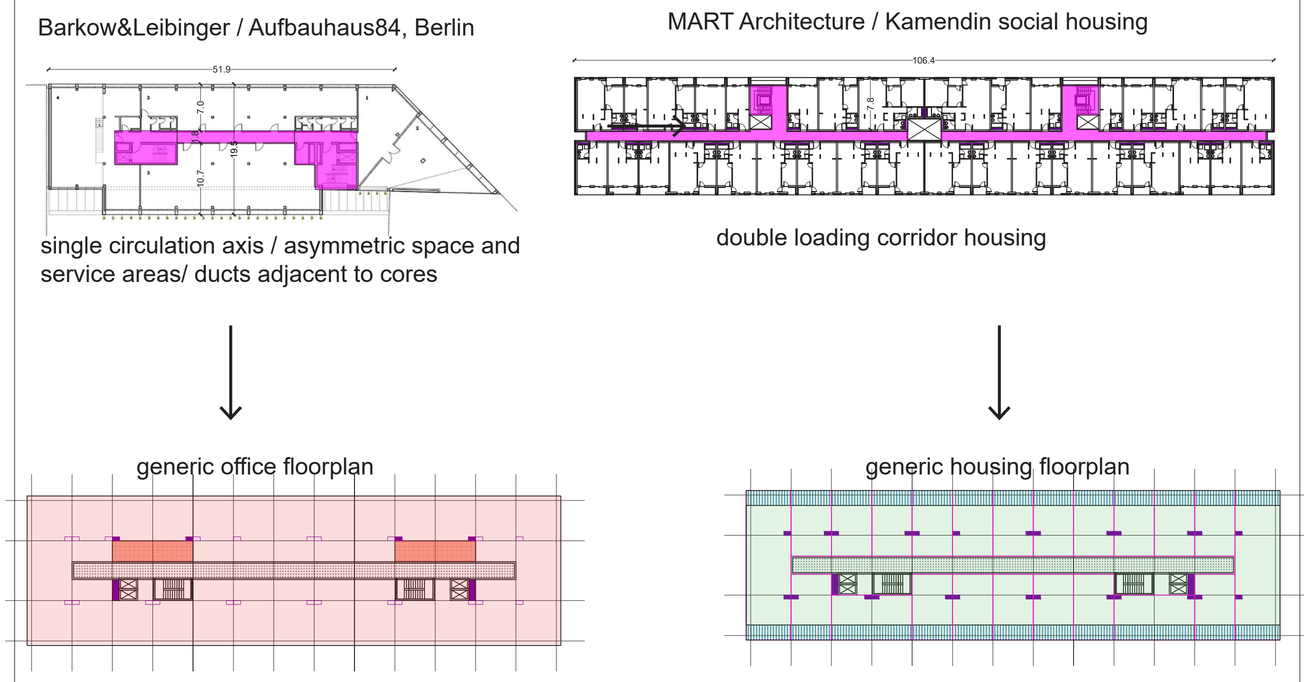


Diagram 14. Aufbauhaus - developing generic functionally neutral plans

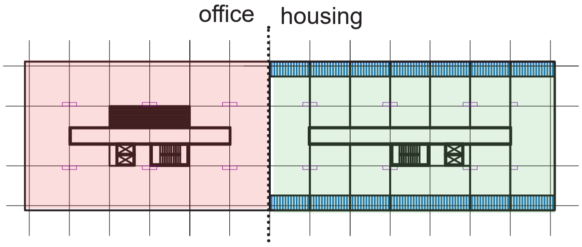
OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

POSSIBILITY OF A MIXED USE PROGRAM

There are two possibilities for a program mix or correction in a building of this generic typology, as the building has two vertical cores, it could be vertically divided into a office and housing section, as the building is not very tall it could be reasonable to anticipate that the one core could satisfy fire regulations for both programs. In case of a taller building of 8+ levels another strategy might be possible to mix the program vertically by introducing a non fireproof central office core and lobby for the lower office floors. The users could still use the residential fire escapes in case of fire.

Horizontally mixed option



Vertically mixed option (non structural) office core

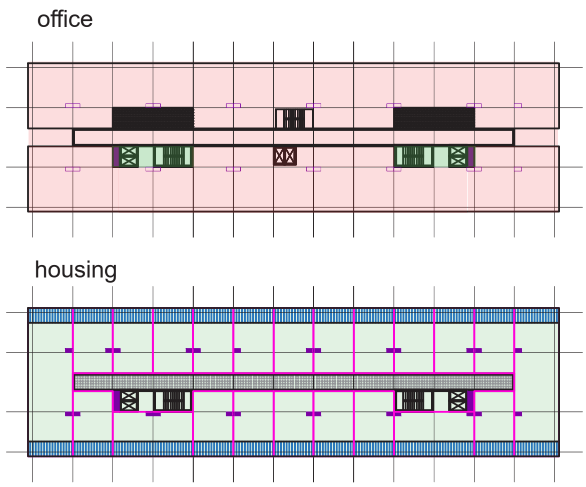


Diagram 15. Aufbauhaus - developing generic mixed use scenario

HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH Houben & Van Meirlo, 2018. (transformation)

POSSIBILITY OF FUNCTIONALLY NEUTRAL ARCHITECTURAL COMPOSITION

As the building is already been transformed from office to housing program it is proven thats its architectural composition can already be considered functionally neutral.

DEVELOPING VOID TYPOLOGIES

This project is the first atrium building which is a subject of a case study, essentially atrium buildings can be considered as flat vertical (slab) volume typologies folded around a void space sufficiently big to develop a program on all sides.
In terms of the scale this building is halfway towards becoming a perimeter block, but still significantly smaller. Therefore it is interesting to look at it in comparison with other slab buildings and their ways of managing the void.

Apparently once a slab building surpasses a certain thickness it becomes too deep to accommodate housing program so the building introduces narrow voids (4-6m) where cores are also located and becomes double bay (Manuel Ruiz Sanchez / Madrid housing. If the void is sealed due to the deeper allowed floor-plate this double bay plan could work for offices as well. If a larger void can be introduces (cca 12-16m) as the case with Den Bosch building, this typology could be suitable for both office with the envelope on the outer edges of the floor-plate, and for housing with recessed facade to create balconies and galleries with entrances. If a building is larger as with the Bordeaux example the similar logic can be applied with the difference that the office plan can become double bay.

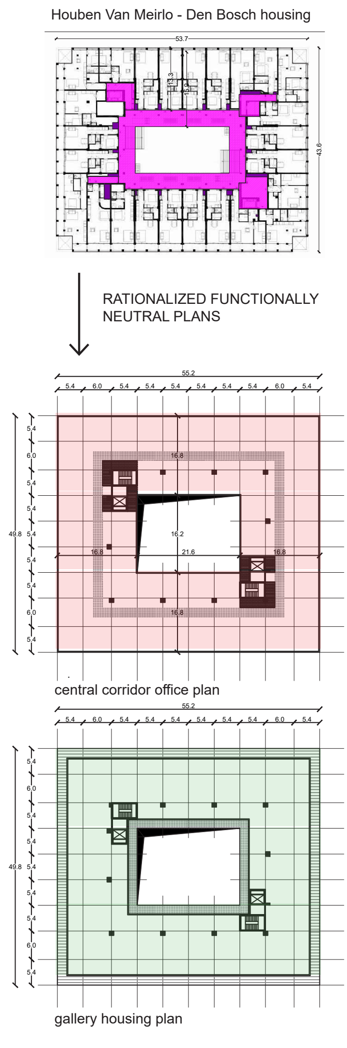
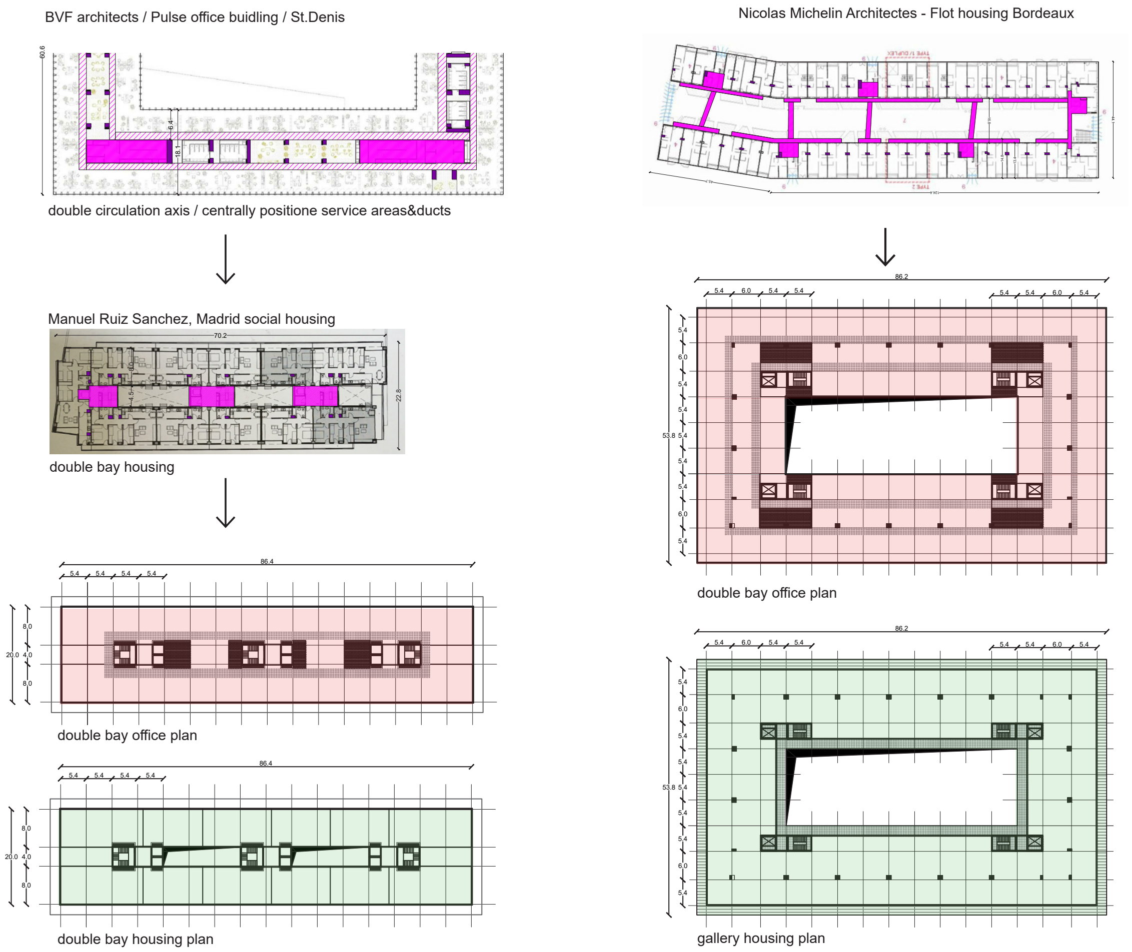


Diagram 16. Schubertsingel: Void typologies - developing generic functionally neutral plans

HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH Houben & Van Meirlo, 2018. (transformation)



Comparative study with similar housing and office plans - developing generic functionally neutral plans

POSSIBILITY OF A MIXED USE PROGRAM

As mentioned in the previous case studies slab typologies with multiple vertical cores can be horizontally subdivided and mixed in various ways. However, the typologies with the small atrium may have a privacy conflict in case of a horizontal mix. But a double bay housing plan can be modified as a vertical mix (in case of a taller building of 8+ levels) by introducing a non fireproof central office core within the void the users could still use the residential fire escapes in case of fire. The same strategy could work for other typologies, half of the cores would work for housing other for offices on the lower levels, in case of fire all cores are used by all programs.

Diagram 17. Schubertsingel: Void typologies -Developing generic functionally neutral plans and mixed use scenario

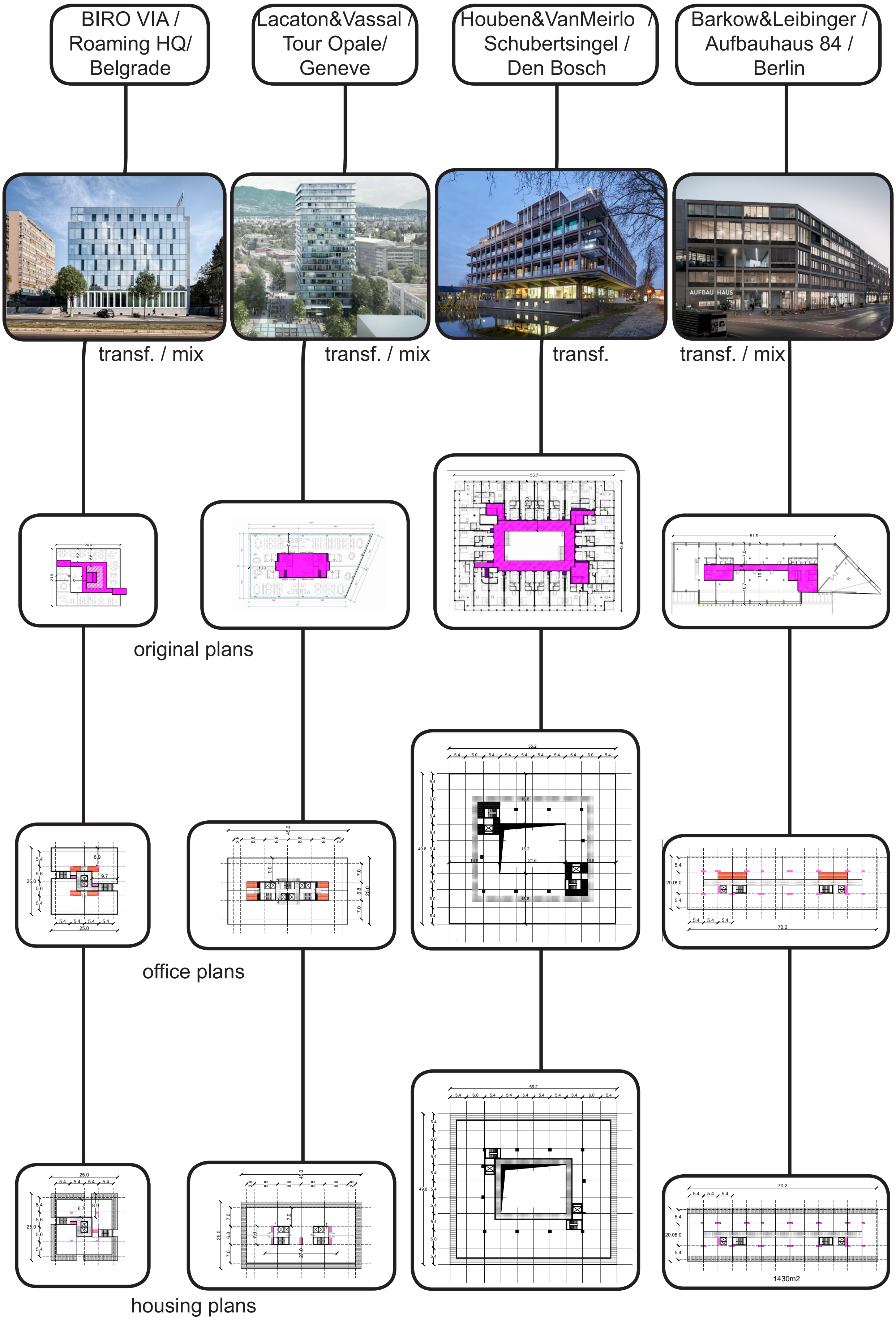


Diagram 18. Interpretation of case study project plans towards functionally neutral housing and office layouts

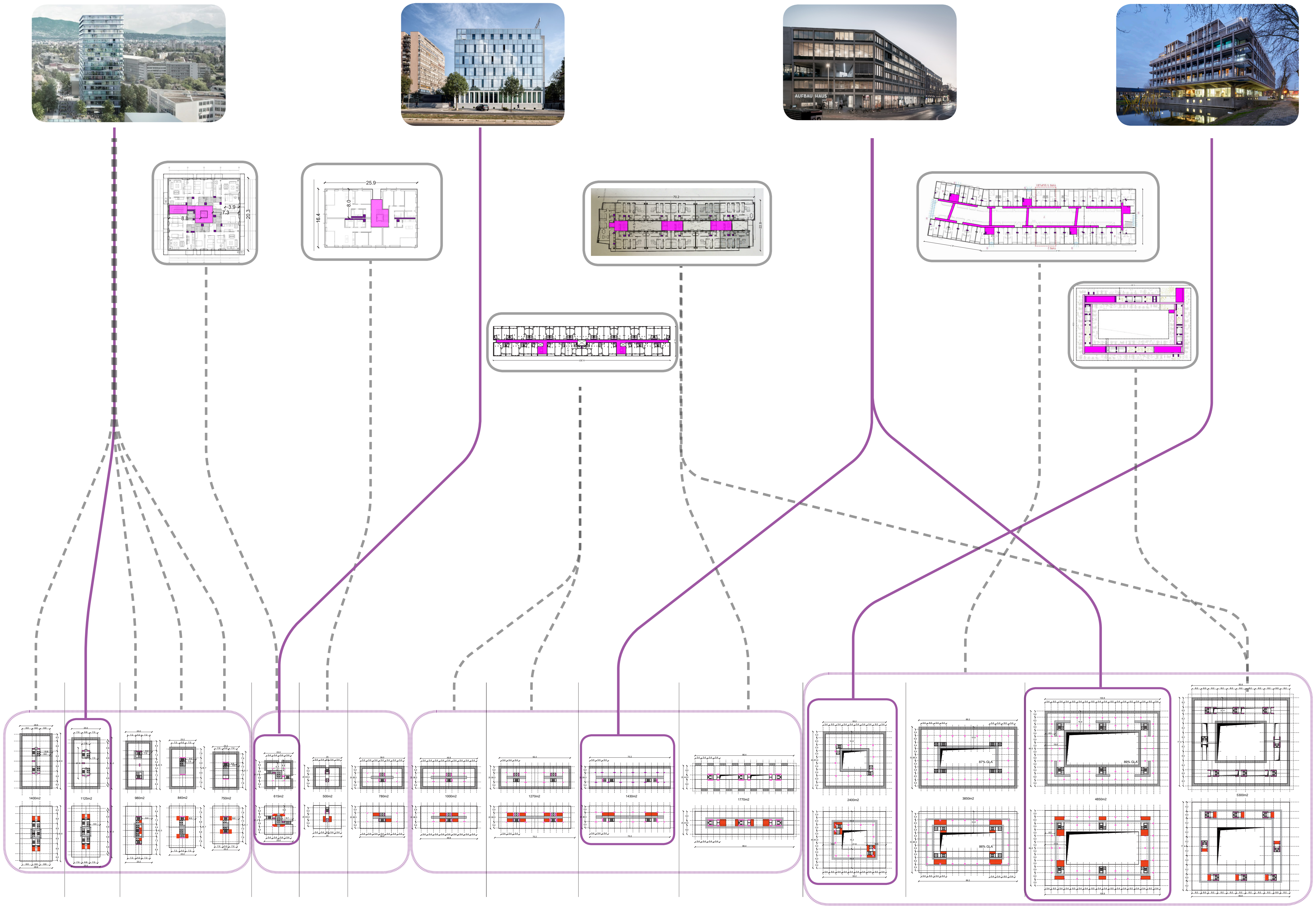


Diagram 19. Relation of analyzed projects to forming a library of functionally neutral typical plans

Diagram 20. Library of functionally neutral typical plans

2.4. STEP 3 - SYNTHESIS & RESULTS : DESIGN GUIDELINES FOR FUNCTIONALLY NEUTRAL AND MIXED USE BUILDINGS; FORMING A REPOSITORY INFRASTRUCTURAL LAYOUTS FOR A SCOPE OF: CUBES AND SLAB VOLUME TYPOLOGIES / OFFICE AND HOUSING PROGRAMS

The results of the performed: case studies (6. Appendix) can be read as several groups of indicators that determine the infrastructures of the architectural compositions of functionally neutral and mixed-use buildings:

The findings of the first step of analysis (Diagram 11) of the case studies can be divided into two segments. The first clarifies the urban context where mixed-use buildings and functionally neutral buildings are being developed. It is the context of the mixed-use city centers, characterized with high land value, high-density city areas, or CBDs indexed with high FAR parameter.

The second segment has clarified the overlapping spatial efficiency indicators for housing and office buildings and determined a set of spatial parameters which can cover both program typologies within the same volume, which is one of the prerequisites for designing functionally neutral buildings or designing horizontally or vertically mixed programs.

2.4.1 Urban indicators

The spatially efficient office and housing typologies are located mainly in the mixed-use city centers indexed with high-density FAR parameters (usually between 2 and 7). In the zones of mixed-use centers of major European cities, buildings, in general, have 6+ levels (HEI 6–21). As the land in these areas is quite expensive, the plot occupancy percentage ranges from 30–80%, where the lower percentage goes for high-rises and freestanding buildings and higher for compact city blocks. The coverage of the underground levels is significantly higher, and it can reach 100%. This is usually followed by mixed-use zoning with moderate to high retail potential. The HEI index usually allows a minimum of 6 levels, whereas 20 levels allows moderate high-rises (Table 8).

Table 8. Urban indicators for functionally neutral buildings

URBAN INDICATORS	Spherical Volumes (Cubic)	Flat Vertival volumes (Elongated Prismatic)	Average
FAR	2-6.7	2.7-4.84	2-7
HEI	6-21	6-11	6-21
COV %	33-60%	50-80%	30-80%
LAND VALUE	$$-$$$	$$-$$$	$$-$$$

2.4.2 Spatial efficiency indicators of functionally neutral buildings

Generally, these indicators are primarily focused on building proportions, depth, and the GLA%, which ranges from 72–90%. In an expensive plot, GLA should not be lower than 85%. More expensive plots have two possible manifestations: many floors or high site occupancy % or both, which is the ultimate goal of developers. The second results in higher CTF depth of a cubic building and the bigger total thickness for a slab building, which result in high depth indexes (CTF/FTC = 2.8 m–3.6 m). Consequences of the larger depths are solved with the higher % of facade openings, which may result in high heat gains and losses and higher energy consumption, which can still be avoided with the use of a high-performance facade system which increases the overall investment or not avoided by simply increasing the operational costs. In general, there is an 8m depth threshold, and deeper spaces are not suitable for housing any more unless the FTC height is significantly increased, which often leads to inefficiency in section. The trend that very deep office buildings before had to subsidize the lack of daylight and air supply with artificial HVAC and lighting systems is slowly being abandoned. If the buildings go, even more, deep voids are introduced, from the scale of air and light shafts to atriums (Table 9).

Table 9. Spatial efficiency indicators for functionally neutral buildings

SPATIAL EFFICIENCY INDICAT.	Spherical Volumes (Cubic)	Flat Vertival volumes (Elongated Prismatic)
CTF(Cubic) / Width (Elongated prismatic)	7.2-11m	15.5-20m
GLA%/GFA	77-90%	72-85%
FTF/FTC (average)	2.7/3.4m	2.8/3.4m
PACK % ((FTF-FTC)xHEI / Height)	20%	12-16%
Depth index CTF/FTC	2.9-3.6	2.8-3.2

2.4.3 Economic indicators

Probably the most interesting fact is the real estate strategies rental and sales. The real estate market in the mixed-use city centers has turned increasingly rental as the land prices in these city areas are constantly rising. All offices developed in the mixed-use centers are spaces for rent, some offices on the outskirts/cheaper land developed as company HQ and are designed for the particular owner. Housing development has at least 50% of rental units, the units for sale sold for financing reasons to bring the faster investment returns (Table 10). Rental program sections are always located on the lower floors. Reconstructions of existing buildings almost always need extensions of 10–15% GFA (Shchubertsingel, Roaming HQ) for the investments to become economically viable, as the use of an existing building structure saves only 8% of the construction cost (according to Van Der Voord). The highest cost in the reconstruction goes for the facade, interior walls, and installations. The return of investment is usually expected after 10 years of the rental period, while after that period it is expected that maintenance costs rise, so investors often go for sales to close the investment, or after a period of 20 years, the buildings go through reconstruction and improvements so they can be sold or rented again for a higher price. With the concept of functional neutrality, it is expected that the reconstruction investment would be significantly lower than at the present time; therefore, this kind of buildings would have higher long-term values.

Table 10. Rental and Sales share per program

Real Estate concept	Housing	Office
Mixed use city center	>50% rental	100% Rental
Other areas	50% < rental	HQ

2.4.4 Structure

The structure is one of the main prerequisites for functional neutrality; even though in the economic breakdowns for transformation costs, it saves only 8% of investment, indirectly it affects many other factors. In general, the primary structure of most of the analyzed projects is skeletal and concrete, (but the skeletal system may as well use steel, or a concrete-wood combination). The spans should be as small as possible but clear modular and with respect to the parking perspective, meaning on the longer side of a building; usually, 5.4 m or 7.8 m–8.4 m spans are used (to host 2 or 3 parking spots). Reducing spans saves the material and reduces the floor packages, which increases the efficiency in the section. With the use of hollower concrete systems and air slabs (flat floor-slabs are possible, so the beams are not present), weight is reduced, formwork simplified, the thickness of the floor package reduced, and the installations conduits take less space. It is also possible to integrate some of the installations inside the slab (floor heating).

2.4.5 The facade is an important factor in the concept of functional neutrality. The choice of the facade concept and facade is context-, orientation-, and climate-related but also related to program and spatial efficiency and costs. The transparency indicated here as % of openings of the facade can depend on several factors (climate zone, regional standards, class of office or housing) and depth which is elaborated through the analysis (Appendix 6), the increase of depth also increases the % of openings (Table 11), as office buildings are deeper, in general, they tend to have more openings and often are entirely glazed. This implies one more consequence – the use of active or passive systems for light/thermal regulations such as shading systems or additional capacities for heating and cooling (which often increases the ceiling package).

Usually, the offices have been using curtain walls, but curtain walls often do not work for housing. However, window walls in combination with solid insulated modular wall segments can be used for both programs to achieve a modular, dismountable, and easily replaceable facade – and this system has been used in almost all analyzed projects (solid walls + windows or window walls + solid wall panels or segments). Both office and housing programs nowadays tend to have operable windows and natural ventilation.

Table 11. Facade opening % for selected program and volume typologies

Façade Opening %	Spherical Volumes (Cubic)	Flat Vertival volumes (Elongated Prismatic)
Housing	50-100%	40-80%
Office	80-100%	50-70%

2.4.6 HVAC MEP and energy

The careful choice and distribution of the HVAC and MEP installation are important prerequisites for functional neutrality. One observation is that the increasing depth implicates the need for a higher capacity of HVAC, which increases the ceiling package. The first action, which is not very costly, can definitively be the careful distribution and planning of the positions of vertical ducts on each floor-plate ready to fit with different programs, which can be achieved without using a lot of GLA either by already building installation chimneys and wrapping them together with the structural elements or leaving the provisionally sealed openings in the floor-plate for the verticals to be added later. In both cases, sufficient capacities of water and sewers or ventilation inlets and outlets should be reserved in advance. The second action is planning the HVAC systems and finding ways to avoid the problems of different operation modes and sources of energy. As central air treatment is slowly being abandoned for the mid-scale office buildings in favor of natural ventilation and autonomous temperature regulation, it is possible to heat up the offices in similar ways as housing and pay it according to the levels of consumption and optimize it with various passive systems applicable to housing as well. As the floor heating is sustainable in terms of the thermal activation of a building structure, heating segments and radiators could be distributed in a segmented way to match the possible compartments of both programs. Cooling, however, may be more flexible with the use of split systems for housing or heat pumps and the visible installation channels for the offices that do not take a lot of ceiling space.

2.4.7 Mixed use strategies (program and circulation)

As already said, there are two principal models for achieving a mixed-use building: horizontal and vertical. Horizontal models are usually more achievable in the case of a larger development or a building, and they work simply by separating programs around the vertical cores with respect to the capacities and fire escape routes. The vertical mix is a bit more complex as the floor plate needs to satisfy the proportional standards suitable for both programs, and it needs separate vertical circulations for each. The latter can often lead to a decrease in GLA; therefore, the floor-plate needs to be large enough to maintain the efficiency of the plan. The organization of the vertical cores is the second action meaning that cores should be dimensioned and laid out in such a way to enable divisions; all cores do not have to reach the building from top to bottom in terms of the circulation but only sometimes to maintain the structural stability and safe evacuation. One way is separating the elevator sets from fire escape stairs having multiple smaller cores (Biro VIA/Roaming HQ). Another interesting method (Lacaton & Vassal/Tour Opale) is adding a “fake core” for the office program in the lower floors, providing an independent vertical circulation, and using the residential cores for fire escape routes.

2.4.8 Functional neutrality /Infrastructural layout

Some previously concluding sections and the overall typological research of the building infrastructures evaluated throughout spatial efficiency indicators and parameters have been partially written down graphically in a set of functionally neutral typical plans created with interpretation and abstraction methods based on the analyzed realized projects (Diagram 18, 19). The scope of the set covers high-rises, cubic, point buildings and slabs, atrium buildings, and perimeter city blocks, providing two program layouts for both and indicating when possible the ways of achieving mixed-use program. This set can be seen as an open-source repository that can be updated and expanded to provide a larger number of typological solutions (Diagram 20). The set of typical plans is laid out in a scalar gradient, and each of the proposed layouts has a certain scope of proportional modification possibilities so it can be used as a typological base for the next step of research, mapping the typical plan to an automatically generated volumetric massing option to generate a functionally neutral composition.

2.5. INFRASTRUCTURAL TENETS OF FUNCTIONALLY NEUTRAL BUILDINGS - CONCLUDING POINTS

As elaborated in Chapter 1, the infrastructural tenet was introduced by Kipnis as a design procedure that organizes the architectural compositions by physically extending the urban infrastructures into the building, which was a claim related to public buildings. However, the term remained open for new interpretations. Since theoretically, almost all city buildings can be perceived as extensions of urban infrastructure, infrastructural tenets are methods that organize the infrastructural elements within their volumes. As this research deals with the programmatically unstable and infrastructure-based architecture emerging in the cities in the 21st century and the predominant economic context of neo-liberal capitalism, functional neutrality may be one of the important driving factors for organizing the architectural compositions in the years to come.

Infrastructural tenets of functionally neutral buildings are presented through typology-related infrastructural layouts (2.4.8) and sets of design recommendations (2.4.1–2.4.8) oriented towards programmatic transformations. Infrastructural layouts written as functionally neutral typical plans and recommendations have the following characteristics that satisfy two programs (within the scope of this research – office and housing):

-suitable on plots with moderate to high urban parameters within mixed-use city centers,

-high GLA percentage,

-optimal/sufficient capacities of horizontal and vertical circulations,

-optimal/sufficient ceiling heights,

-optimal plan depths suitable for natural lighting and ventilation,

-modular facade for the flexibility of customizing transparency levels, the possibility of positioning the

facade elements on different depths,

-rational structural systems,

-projective positioning of vertical ducts and service areas,

-possibility of horizontal or vertical program mix,

-possibility of using and combining rental and sales real estate strategies,

-easy and cost-effective reprogramming and renovation.

In the next chapter, the aim will be to evaluate the plots in the mixed-use city center in terms of suitable block size, program flexibility, profitability, and maintaining the appropriate land use in a time resilient manner. Achieving functional neutrality through designing transformable and/or possibly mixed-use architectural compositions can be a sustainable way to extend the life cycle of a building through program flexibility following the market flows with user participation towards a process-based architecture.

3. URBAN AUTOMATION AND PROCESS BASED ARCHITECTURE

This chapter introduces a possible implementation of the research on the transformative, functionally neutral, and mixed-use building typologies based on infrastructural tenets. The existence of these typologies relies primarily on the land-use strategies of a particular urban context. A proposed urban automation tool (UAT) evaluates urban parameters and zoning laws to find the particular plots to implement the most rational building typologies (and their infrastructural layouts) and maximize land use potentials. As the proposed software tool requires networked knowledge and expertise from different disciplines, a brief overview of the ongoing researches in this field, emerging technologies to be employed to create such a tool will be provided. Further, an overview related to the automation software currently developed in the field of architecture and urbanism will be presented. Finally, this chapter will define the scope of applicability of the current research (from Chapter 1 and 2) to demonstrate a central part of the proposed tool by defining the target groups, specific urban conditions, and the buildings typologies that will be used.

3.1 ACHIEVING URBAN AUTOMATION BY PRE - DESIGNING PROCESS BASED ARCHITECTURE : DETERMINING THE INFRASTRUCTURAL LAYOUTS OF VOLUME TYPOLOGIES BASED OF THE URBAN PARAMETERS OF A PLOT

3.1.1 Context

> "Rather than seek to establish better defenses for the public against the 'ignominious real estate developer' the research starts with the presumption that the community can lead the process of envisioning its future built environment, but in this it needs to be supported by analytical tools, data management, and a comprehensive understanding of the idealistic and pragmatic trade-offs in having their objectives realized. By utilizing data science a much more complex and rigorous process of decision making is to be formulated for the real estate development process, and with the assistance of Artificial intelligence (AI) urban communities can be empowered to determine their own futures and have those futures represented in their built environment." [173]

Reinier de Graaf is one of the architects who believe that integrated planning procedures could enable the real estate development process to become more transparent and provide a better way of communication between the city, developers, and local communities.

Recently as Uber and Airbnb have installed a bug into the current system, the transportation and rental markets have changed with the sharing economy principles. Many ongoing processes in the present information era also imply a new take on the architectural composition towards a process-based architecture. The fundamentally changed understanding of ownership forces architecture to try to adapt and reestablish itself in order to follow the changing habits of its users through concepts of co-living and co-working programs. This process is essentially nothing new and can be perceived rather as an optimization than innovation.

What is a process-based architecture? It is an architecture whose content as a whole, from the concept to the materialization, is transforming since its conception all the way through design, construction, and exploitation. It may exist only in the virtual realm and never see its physical presence but still may influence its physical urban context. Such architecture is ready to grow and diversify its functional units as the user groups change their needs through time – a resource equally important as space.

173 Reinier De Graaf, "Creation, Calculation, Speculation - A short history of Real Estate Development," *BAUMEISTER* (June 2019): 42. https://curated.baumeister.de/en/reinier-de-graaf/#magazine.

3.1.2 The tool

The proposed tool is a multidisciplinary-oriented (architectural + urban design, real estate, economy, and social) tool for urban automation and a process-based architecture. A tool that can create a computer-generated virtual landscape of possibilities whose elements (pixels as plots) are fed, updated, and actualized with the customized infrastructural demands. This means that the mentioned virtual landscape is generated in a bottom-up fashion: from a unit

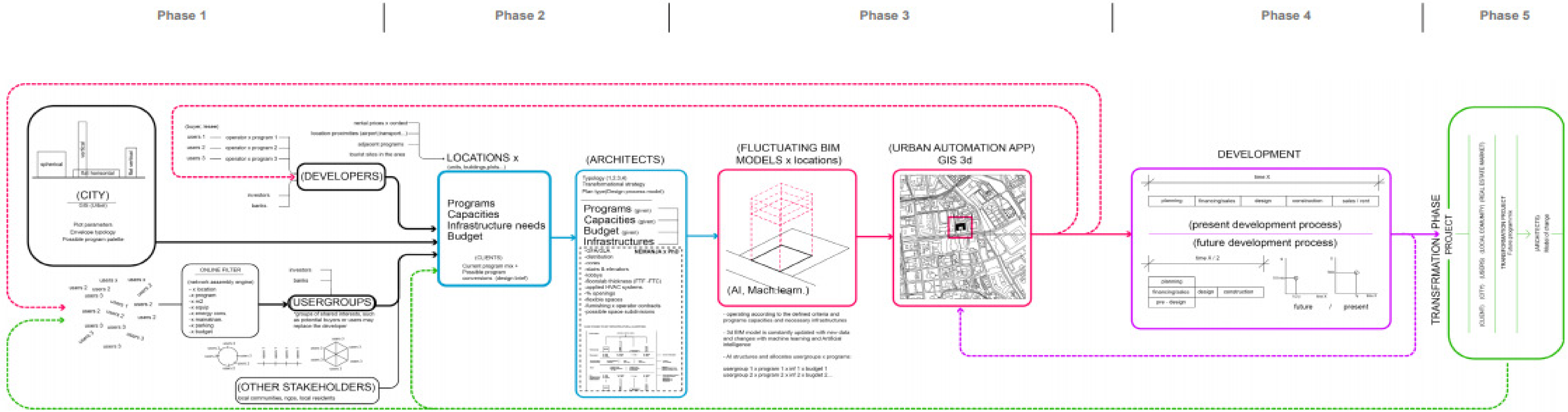
Figure 28. A virtual GIS generated landscape of possible developments according to zoning laws (illustration, collage on Belgrade landscape)[174]

3.1.3 How to achieve a process based architecture with an urban automation tool?

Defining, evaluating, and designing the customized infrastructure of architectural composition, according to the available city infrastructures (electricity, heating, cooling, telecommunication, the Internet, roads and traffic, etc.) could help to achieve the optimal time/space balance of use in contemporary buildings. The research on the main architectural massing typologies and programs, with algorithms that express the distribution and effects of the implemented infrastructures on a schematic level, could become a base for deploying the research into an urban realm. Besides the previously elaborated physical infrastructures that have been supporting programs and programmatic changes, it is the informational infrastructure that operates our buildings on a day to day basis through the processes of investments-rentals-refurbishing, providing gradients of levels of service/security/standard/quality and cost.* If the structure and complexity which lies in the before mentioned chain can be understood through a graphical interface which essentially is an algorithmic architectural drawing or a building information model (BIM), it would be possible to define customized informational and physical infrastructures for the new buildings.

There are different data flows (belonging to few different but interconnected fields: real estate, urbanism, architectural design) which we must harness in order to generate this model: 1)real estate finance, 2) exploitation, 3) operation costs, 4)data flows of ownership relations, 5)data flows of urban parameters, 5) data flows of spatial efficiency, 6) data flows of energy efficiency and maintenance.

174 Image used for the collage: Ursula Frick and Tobias Grabner, "Adaptive Urban Fabric," , 2012, https://www.evolo.us/adaptive-urban-fabric/.



Phase 1 (Planning): this phase anticipates collecting data flows from different sources that can be directed towards a specific location (plot). These sources include developers and organized user groups as their competitors, the city with its GIS publicly available data and urban parameters, locations parameters (proximities, real estate values, rental prices, tourist routes...). Data collected for each plot is used to towards formulate "vague design briefs" as infrastructure requirements.

Phase 2 (Briefing/Predesign): According to the "design briefs" (formulated from the data gathered from the city, developers, users…), an array of massing configurations based on functionally neutral architectural compositions (and spatial efficiency guidelines) will be proposed. This step will employ the previous research on infrastructural tenets and the typological repository based on the case studies. The results should be expressed through sketchy 3d options and evaluated through: numbers, ratios, efficiency indicators and other visualized data. The current "best options" are chosen to be displayed.

Phase 3 (Prediction): All the data that is gathered is associated with adjacent plots and synthesized into "fluctuating BIM models," which are based on a supervised machine learning process and are being constantly updated as the inputs change. The BIM models are sent back and mapped on their plots into GIS, to form a vast virtual landscape (like Google Maps 3d) that show existing and the non-existing "predicted" - potential buildings developments that can be actualized or modified with the stakeholder interaction.

Phase 4 (Design and Development): The previous phases (planning, briefing and prediction) anticipate the parallel marketing, pre-sale and contracting processes, so there is a clearer (and shorter) design phase synchronized with the available construction technologies and processes (that can also be potentially automated through existing prefab technologies but also through robotic automation). This reduces the time of the investment cycles. The developments are started faster and more inclusive with the end-users being co-investors. Developments could achieve the profit without waiting for the highest achievable real estate price on the market, but with being fast and shortening the overall cycle.

Phase 5 (Transformation): It is anticipated that the architectural compositions of the developed buildings are based on functional neutrality and that their infrastructural layouts are designed with a high but realistic level of transformative potential. With the changes in the market, climate, urban context or in the moment when the operation contracts are over, the building is reevaluated and goes back in the UAT loop towards a potential reconstruction/transformation project.

Diagram 21. Urban automation tool - phasing

This drawing/model is generated by the information synthesized from the data obtained through different media that contain and mediate data about different target groups (inhabitants, investors, architects, and urban planners, authorities, operators, owners). This information would be given back to its peers to generate new data and collect it again to update the informational model. Urban automation tool uses GIS service and publicly available urban regulation data and available data from the previously mentioned flows to generate a virtual landscape of possibilities whose elements (pixels as plots or buildings) are, in fact, self-generated fluctuating BIM models operated with artificial intelligence. The AI-operated fluctuating BIM models will be based on the algorithms derived from the case studies of the volume/program typologies; later, they will "learn" from their context.

3.1.4 How to participate?

Participation is an important component of the tool. Besides turning large portions of publicly available data (such as urbanistic plans and parameters, ownership maps, GIS maps, Google maps and places of interest, etc.) into the information available to users, the user feedback is necessary to sustain the system and to organize its participants into groups of shared interests. These groups could define needed services/standards/quality and budget and eventually some particular infrastructures for particular locations and plots – all the prerequisites to "predefine" some customized architectural compositions. The tool could visualize, analyze, calculate, and eventually help the projects to develop if all the stakeholders are better connected with each other through a mediated and platformed dialogue (Figure 29, Figure 30).

3.1.5. How it works?

Urban automation can be understood through 5 phases continuously looping, being updated and self corrected (Diagram 21):

- Phase 1 (Planning): this phase anticipates collecting data flows from different sources that can be directed towards a specific location (plot). These sources include developers and organized user groups as their competitors, the city with its GIS publicly available data and urban parameters, locations parameters (proximities, real estate values, rental prices, tourist routes...). Data collected for each plot is used to towards formulate "vague design briefs" as infrastructure requirements.
- Phase 2 (Briefing/Predesign): According to the "design briefs" (formulated from the data gathered from the city, developers, users…), an array of massing configurations based on functionally neutral architectural compositions (and spatial efficiency guidelines) will be proposed. This step will employ the previous research on infrastructural tenets and the typological repository based on the case studies. The results should be expressed through sketchy 3d options and evaluated through: numbers, ratios, efficiency indicators and other visualized data. The current "best options" are chosen to be displayed.
- Phase 3 (Prediction): All the data that is gathered is associated with adjacent plots and synthesized into "fluctuating BIM models," which are based on a supervised machine learning process and are being constantly updated as the inputs change. The BIM models are sent back and mapped on their plots into GIS, to form a vast virtual landscape (like Google Maps 3d) that show existing and the non-existing "predicted" - potential buildings developments that can be actualized or modified with the stakeholder interaction.
- Phase 4 (Design and Development): The previous phases (planning, briefing and prediction) anticipate the parallel marketing, pre-sale and contracting processes, so there is a clearer (and shorter) design phase synchronized with the available construction technologies and processes (that can also be potentially automated through existing prefab technologies but

also through robotic automation). This reduces the time of the investment cycles. The developments are started faster and more inclusive with the end-users being co-investors. Developments could achieve the profit without waiting for the highest achievable real estate price on the market, but with being fast and shortening the overall cycle.

- Phase 5 (Transformation): It is anticipated that the architectural compositions of the developed buildings are based on functional neutrality and that their infrastructural layouts are designed with a high but realistic level of transformative potential. With the changes in the market, climate, urban context or in the moment when the operation contracts are over, the building is reevaluated and goes back in the UAT loop towards a potential reconstruction/ transformation project.

3.1.6 Who is it for and what is the architect's role?

The tool does take the capitalist motivations of the real estate market to start with, but only because the ongoing market processes are in a way measurable and predictable. It is very obvious that the tool could be very useful for the real estate developers (1) as stakeholders. However, sharing the same information with other stakeholders such as (2) city governments and NGOs or (3) end users and (4) professionals: urbanists, engineers, architects – aims to pursue a new balance of interests for all, and therefore in a way reveals the information and analytics normally only available to the real estate developers and traders. The clear task of the architect in this process is yet to be defined; their role could be mediative or integrative in a larger process driven by the interests of different stakeholders. Real architectural design is not excluded; it would be driven with a clearer design brief defined through the platform-mediated the consensus of different parties; design still needs to bring the spatiality which goes beyond the mere interests of the capital, local government, or the end user.

The process can be illustrated with hypothetic scenarios in different scales:

- New planning regulations are being issued for the development of a mixed-use city center in the prime location of a city. Developers are looking to buy the land in a complicated ownership situation. They seek to develop a programmatically diverse business-residential development, with diverse sales strategies to lower the investment risks, achieve an optimal revenue potential within a very short investment cycle. They are using the feasibility model to connect landowners, operators, end-users, and banks to support the investment.

-On a micro-scale, merging three neighboring flats that could become a small hostel or dividing apartments and renting them out on Airbnb.

-Converting an industrial building into retails or offices or Universities renting out and adapting neighboring buildings to expand to accommodate students and facilities. Students are paying for different accommodation within cities to private owners or agencies anyway.

-Several owners connected plots in advance and sold the land to investors for a good price; they agreed in advance just by bidding like on a GIS E-bay. The investor wants to build max m2. Due to the bigger plot, and infrastructural rationalization, the city gives more generous but reasonable building parameters for the new bigger plot - more GFA allowed, but also more green space % is allocated – a win-win situation.

-A group of apartment buyers organized themselves in a housing cooperative, looking for a suitable plot; an architect and a contractor became developers, having more affordable, larger, and customized apartments for their families…

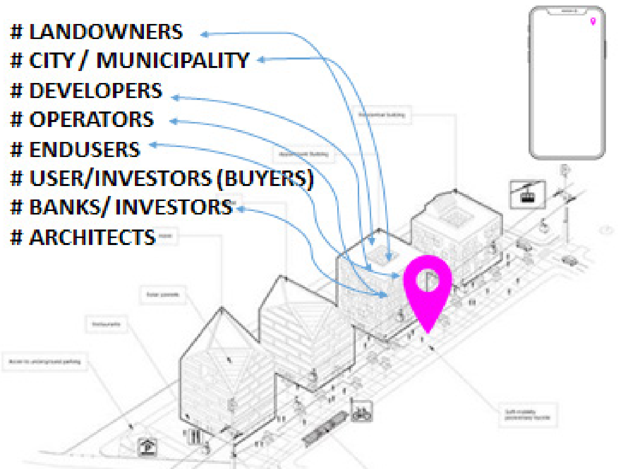


Figure 29. Filter based plot selection example

Figure 30. Stakeholders on the plot[175]

3.1.7. Possible consequences

The result could be a more democratic process of urbanization and, potentially, slight redistribution of wealth acquired through real estate. Essentially, the faster urbanization and development could result with more significant social diversity and maybe a little less social segregation, as the land would not be sold and developed by the highest bidders but to the fastest and most interested.

All this would not mean the end of architecture but actually a bit further than the beginning. Even in the well-regulated countries, from all the buildings being built are signed by an architect; 90% of these are generic houses, but are not considered architecture. What if the process could be optimized for this 90% to have their briefs clearly defined before they are finally designed and shaped, what if more time and financial resources would be possible to spend on the creative design side?

3.1.8 Launching point

Many aspects of the proposed concept rely on existing technologies and procedures (GIS, BIM, Data mining, AI, and Machine Learning), so a multidisciplinary approach and interdisciplinary collaboration are anticipated. As this research is based on the architectural design, it addresses only the central part of the proposed automation process. Since the scope of possibilities is practically infinite. The research starts with the most common program typologies with a significant degree of repetition, such as office and housing, most expensive and fastest-changing city land – mixed-use city centers, and most common volume typologies for the European context slabs and cubes (including the smaller high-rises).

Determining the infrastructural tenets for the functionally neutral architectural composition of the previously mentioned typologies is a central part of the overall research (Chapter 2), but also represents a base to demonstrate the central part of the proposed software tool UAT (Urban Automation Tool). The next chapter (Chapter 4) will demonstrate how the application of infrastructural tenets of functionally neutral building typologies could contribute to a faster and more transparent, and participatory-oriented urbanization process of the mixed-use city centers.

175 Image used for the collage: SO/AP agency, "Parametric Design In Urbanism," , 2014, http://www.evolo.us/wp-content/uploads/2014/11/parametric-urbanism-13.jpg.

3.2 IMPORTANCE OF THE MULTIDISCIPLINARY APPROACH (INFORMATION AND DESIGN TECHNOLOGIES, URBANISM AND REAL ESTATE ECONOMICS)

The following section aims to stress the importance of multidisciplinary approach and provide and overview of the current state of research of from the supporting disciplines and the current products related to urban automation already being developed on the market.

3.2.1 Information technologies

> "From here we see that contemporary Cloud platforms are displacing, if not also replacing, traditional core functions of states, and demonstrating, for both good and ill, new spatial and temporal models of politics and publics. Archaic states drew their authority from the regular provision of food. Over the course of modernization, more was added to the intricate bargains of Leviathan: energy, infrastructure, legal identity and standing, objective and comprehensive maps, credible currencies, and flag-brand loyalties. Bit by bit, each of these and more are now provided by Cloud platforms, not necessarily as formal replacements for the state versions but, like Google ID, simply more useful and effective for daily life. For these platforms, the terms of participation are not mandatory, and because of this, their social contracts are more extractive than constitutional. The Cloud Polis draws revenue from the cognitive capital of its Users, who trade attention and microeconomic compliance in exchange for global infrastructural services, and in turn, it provides each of them with an active discrete online identity and the license to use this infrastructure.''[176]

In his speculative essay announcing the forthcoming book The Stack: On Software and Sovereignty (MIT Press), Benjamin Bratton discusses the planetary scale computation infrastructures whose sovereignty reaches above and beyond the ones of states. For him, the Stack is a layered structure constituted out of six layers: Earth, Cloud, City, Address, Interface, and User. First, he discusses the competing nature of the State and the Cloud as an entity slowly overgrowing it towards a para-state condition and the ambivalent nature of its user as both an important data holder and an anonymous actor within the Cloud.

With the rise of the AI, where the degree of human surveillance and interaction is not yet clear, he announces the shift in the designer's position in the future from the author of the Anthropocene towards the role of supporting actors in the arrival of Post-Anthropocene. [177] In the light of the overall research of this thesis which concerns the near future, this means that the two Anthropocene (the current and the future one) already started to coexist so we could intertwine the two of them – with a cloud-based software infrastructure which has access to the already available information about urban environments and physical infrastructures. Machine learning as a computational technique saturates almost every aspect of automation in many fields in architecture and urbanism as well. In the essay Automation Aesthetics: Artificial intelligence and Image Culture, Lav Manovich[178] introduces the audience to the term machine learning, which was first introduced in the '50s when the goal was to teach a computer to perform a range of cognitive tasks. For him: "Today, AI (especially in the form of supervised machine learning) has become a key instrument of modern economies employed to make them more efficient and secure: making decisions on consumer loans, filtering job applications, detecting

176 Benjamin Bratton, "The Black Stack," *e-flux*, no. 3 (2014): 53. (n.d.), https://www.e-flux.com/journal/53/59883/the-black-stack/.

177 Ibid.

178 Lev Manovich is an author of books on new media theory, professor of Computer Science at the City University of New York, Graduate Center, U.S. and visiting professor at European Graduate School in Saas-Fee, Switzerland. Source: Wikipedia

fraud and so on..”[179]

A geographic information system (GIS) is defined as: “a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations.’’ [180]

Most of the data inputs related to urban development can be found on publicly available GIS platforms in most European capitals and major cities. The research anticipates that GIS can host not only the data about the real and existing but also the data about the possible. The draft 3d models could be mapped back into GIS, providing information and hosting dialogs about the various locations with the quantified and visualized data.

The previously mentioned technologies are to be employed for a variety of tasks in the previously mentioned process, such as:

-to anticipate and fill the blanks between collected data,

-to automate the creation of volume boundaries using the inputs of the local urban regulations,

-to generate the fine gradients between applicable building typologies,

-to recognize the economically viable patterns,

-to generate the fluctuating BIM models according to the inputs,

-to streamline the information from BIM flow to and from GIS platforms,

-to mediate the stakeholder dialogue and update the BIM model according to the participants’ inputs.

3.2.2 Urban Economics, Prop-tech and real estate industry

Prop-tech is an emerging sector of the real estate industry which aims to assist all stakeholders in planning, developing, and managing real estate properties. The scope of it ranges from data collection, cost modeling to visualization, and VR for sales and marketing purposes. For the implementation of a tool such as the proposed urban automation tool, the data about the real estate market and cost modeling methods are very important to grasp. However, most of the innovations in this industry are oriented towards the efficiency and optimization of the current systems and chain of the real estate industry and the relations city – developer – operator – customer (buyer or tenant). Local communities are often seen as the obstacle in developments rather than active participants; the first problem to be addressed is probably the lack of transparency.

One of the data streams which is not entirely publicly available is the data stream of real estate prices which a group of researchers from ETH Zurich aimed to make public using the technology of machine learning using only the publicly available data as an input. They developed “data-driven services for a spatial and temporal sensitivity analysis in the real estate market to be

179 Lev Manovich, “Automating Aesthetics: Artificial Intelligence and Image Culture,” http://manovich.net, 2017, http://manovich.net/index.php/projects/automating-aesthetics-artificial-intelligence-and-image-culture.

180 Keith Clarke, “Advances in Geographic Information Systems,” *Computers Environment and Urban Systems 10* (December 1986): 175-184, https://www.researchgate.net/publication/222231072_Advances_in_Geographic_Information_Systems.

used by different stakeholders,"[181] making the processes of decision in the real estate industry more transparent. The data gathered from the OpenStreetMap and real estate portal's advertisements included the prize, sq. meters, and all the data about the property structure facilities and infrastructure was used to generate the healthy base for estimation for the real estate prices for neighboring areas with similar urban characteristics. The study showed "dynamically crawled data set has other values, where for example one can develop several types of business analytics for different kinds of stakeholders such as potential tenants, landlords, construction companies, and economists (Figure 31)."[182]

Knowing this, we could add architects to the aforementioned list as well and propose using the same method for estimating and projecting the real estate potential for future yet non-existing developments.

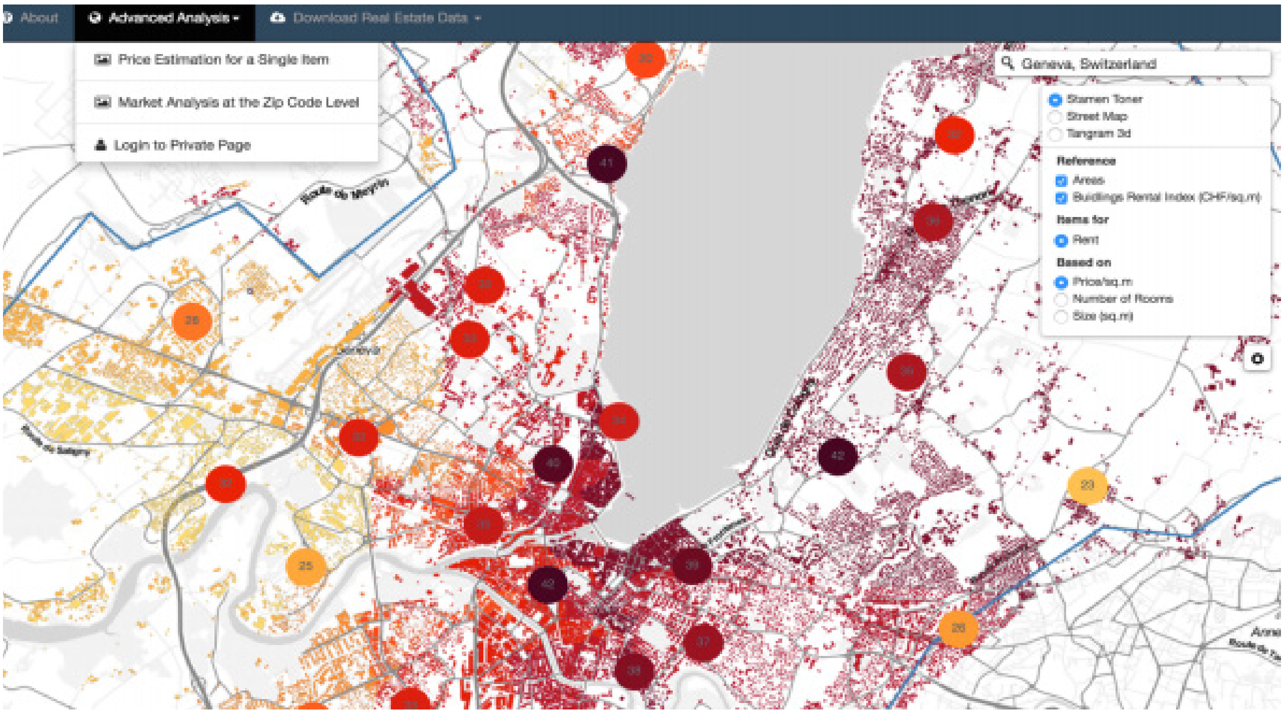


Figure 31. AI generated real estate value zones of Geneva[183]

3.2.3 Cost modeling

There are various cost modeling methods used by real estate managers and developers used for the development of buildings (Figure 32); according to De Jong, there are two principal approaches to them – a descriptive (experience-based, mostly used by developers) cost model (Figure 33, 34, 35), and a design-supporting cost model (which could be used by architects).[184] De Jong suggests that the two models could be combined for higher accuracy. Now the design supporting cost models can use the information from a building information model(BIM).

181 Vahid Moosavi, "Urban Data Streams and Machine Learning: A Case of Swiss Real Estate Market," www.vahidmoosavi.com, accessed January 5, 2021, https://arxiv.org/ftp/arxiv/papers/1704/1704.04979.pdf., 1.
182 Ibid.,7.
183 Image acquired from the paper: Vahid Moosavi, "AI generated real estate value zones of Geneva," , 2017, https://arxiv.org/ftp/arxiv/papers/1704/1704.04979.pdf., 3.
184 Peter De Jong and Hans Wamelink, "DESCRIPTIVE COST MODELS VERSUS DESIGN SUPPORTING COST MODELS" (Conference session presented at WCPM2007, Delft, n.d)., 1-2.

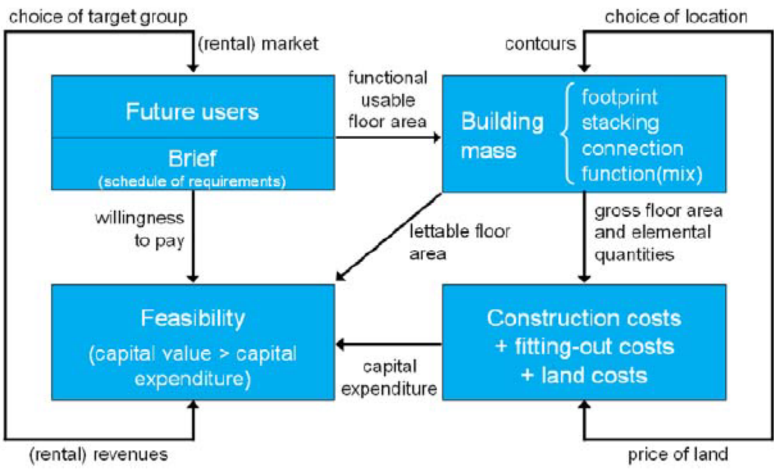
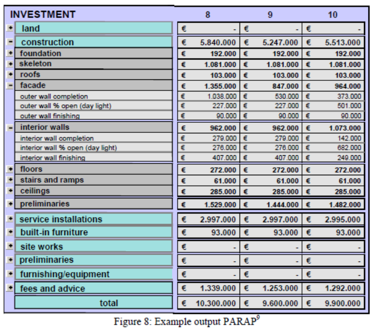


Figure 32. Development cycle of buildings[185]



INVESTMENT	8	9	10
land	€ -	€ -	€ -
construction	€ 5.840.000	€ 5.247.000	€ 5.513.000
foundation	€ 192.000	€ 192.000	€ 192.000
skeleton	€ 1.081.000	€ 1.081.000	€ 1.081.000
roofs	€ 103.000	€ 103.000	€ 103.000
facade	€ 1.355.000	€ 847.000	€ 964.000
outer wall completion	€ 1.038.000	€ 530.000	€ 373.000
outer wall % open (day light)	€ 227.000	€ 227.000	€ 501.000
outer wall finishing	€ 90.000	€ 90.000	€ 90.000
interior walls	€ 962.000	€ 962.000	€ 1.073.000
interior wall completion	€ 279.000	€ 279.000	€ 142.000
interior wall % open (day light)	€ 276.000	€ 276.000	€ 682.000
interior wall finishing	€ 407.000	€ 407.000	€ 249.000
floors	€ 272.000	€ 272.000	€ 272.000
stairs and ramps	€ 61.000	€ 61.000	€ 61.000
ceilings	€ 285.000	€ 285.000	€ 285.000
preliminaries	€ 1.529.000	€ 1.444.000	€ 1.482.000
service installations	€ 2.997.000	€ 2.997.000	€ 2.995.000
built-in furniture	€ 93.000	€ 93.000	€ 93.000
site works	€ -	€ -	€ -
preliminaries	€ -	€ -	€ -
furnishing/equipment	€ -	€ -	€ -
fees and advice	€ 1.339.000	€ 1.253.000	€ 1.292.000
total	€ 10.300.000	€ 9.600.000	€ 9.900.000

Figure 8: Example output PARAP[9]

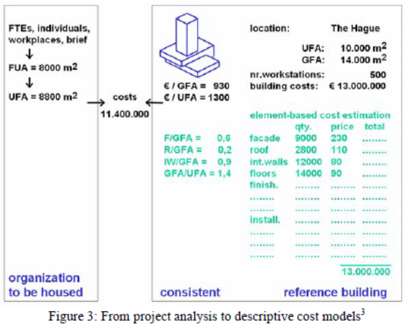


Figure 3: From project analysis to descriptive cost models[3]

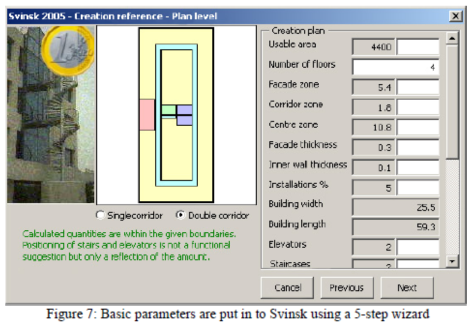


Figure 7: Basic parameters are put in to Svinsk using a 5-step wizard

Figure 33. Output of PARAP[186] Figure 34. Analysis - descriptive model[187] Figure 35.SVINSK[188]

These models are formed and adjusted for different real estate markets and their specificities. For the local real estate market of Belgrade, Serbia, research performed by Furundzic (2016)[189] is relevant for this research since it evaluates the profitability of different plots with respect to the urban parameters in residential – business zones. This research gives an overview of different profitability evaluation methods and formulates a descriptive experiential model proven locally through case studies of realized projects, which may be used by architects for verification and plot evaluation.

> "The role of the architect is the integrator. Along with financial information he must bring all other disciplines together in the design, with regard to the demands and his own standards. So, the model should be designed as a tool for the architect, a product of cost experts instead of for cost experts."[190]

With today's growing BIM implementation into the legislation procedures, the construction cost will be even more oriented towards the design-supporting model, as BIM parametric models can update the bill of quantities in real-time. Therefore, the constructional part of the overall investment can be done with precise estimations as a solid base, and when combined with the other cost data (land acquisition, communal taxes, VAT, financing cost, sales cost, marketing costs, etc.), it can be compared to the descriptive cost model once more for the overall picture.

185 Ibid., 2.
186 Ibid., 10.
187 Ibid., 5.
188 Ibid., 9.
189 Danilo S. Furundzic, "Defining model of profitability evaluation for planned urban parameters of residential-business zones in Belgrade," (PhD diss., University of Belgrade, 2016).
190 Peter De Jong and Hans Wamelink, "DESCRIPTIVE COST MODELS VERSUS DESIGN SUPPORTING COST MODELS" (Conference session presented at WCPM2007, Delft, n.d)., 11.

3.2.4 Design technologies : Parametric design tools and BIM (Building Information Modelling)

Parametric design tools are used to generate and dynamically evaluate multitudes of design options using the typological infrastructural tenets and the previously elaborated repository of typical plans, which they could further use for customization in terms of the dimensions, facade typologies densities, etc. In this research, Rhino & Grasshopper software has been used for the first phases, but the plan is to integrate this process with BIM.

"Building Information Modeling (BIM) are essentially parametric models defined as: a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition."[191]

BIM goes beyond traditional 2d planning documentation, even beyond 3d representation, but includes as well time (4d) and costs (5d). BIM software is essentially parametric software, and recently it has provided a certain degree of customized control either through integration with existing code languages (C++ or Python) or working with predefined user-oriented parametric design components integrated like *Grasshopper* for *Rhino* or *Dynamo* for *Revit*.

Integrating the technologies of AI and machine learning into BIM is certainly a big challenge, and there is extensive research being performed on various topics in this direction. One of them, conducted in KHG (Katholische Hochschulgemeinde) in Munich has been trying to introduce automation techniques in the process of architectural design in a similar manner as AI is currently used for recognizing images , by recognizing the similarity pattern in reference projects (from a BIM database). Their research aimed to speed up the time-consuming process of searching for reference projects and solutions that are a part of the process of architectural analysis prior to building design.[192] Their approach is based on the assumption:

> "The reference solutions (i.e. Building designs) are stored in a repository as Building Information Models (BIM) using the open data model Industry Foundation Classes (IFC). In order to find suitable reference solution for a given problem, a measure of similarity has to be defined. To this end, we introduce the notion of the building fingerprint as a way to capture the main characteristics of a building design. A major component of the fingerprint is the representation of the adjacency relationships between the spaces, which can be expressed by an adjacency graph. Another component is the accessibility relationships, which again can be expressed by a corresponding graph."[193]

The idea of using a design repository presented by Simon Daum (KHG) influenced the decision to also formulate a repository for this research. In the context of my research, the design repository is based on building typologies and generic architectural compositions while the researchers from KHG used a large database of BIM models of existing buildings to form theirs. This research works with typical plans and internal and external infrastructures with an indication about the program, while the *building fingerprint* concept work closely with particular programmed spaces and their adjacency and logistics.

The research conducted here is more design-oriented and plans to be implemented using BIM technology, at the moment for the demonstration for the central parts of the UAT in Chapter 4

191 "Frequently Asked Questions About the National BIM Standard-United States™," National BIM Standard - United States, last modified 2019, https://www.nationalbimstandard.org/faqs.

192 Simon Daum et al., "Automated generation of building fingerprints using a spatio-semantic query language for building information models" (Paper presented at 10th European Conference on Product & Process Modelling, Vienna, September 2014).,1.

193 Ibid., 1.

(Phase 2 and Phase 3) the following sequence of operations using some of the following software tools: Rhinoceros & Grasshopper, Revit & Dynamo, GIS, VR, MS Excel (Diagram 22).

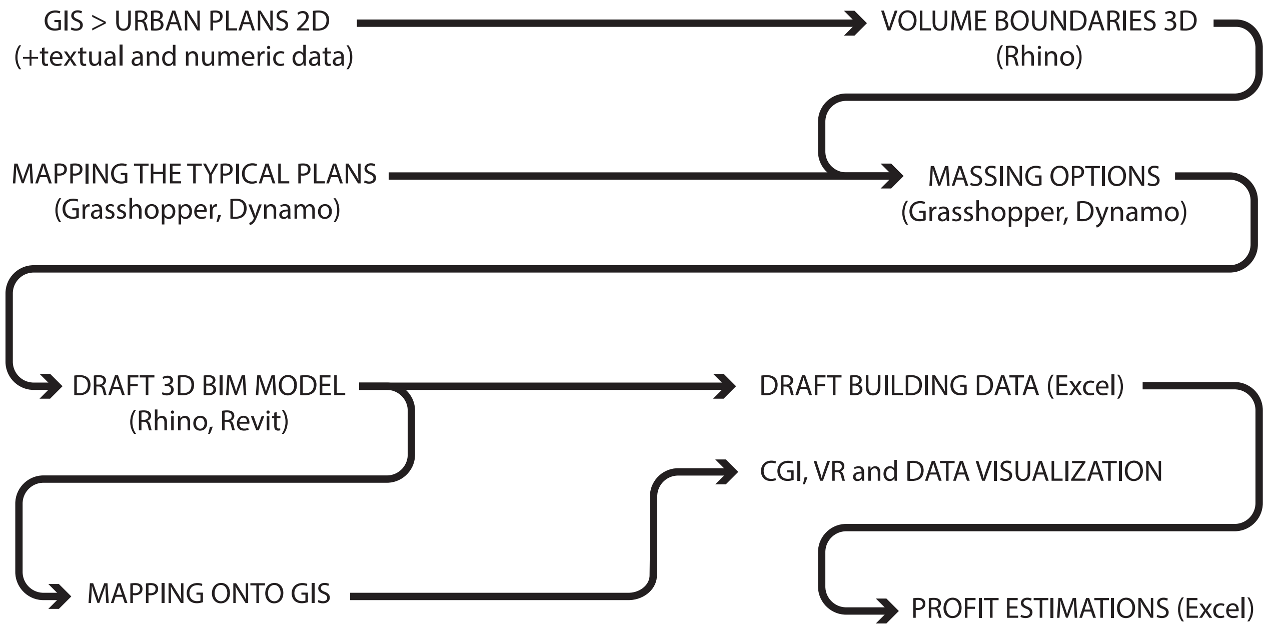


Diagram 22. Operation sequences of the Urban Automation Tool

3.3 TARGET GROUPS AND CURRENT STATE OF THE MARKET

The Urban Automation Tool is a vision for a very broad platform to perform many interventions within various urban contexts; however, the scope of this research can be seen as a demo/starting point dealing with the urban contexts of mixed-use city centers and office and housing as dominant program typologies.

3.3.1 Target groups

This proposal that employs the research-based approach in the field of architectural and urban design is addressing several target groups who could benefit from such a platform. It is important to understand that the ones we should be building for are essentially people and not the capital, therefore the idea that the end users take a central place in the overall process. In the context of housing, the first participant could be:

- **housing cooperatives -** groups or networks of people of the shared interest of obtaining homes so that eventually they could become their own investors/developers and have the chance to customize, participate and influence the projects being developed early on and therefore benefit from the process towards more sustainable rent or mortgage or the easier and more fair ways or acquiring property. The problem with housing cooperatives is a legal and procedural one, and the process usually takes a long time but does often result in good and innovative results in the realm of non-profit housing. One of the proposals initiated with the rise of sharing economy and block-chain technologies is DOMA.CITY's platform for equity tokens (shares) that replace the rents and mortgages. Through a new way of ownership mediated with smart contracts, the rent is replaced with network ownership equities, and it is being reduced over time as ownership share grows until the extent that the monthly fee equals only the maintenance cost..[194]

194 Stephen Cousins, "Blockchain Scheme Bypasses Overpriced Housing Market," *RIBA Journal Magazine: Architecture Information and Inspiration* | RIBAJ, accessed January 5, 2021, https://www.ribaj.com/products/virtual-tenure-blockchain-scheme-bypasses-overpriced-housing-ukraine-stephen-cousins.

- **buyers & tenants –** when buying or renting a housing unit that is in the development process, the end users could benefit from having a certain degree of customization or the level of finish when choosing a property, which could benefit both the user and the developer
- **developers -** usually have their own ways of looking for land or property for investment, but using the UAT could bring a much larger scope of property into consideration together with profitability indicators. Besides that, they can be more directly linked with landowners, buyers, and/or potential tenants, as well as local communities, and propose developments related more precisely to market needs.
- **co-working developers** - the current tendency of the office market is a move from headquarters concept towards a growing co-working concept of offices. So most of the new offices are not operated by the owners but rather rented out to companies and freelancers, as multi-tenant and open space offices are usually mixed. Co-working developers could be interesting partners for the housing cooperatives, as they may bring the starting amount of funds for project financing.
- **retailers** - this research addresses the retail program as a secondary one most of the time, anticipating it as street-level retail that boosts the use of the open public spaces. However, if the retail potential is higher, podiums are anticipated in the mixed-use city centers. But the retail program potentials would need to be researched more precisely in further research that goes beyond the scope of this PhD.
- **city/municipal governments –** The local governments could possibly have the largest benefit from the Urban Automation Tool, as they already own and operate the GIS platform and aim to maintain a degree of "loose control" over the urban development according to the urban plans and development strategies. Visualizing the zoning laws and making the possibilities for developments understandable and transparent to various stakeholders could boost the property market and speed up the development of strategic areas with the local communities involved.

3.3.2 Current state of the market

The automation processes in the fields of urban and architectural design already started to be implemented within the last couple of years. There are several examples of different software concepts ranging from: floor-plan generators, massing tools that size up the plots and interpret urban parameters as a service for the developers, platforms for negotiating with local stakeholders to the design/data collection and interactive platforms for housing. After the overview, this section will offer a brief summary to identify the similarities and differences between the proposed Urban Automation Tool and the tools currently on the market.

- THE PRISM / BRYDEN WOOD & CAST & MAYOR OF LONDON, LONDON 2019.

https://www.prism-app.io/
The PRISM is an interactive, publicly available online platform developed with the aim to help to solve the housing scarcity in London. It offers several typologies related to prefabricated building systems that could be applied to any site in London. The data should be exported and visualized; for now, the app does not include zoning rules; therefore, it is primarily used for market research and data collection.

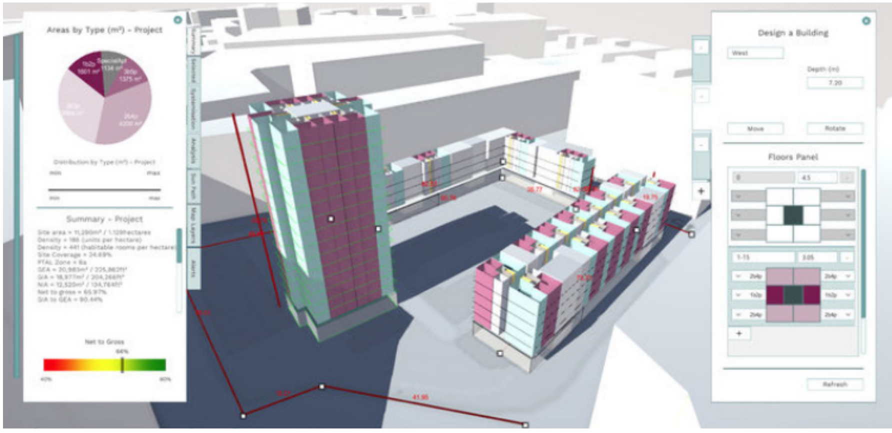


Figure 36. PRISM app screenshot[195]

- SPATIAL OPTIONEERING / CERTAIN MEASURES/ BOSTON-BERLIN 2016-2019.

https://certainmeasures.com/spatial_optioneering.html
A parametric typological tool that evaluates the efficiency of different massing options and floor-plan layouts developed as a tool for a real estate developer specializing in student housing projects.

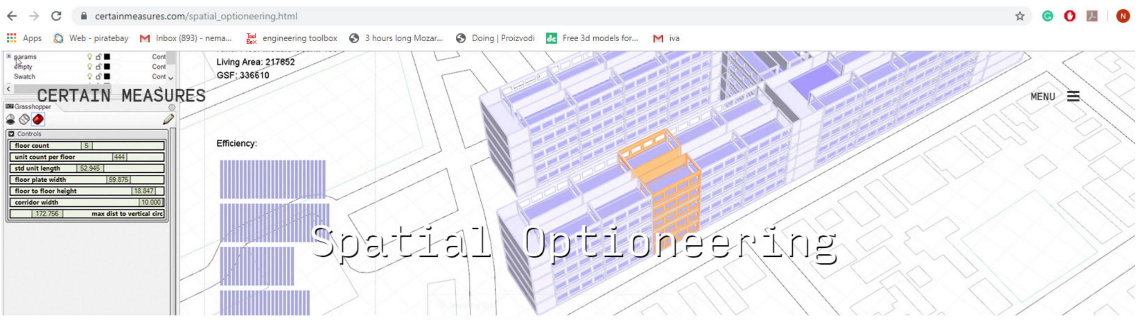


Figure 37. Spatial optioneering, screenshot[196]

- ENVELOPE.CITY / NEW YORK 2016. https://envelope.city/

Envelope interprets zoning laws using the information from GIS and works with volumes and programs; it gives data visualizations as outputs (areas, programs, ownership information, even the basic layouts). In a three-year period, this company has been able to cover the whole Manhattan area.

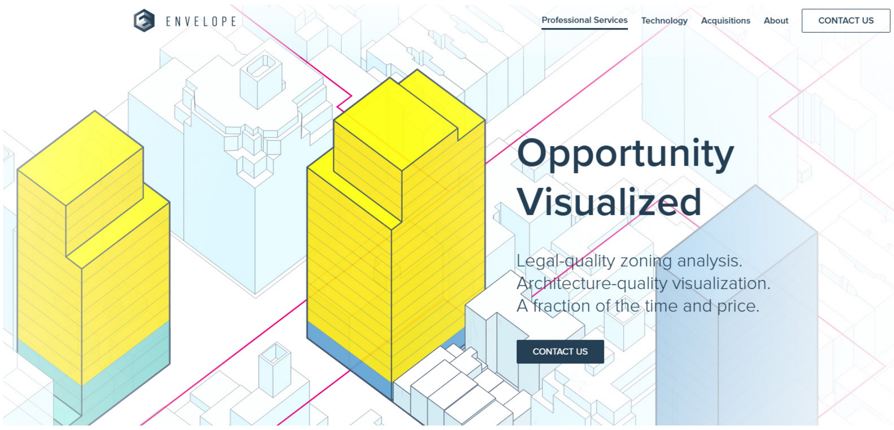


Figure 38. ENVELOPE app demo screenshot[197]

195 "PRISM app screenshot," , n.d.https://www.prism-app.io/.
196 Certain measures, "Spatial optioneering, screenshot," , 2019, https://certainmeasures.com/spatial_optioneering.html.
197 ENVELOPE.city, "ENVELOPE app demo screenshot," , 2019, https://envelope.city/.

• FINCH 3D / ADAPTIVE PLANNING / MALMO 2019. http://finch3d.com/
Finch uses Grasshopper software to speed up the early phase of the design; it uses a series of interactive scripts to define the massing, the number of floors, lengths, and depths, roof inclinations, etc. The other tools developed by finch use the typical program units, such as apartment layouts, that adapt to different dimensions and shapes of the floor plate.

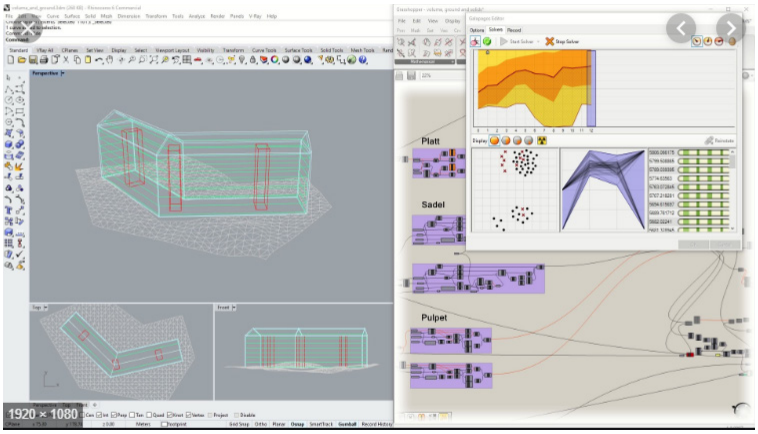


Figure 39. Finch 3d - massing script screenshot [198]

• COURBANIZE / BOSTON 2016. https://www.courbanize.com/
Courbanize is a platform that works as a mediator between local communities and developers; it works with a data collection and social tool to speed up the community-developer-city dialogue and help to avoid the project-related costly delays.

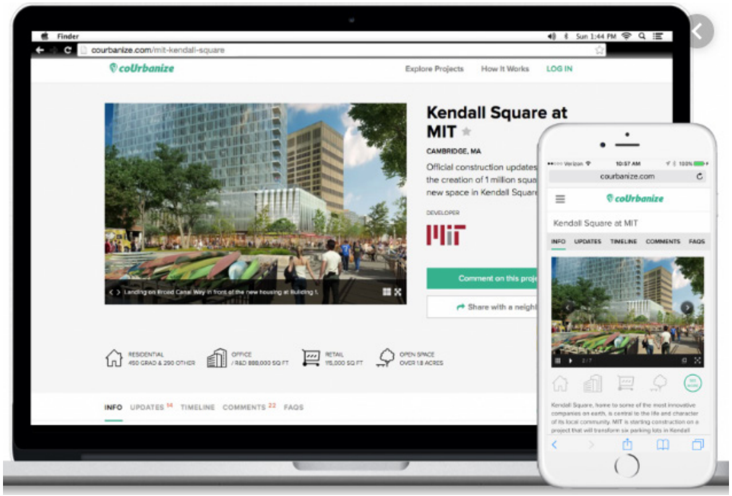


Figure 40. coUrbanize app screenshot[199]

• REAL+ by MLAPLUS / ROTTERDAM 2019. https://www.realplus.biz/
REAL+ combines economic data and real estate development models with spatial information and analysis and architectural and urbanistic knowledge. As a platform, it not only allows for precise and risk reducing answers but it also invents a new form of collaboration between all parties involved in an early stage of project development.

198 Finch3d, “Massing script screenshot,” , 2019, http://finch3d.com/.
199 COURBANIZE, “coUrbanize app screenshot,” , 2019, https://www.courbanize.com/.

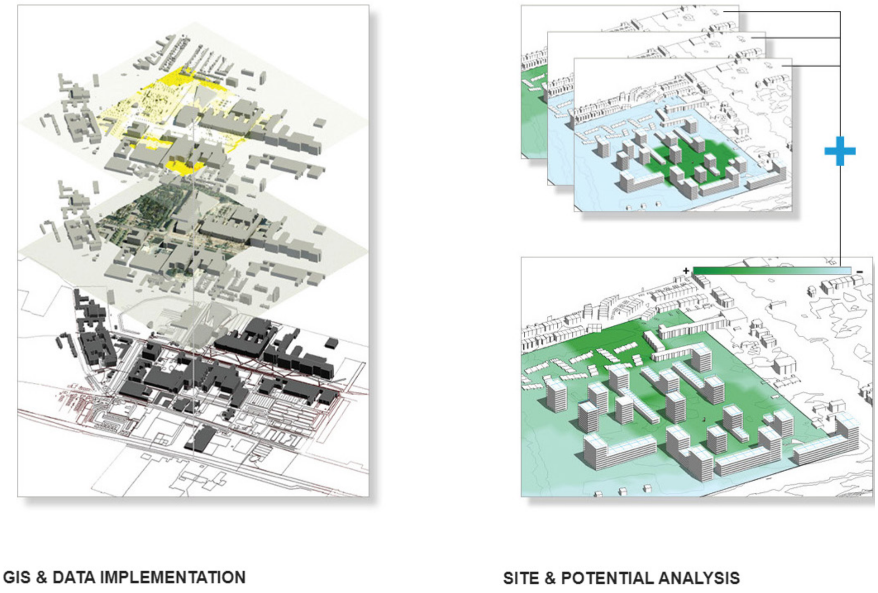


Figure 41. REAL+ app demo screenshot[200]

The brief overview of the ongoing research and current state of the market showed that the automation process has already begun within the field of architectural and urban design, and it is taking place mainly as a part of the prop-tech industry and as a part of the already established architectural practice and consultancy agencies and public sector. However, the disciplinary-specific scientific background and the criteria for this software remain unclear, or a secret as a trait of the business. There are similarities and differences to the proposed UAT, which was conceived prior to being aware of all the existing or developing software apps. The similarities are automated reading of the zoning laws (Envelope.city), generative output (Certain Measures), and inclusion of different stakeholder groups (CoUrbanize, Real+). While the differences are a design-based approach based on infrastructural tenets, a focus on functionally neutral building typologies, a focus on the particular mixed-use city center urban areas, open-source character, and transparency for the public by proposing a connection to publicly available GIS datascapes.

The aim of this chapter was to introduce a scenario for the possible application of the research. This was firstly done by presenting a vision of the Urban Automation tool with an overview of the wide range of automation possibilities that significantly exceeds the scope of the research presented in the previous chapters. The second part of the chapter provided an overview of the research context from the fields of information and design technologies, urbanism, and real estate economics that shows the necessity for a multidisciplinary approach. Finally, this chapter provided an overview of the current development of software already on the market with their similarities and differences with the UAT.
The last chapter will demonstrate how the achievements of the research (conducted in chapters 1 and 2) -a design approach based on infrastructural tenets and functionally neutral typologies (within their mixed-use city center urban context) could become the first niche where the UAT could be applied.

200 MLA+, "REAL + app demo screenshot," , 2019, https://www.realplus.biz/.

4. SYNTHESIS AND DEMONSTRATION - APPLYING SPATIALLY EFFICIENT AND FUNCTIONALLY NEUTRAL ARCHITECTURAL COMPOSITIONS TO AN EXISTING URBAN PLAN (SIMULATION OF URBAN AUTOMATION PROCESS)

This chapter aims to employ the previous findings and showcase how functionally neutral architectural compositions based on infrastructural tenets can be applied in a particular urban context of a mixed-use city center. This demonstration will loosely follow the phases of the previously proposed Urban Automation Tool (UAT), focusing on the central segments of the tool (Phase 2 and Phase 3), where the typologies based on infrastructure are generated, evaluated, and adjusted.

The chapter starts with a hypothetical inquiry scenario from the perspective of a real estate developer who discovers a potential location for his new development in Block 18 in Belgrade – a planned mixed-use city center. This inquiry opens a section of critical evaluation and analysis of the current planning procedures, showing how the actual planning is still conducted through a top-down procedure and vague criteria, which results in many obstacles, inconsistencies, and lack of transparency, efficiency, and projective thinking, since the zoning laws of a mixed-use city center are currently not favoring the mixed-use and long-lasting functionally neutral typologies. This is followed by a section that investigates the optimal block size to apply the functionally neutral typologies, so an alternative size or urban matrix is proposed following the urban parameters (allowed by a plan of higher rank).

The second sub-chapter demonstrates and illustrates the UAT phases (Phase 2 and Phase 3) through 10 steps by using the mixed-use and functionally neutral infrastructural layouts to achieve the maximal build up within the selected block and demonstrate the possibilities of different program ratios, real estate strategies, profitability projections and visualizations.

This demo uses the previously selected scope of programs: housing and office – considered as primary programs with retail functions as additional. The volume typologies considered are cubes and slabs (with the possibility of smaller high-rises). The following demonstration uses the previously established repository of the functionally neutral typical plans and spatial efficiency indicators that show the benefits of the applied building typologies on this site located in a mixed-use city center (Block 18 in Belgrade).

4.1 APPLICATION ONTO AN URBAN PLAN – CASE STUDY: BLOCK 18, BELGRADE

4.1.1 Mixed use city centers as polygons for functionally neutral buildings

The collected urban parameters from the case studies indicate the possibility of the presence of transformable, mixed-use, and functionally neutral buildings with the urban contexts of the mixed-use city centers.

Mixed-use zoning or mixed-use planning is a type of urban development, urban planning, and/or a zoning type that blends residential, commercial, cultural, institutional, or entertainment uses into one space, where those functions are to some degree physically and functionally integrated, and that provides pedestrian connections.[201] In previous case studies, projects have been chosen from a different context with the EU and major European cities to capture the general tendencies in housing and office developments within the European context. However, since the power and the algorithmic nature of the proposed tool (UAT) can be only determined with the power to deal with local problems in a particular context, a mixed-use city area with developing (but still unclear) planning has been chosen for this demonstration – Block 18, Belgrade. This case study – demonstration will focus on the scales of a city block, while the larger zoning that includes public, cultural, and institutional buildings remains as the context that may influence the commercial developments but is excluded from the research.

The chosen area for the demonstration is characterized by the following:

- CONTEXT DENSITY: Mixed-use plots, city centers, FAR>3
- PROGRAM: Housing and office program typologies (retail as secondary)
- VOLUME TYPOLOGIES: Cubes (+ extended cubes) and Slabs

4.1.2. Sequences of urban automation algorithm

Besides being a testing ground for the research, this demonstration case study is also a testing ground for the proposed software platform towards making a base for a minimum viable product. The proposed diagram for the UAT software platform anticipates a very large scope of inaccessible information and data and the involvement of expertise from different fields; so this demonstration focuses on its central part of it (Diagram 23).

The demo will implement the infrastructural tenets for functionally neutral buildings (as a central part of the overall research), which are disciplinary-specific to the field of architectural and urban design. Demonstration is scenario-based; it starts with an inquiry (with assumed figures and demands) from a potential UAT user (real estate developer) and looks out for the ways how his intentions could be met in the particular context of Block 18 (zone of the mixed-use city center) in Belgrade (Figure 42).

201 Grant I. Thrall, Business Geography and New Real Estate Market Analysis (New York: Oxford University Press, 2002), 216.

The demonstration/case study is performed through several steps:

- inquiry scenario for a UAT user: search engine + search results (4.1.2),
- introduction and analysis of an existing condition of the location, location parameters, and zoning laws (4.1.3, 4.1.4, 4.1.5),
- overview of planning stages and zoning laws for the location (4.1.6),
- critical evaluation of the actual urban plans for Block 18 (winning competition entries, Preview of a plan of Detailed Regulation – PDR). The evaluation is based on competition jury report, block sizing and distribution of urban infrastructure, program distribution, capacity analysis, the intensity of land use (4.1.7),
- critical quantitative analysis of dimensioning the typical city block (winning competition entries, Preview of a plan of Detailed Regulation – PDR), a proposal for a new size of a typical city block that approaches the maximal capacities achieved with the spatial efficiency of the proposed typologies based on the infrastructural tenets (4.1.8),
- comparative analysis of the typical blocks of the three master plan proposals – which will be comparing the capacities of te three massing options in terms of maximizing the land use potential of the block (4.1.9),
- evaluation of the possible massing options in terms of spatial efficiency and program neutrality of the chosen typical block (4.1.10),
- - choosing the most flexible massing option with the application of functionally neutral typical plans, quantification, visualization, and profitability evaluation.

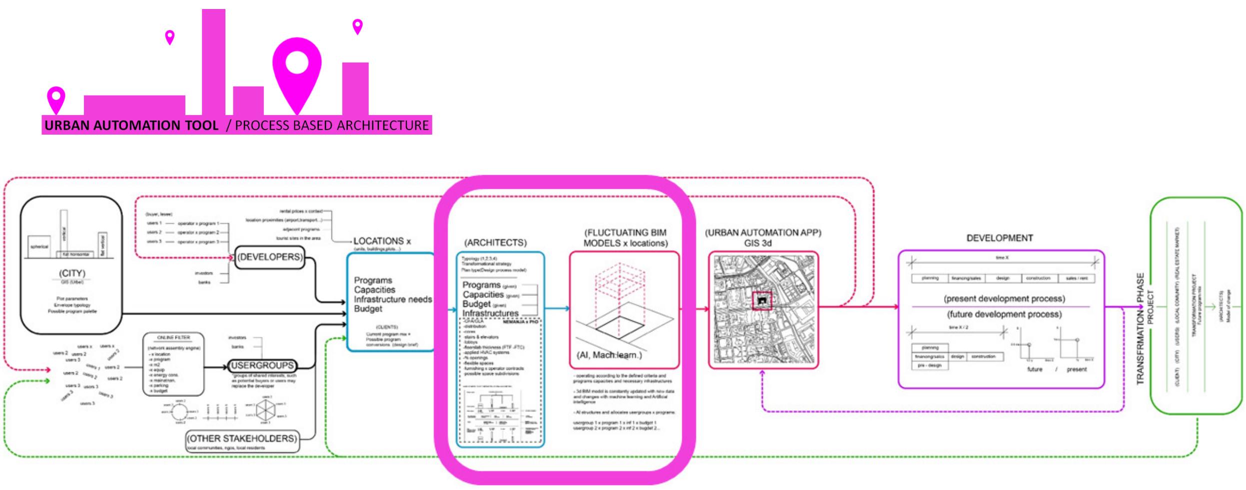


Diagram 23. Locating the research within the Urban Automation Tool algorithm

INQUIRY SCENARIO (SEARCH ENGINE + RESULTS)

Figure 42. Online filter for plot search (illustration)

According to the search inquiry, several locations in Belgrade match the on-line filter. Block 18 in New Belgrade is the one that matches the most. The intersecting set urban parameters showed in Diagram 9 (Chapter 2.3) for housing and office programs, and cubic and slab volume typology is applicable on this site as a potentially suitable site for developing functionally neutral typologies based on infrastructural tenets.

POSSIBLE MIXED USE LOCATIONS

/ CITY CENTERS 50% HOUSING / 50% OFFICE + RETAIL
LOCATION SEARCH RESULT : BLOCK 18 , BELGRADE

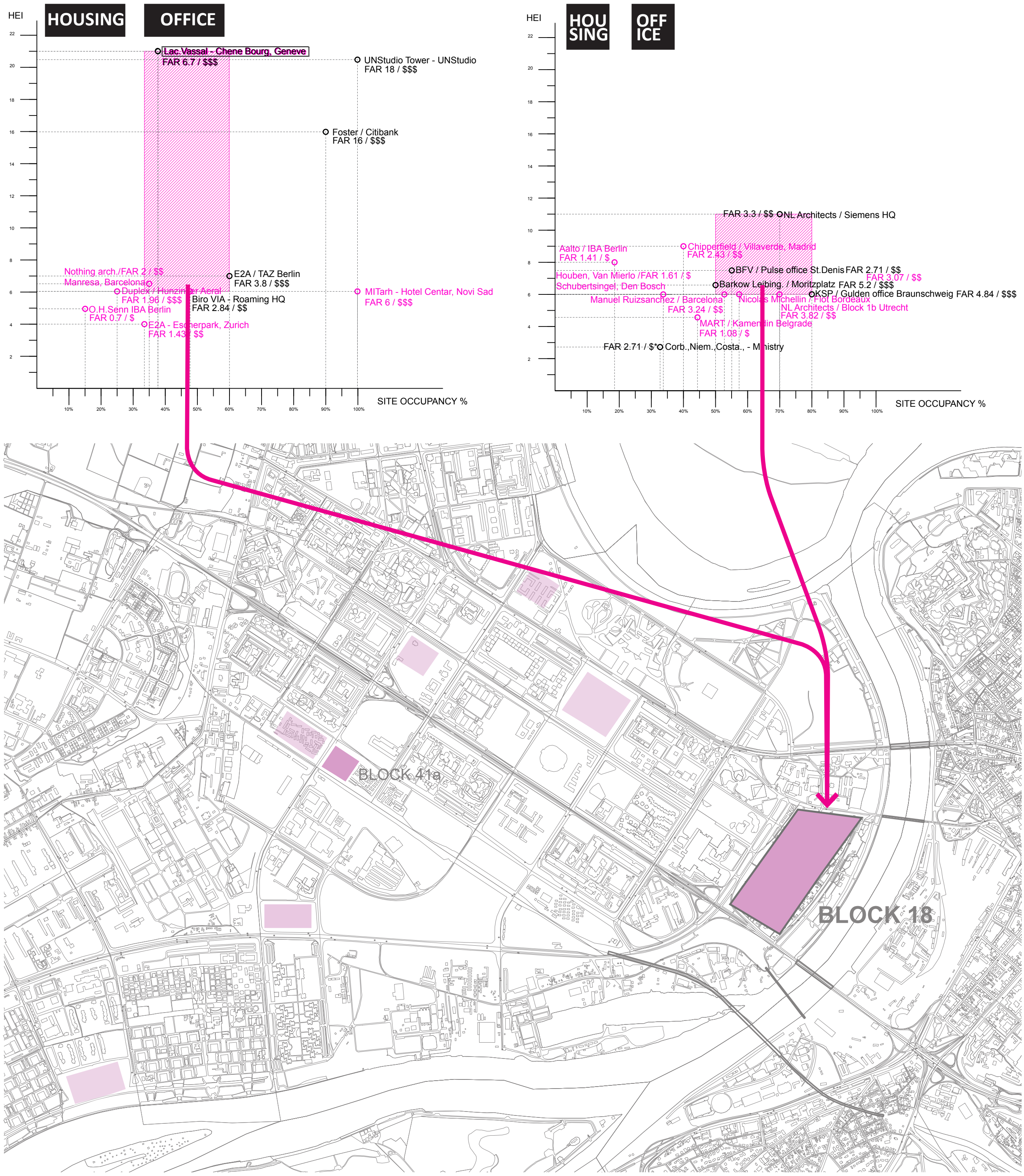


Figure 43. Search matching mixed used city center zoning areas in Belgrade (illustration)

4.1.3 Block 18 - introduction and analysis of the existing condition of the location, location parameters, and zoning laws

Browsing through the Belgrade official GIS Online app BEOinfo, a Block 18 can be selected, and it is available to the public to read the relevant city plans for this location. The latest is the early version of PDR (2017) based on the results of an urban design competition from 2016 and the higher-ranked Plan of General Regulation. By reading out the extensive amount of textual and graphic documentation, we can learn about the location and about and the development of the planning procedure.

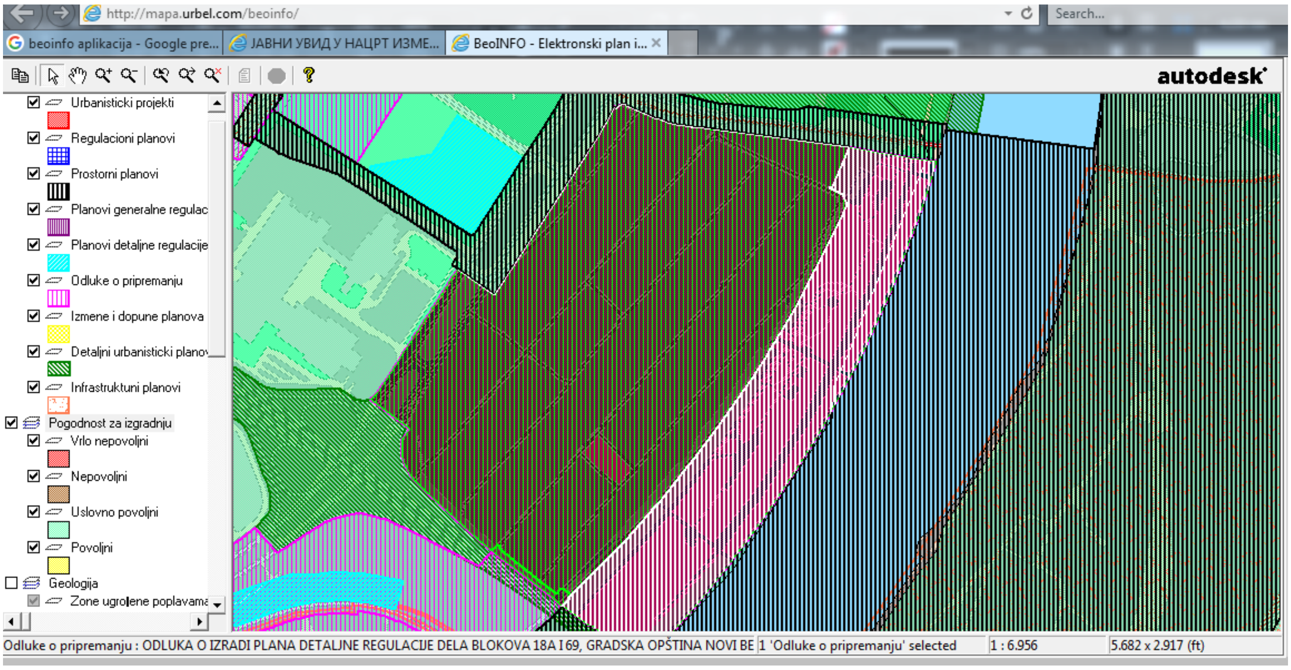


Figure 44. Block 18 in Belgrade GIS app - Beoinfo

Figure 45. Preview plan of detailed regualtion (PDR), 2017.[202]

202 Ana Graovac and Ana Lazovic, Plan detaljnje regulacije bloka 18 - Elaborat za rani javni uvid, (Belgrade: Direkcija za gradjevinsko zemljiste i izgradnju beograda, 2017), http://www.beograd.rs/lat/gradski-oglasi-konkursi-i-tenderi/1732006-rani-javni-uvid-u-plan-detaljne-regulacije-bloka-18/.

4.1.4 Block 18 - Existing condition

Block 18 is an area centrally positioned within the overall Belgrade metropolitan area located in New Belgrade, an area developed throughout the period of socialist Yugoslavia (1945–1991) as a top-down modernist project aiming to form a new capital for a new socialist country.

It is bordering an old fairground on the north; on the west, it is bordering a convention center and a business district. On the southwest is an industrial zone, and on the east is a public park along the Sava river. There have been many plans and competitions to develop this area; until today, it remained occupied with inappropriate low-rise housing, half of which is assumed to be illegal (Figure 46, Figure 47).

Figure 46. Broader context of Block 18

Figure 47.Current state of Block 18 (Google Maps, Google street view)

4.1.5 Block 18 - Development perspectives and problems

The Block 18 area is not yet fully urbanistically regulated, but already there are media indications announcing the large development illustrated with images from a winning competition entry from 2016 titled Block 18 – a new city like New York, Paris or Singapore, announcing that there are investment funds interested and have already acquired some of the land (Figure 48, Figure 49).

The urban planner Ana Graovac[203] (from Urbanistički Zavod Beograda) responsible for the latest urban plan says that the new plan is only partly based on the competition results and that the new plan is yet to provide the framework for the location development, which is according to her opinion is not going to happen any time soon due to the complex and unclear ownership situation (a large number of private owners, state-owned, land under legal dispute, illegally occupied land). The author of the winning competition entry Vanja Panic[204] says that he had no involvement in the further development of his urban plan after the competition, knowing that there will be very little implemented. Since there is a lack of information on the current ownership status and planning regulation, the media started the bombastic announcements but also raising suspicions about possible corruption. All this raises the question of how, who, and when this valuable land will be developed? This case study will focus on the How? How can it (or just Can it?) really be a city like New York, Paris, or Singapore?


ПОЛИТИКА

Ponedeljak, 09.09.2019. † Verski kalendar € Kursna lista

Svet Politika Društvo Pogledi Hronika Ekonomija Kultura Beograd Sport Region Mozaik Sve

Početna /

Blok 18 – novi siti nalik na Njujork, Pariz ili Singapur

Ruski investicioni fond „Marera propertiz" zainteresovan je da preko puta „Beograda na vodi" gradi poslovni centar

Autor: Daliborka Mučibabić sreda, 16.01.2019. u 08:24

Победничко решење урбанистичког конкурса за Блок 18 из 2016.

Ruski investicioni fond „Marera propertiz" bacio je oko na Blok 18, a o ulaganju njihovog kapitala u beogradsko priobalje biće reči sutra, saznaje „Politika", kada u Srbiju stiže predsednik Ruske Federacije Vladimir Putin.

Blok 18, prostor preko puta „Beograda na vodi", kako saznajemo u Gradskoj upravi, nakon ruske investicije mogao bi da postane dom za sve organe Vlade Srbije i Skupštine Beograda sa sekretarijatima. Na taj način bi Beograd i Republika, bez utroška novca iz budžeta, dobili najmodernije i najfunkcionalnije uslove za rad.

– U novobeogradskom Bloku posedujemo pola hektara i izuzetno smo zainteresovani za razvoj tog područja kako bi i Beograd dobio svoj siti nalik na Njujork, Pariz ili Singapur. To bi trebalo da bude novi deo prestonice sa više od 350.000 kvadrata u kojima bi bio smešten centar poslovnih zbivanja ovog dela Evrope – kažu za naš list u beogradskom predstavništvu „Marera


Danas

NOVO Politika Dijalog Društvo Ekonomija Svet Sport Kultura Scena Život Auto IT Ljudi Beograd

Lični stavovi

Kako su list Politika i njen "izvor iz gradske uprave" zloupotrebili posetu predsednika Rusije Vladimira Putina

Nepostojeći ruski investicioni fond gradi „Beograd na vodi 2"

Dan pred posetu ruskog predsednika Vladimira Putina u Beogradu je eksplodirala medijska bomba čija je detonacija uzdrmala ceo region.

Figure 48. Block 18 in famous *Politika* newspaper (screenshot)[205] Figure 49. Block 18 in *Danas* newspaper (screenshot)[206]

203 Ana Graovac, Phone Interview, Belgrade, June/July 2019.

204 Vanja Panic, Phone Interview, Belgrade, July/August 2019.

205 "Block 18 - a new city like NewYork, Paris or Singapore", translated title fron the article: Daliborka Mučibabić, "Blok 18 - novi siti nalik na Njujork, Pariz ili Singapur," Politika, January 16, 2018, xx, http://www.politika.rs/sr/clanak/420402/Blok-18-novi-siti-nalik-na-Njujork-Pariz-ili-Singapur.

206 " A nonexhisting Russian investment fund is building "Belgrade Waterfront 2", translated title from: Miša Brkić, "Nepostojeći ruski investicioni fond gradi "Beograd na vodi 2"," Danas, January 21, 2018, xx, https://www.danas.rs/dijalog/licni-stavovi/nepostojeci-ruski-investicioni-fond-gradi-beograd-na-vodi-2/.

4.1.6 Block 18, Belgrade – planning regulations and zoning laws

The Block 18 location is regulated through three urban plans and one plan preview based on the results of the latest urban-architectural competition from 2016. As the latest Plan of Detailed Regulation is not yet fully operational, the parameters and indicators from the Plan of General Regulation still apply, and they were the basis for the brief of the mentioned competition. The parameters given by the Plan of general regulation are ambitious, high for Belgrade but this location seem to have appropriate capacities. Of course, the urban parameters are not nearly close to those of New York and Singapore.

Capacity :
Total land area: 46.8 Ha (468 000m2)
Traffic areas: 7 Ha
Public areas, buildings and open areas: 9 Ha
Mixed use city center: 17.5 Ha (175 000m2)

Projected population:
Inhabitants 373 / ha, users 670/ ha , Housing units 4300 /
Number of inhabitants 12470
Number of workplaces 10630

Density parameters:
FAR = 4 (max 5 / corner plots)
Site occupancy MAX 60%
Highrise - allowed

Program:
51% Office and Retail 49% Housing
(possible to balance 0-80% / 20-100%)[207]

Real estate value (estimation):
Housing 343 000 m2 and Office/R 357 000 m2. (rough.est)
Housing price avg. 2500 eur/m2 and Office/Retail price avg. 3500 eur/m2 (rough.est)
Housing real estate value: 857 million Eur
Office/ retail real sale value: 1 249 million Eur
Total potential real estate value: ~2.2 Billion Eur

207 Direkcija za gradjevinsko zemljište i izgradnju Beograda u saradnji sa Udruženjem Arhitekata Srbije, PROGRAM za otvoreni anketni jednostepeni anonimni urbanističko-arhitektonski konkurs za Blok 18 u Novom Beogradu, (Belgrade: City of Belgrade, 2016), http://dab.rs/images/21.2.%20-%20Program%20konkursa%20K-1-16.pdf.

4.1.7 Critical evaluation of the actual urban plans for block 18 (winning competition entries, preview of a plan of detailed regulation - PDR)

The competition in 2016 was won by a team of three Belgrade based architects: Vanja Panic, Marko Veskovic, and Aleksandar Knezevic, who proposed a clear orthogonal matrix of about 30 perimeter (closed or semi-open) blocks, with buildings reaching up to 30 m with few high-rises at the outer boundaries of the location. There is a clear programmatic, almost Corbusiean subdivision in the master plan, housing, work, and public buildings, each in their own zone and blocks (Figure 50, Figure 51).

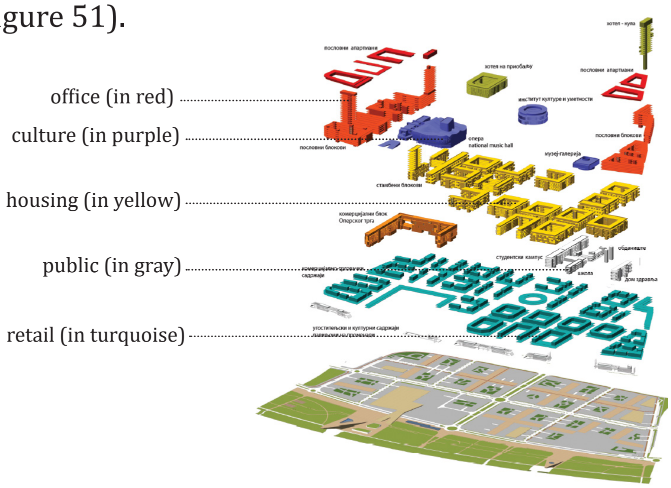


Figure 50. Winning competition scheme - exploded diagram of program distribution[208]

Figure 51. An aerial perspective of the winning proposal[209]

Extracts from the competitions jury report:
- well positioned and dimensioned central axis
- well positioned and clear border street towards waterfront area
- well dimensioned street profiles and sizes of the blocks
- proposed height of buildings corresponds with street profiles, medium height under 30m
- subdivision enables phased construction[210]

208 A complete project documentation of the winning competition proposal is acquired from the author (Vanja Panić) for the purpose of this research, on 24.09.2019.

209 Ibid,.

210 Direkcija za gradjevinsko zemljište i izgradnju Beograda, Katalog radova - otvoreni anketni jednostepeni anonimni urbanističko-arhitektonski konkurs za Blok 18 u Novom Beogradu, (Belgrade: City of Belgrade, 2016), https://www.beoland.com/aktuelnostidgz/273-rezultati-urbanisticko-arhitektonskog-konkursa-blok-18.html.

4.1.8 Critical quantitative analysis about the typical city block in the Block 18

The winning competition project proposed a matrix of 30 blocks typically dimensioned 65x65 m. The brief quantitative analysis will try to evaluate the proposed typical block in terms of its spatial efficiency and urban quality but also topics of functional neutrality and mixed-use ability.

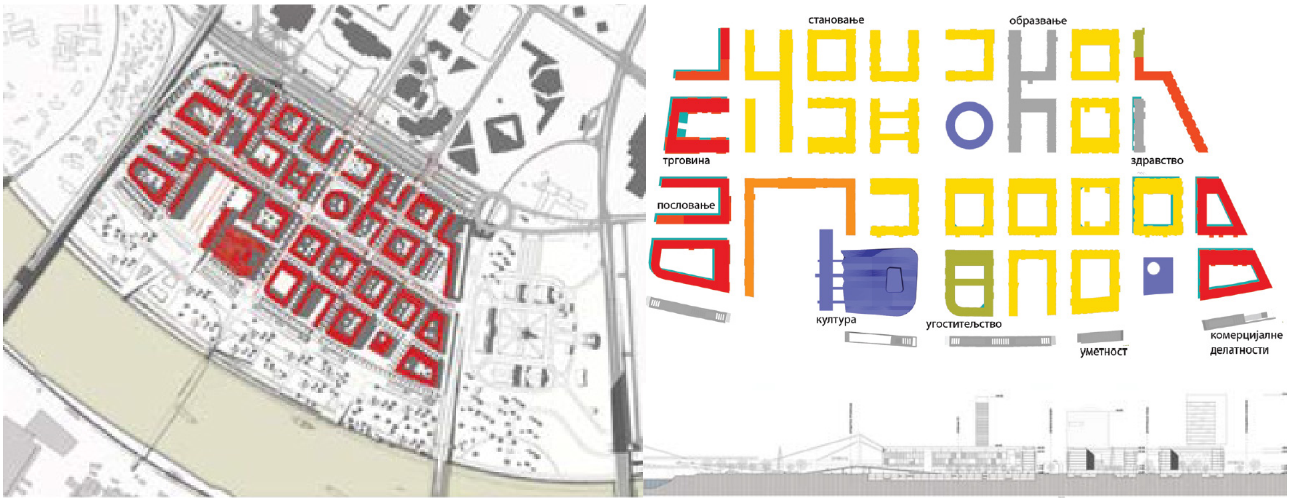


Figure 52. Situation, program layout and transversal section of the urban proposal[211]

The proposed dimensions of a typical block for the zone of a mixed-use city center seems quite small when compared to the neighboring blocks in New Belgrade, so a question can be raised whether the dimensioning of the current ownership matrix and current streets have influenced the dimensioning of the block (Diagram 24).
It can be speculated that this decision to partially adopt the current matrix was influenced by the area's ownership status and the fact that the legal procedures and land acquirement can be simplified if a similar matrix is adopted. The current matrix has 70 m deep and 20 m wide plots facing two streets on its narrow side. The proposal adopted the matrix with three transversal streets and merged the riverside plots together with the last river-facing row of properties, the streets have been given proper profile capacity, but the matrix remained simple and alike to the existing one.

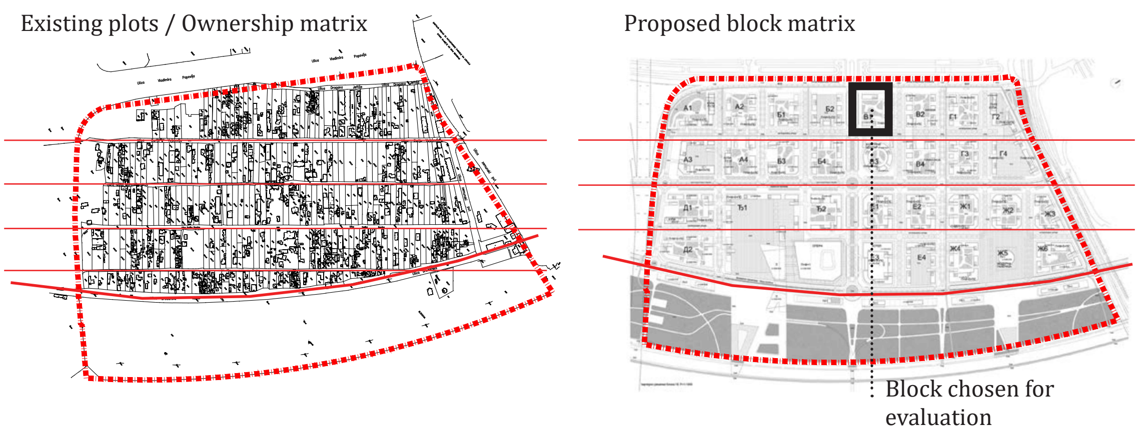


Diagram 24. A comparison of the existing and proposed street matrix and block size

211 A complete project documentation of the winning competition proposal is acquired from the author (Vanja Panić) for the purpose of this research, on 24.09.2019.

• Program:

The typical block envisioned as a compact perimeter block closed or semi closed is a typical solution for the masterplan, it is interesting that the same dimensioned typologies are proposed for different programs and are envisioned as mono-functional with only ground level reserved for commercial use with small and limited capacities due to dense cores. However this strategy does not comply to the planning guidelines which suggests <u>60:40%</u> ratio of housing, which cannot be achieved within this block due to the fact that office and retail programs could be situated only within the areas of ground levels, which doesn't leave enough program flexibility for developers and investors (Diagram 25).

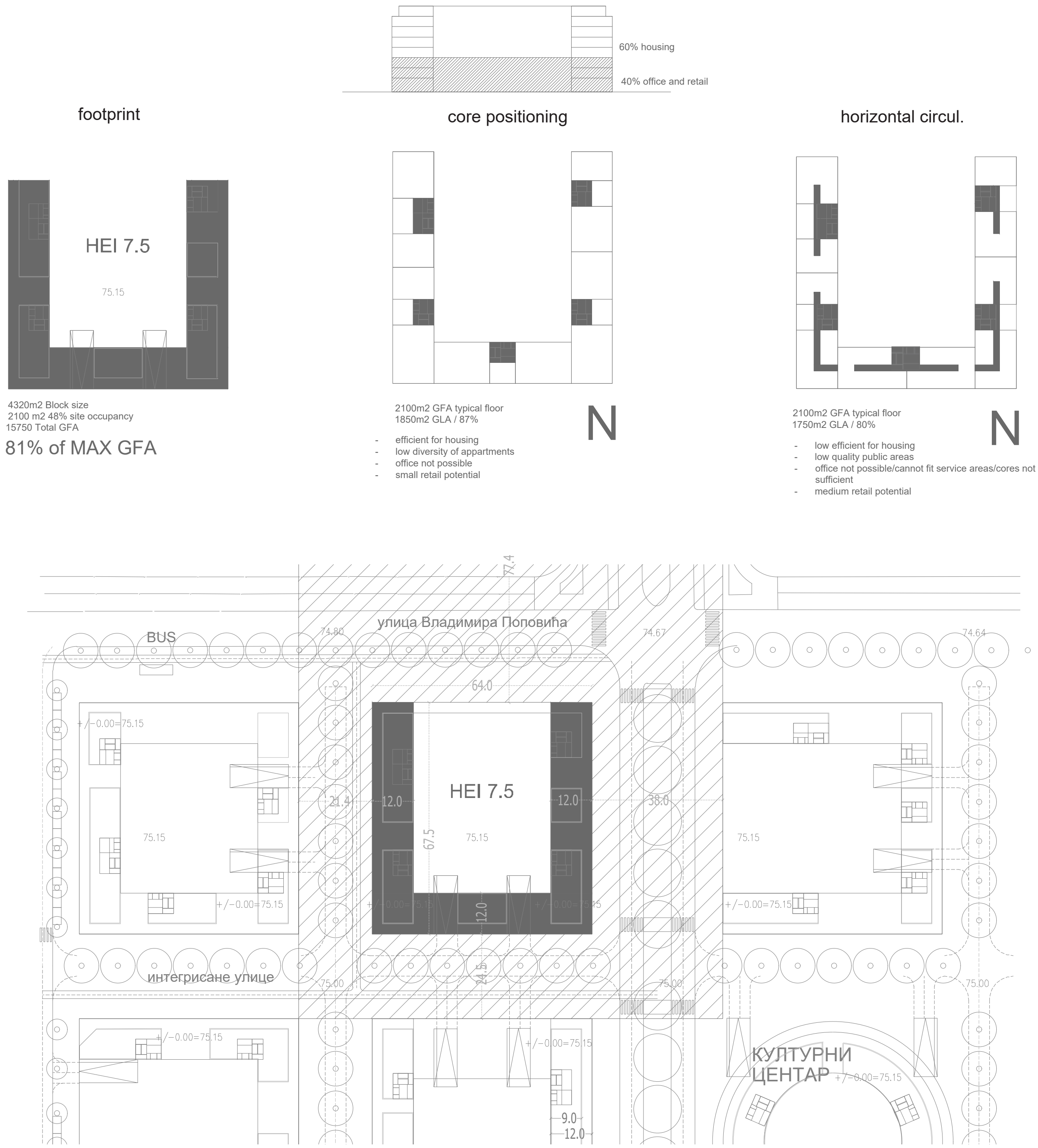


Diagram 25. Brief spatial efficiency analysis of a typical mixed use block

- Land value:

Having in mind the FAR index for the block and the land value no investor would build a semi open block limited to HEI 8, because this type of block achieves only 81% of the max GFA. So the perimeter block is the only remaining solution.

- Housing efficiency:

Both possible typologies in a HEI 8 and 12m thick housing slab, perimeter block don't achieve a high level of efficiency in plan at most 87% GLA/GFA efficiency can be achieved with very few cores and too large apartments. Another option available with central corridor offers more diversity in terms of apartment sizing but having long corridors and majority of single oriented apartments qualifies the development suitable social housing. Unfortunately this option results in reducing GLA/GFA ratio to 75-80% which is not sufficient for housing, for social housing even less so developing this block would result paradoxically with expensive, unaffordable social housing on a premium location.

- The winning entry evaluation can be summarized with following points:

PROS:

-well dimensioned main traffic routes, central axises in both directions

- clear block matrix

CONS:

- Top down program distribution

- Homogeneous land use, mono-functional blocks may not attract investors to develop the location block by block, low retail potential

- Programmatically homogeneous blocks

- Enclosed low quality communal spaces not used intensively

- Limited number of possible typologies

- Typologies, under-dimensioned for such an expensive location, not spatially efficient (heights, slab thicknesses)

- Questionable dimensions of the proposed block matrix

- Boulevard along the river cuts out the waterfront

- Looking for the optimal block size

As the typical block size for the zone of a mixed use city center proves to be inefficient (based on the analysis in chapter 4.1.8), a quick comparative analysis is performed using the overview if the other proposals submitted for the same competitions in order to find the "optimal" block size which could be used in the search for a more efficient dimension solution following the similar concept of a clear block matrix.

WINNING ENTRY (01, Panić, Vesković, Knežević)

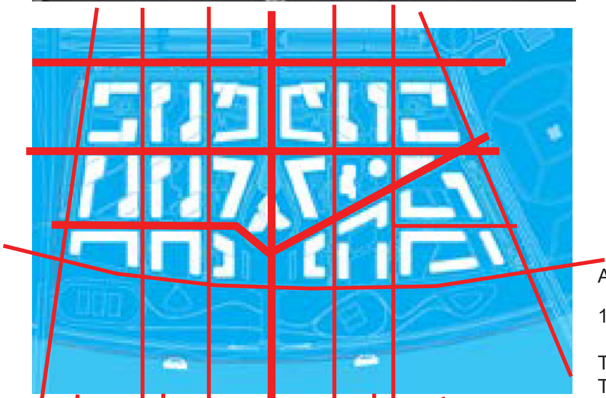
30 blocks / Typical block size 60x60m

Typical slab thickness 12m

AWARDED ENTRY (08, Stjepanović, Vujović)

12 blocks / Typical block size 160x160

Typical slab thickness 15- 20m



AWARDED ENTRY (Deka inženjering.do.o.)

18 blocks / Typical block size 90x120m

Typical slab thickness 20m
Tower plate size 35x35m

SHORTLISTED ENTRY (Damjanović, Vukosavljević, Čarnojević)

12 blocks / Typical block size 130x160m

Typical slab thickness 12-18m
Tower plate size 20x20, 20x40m

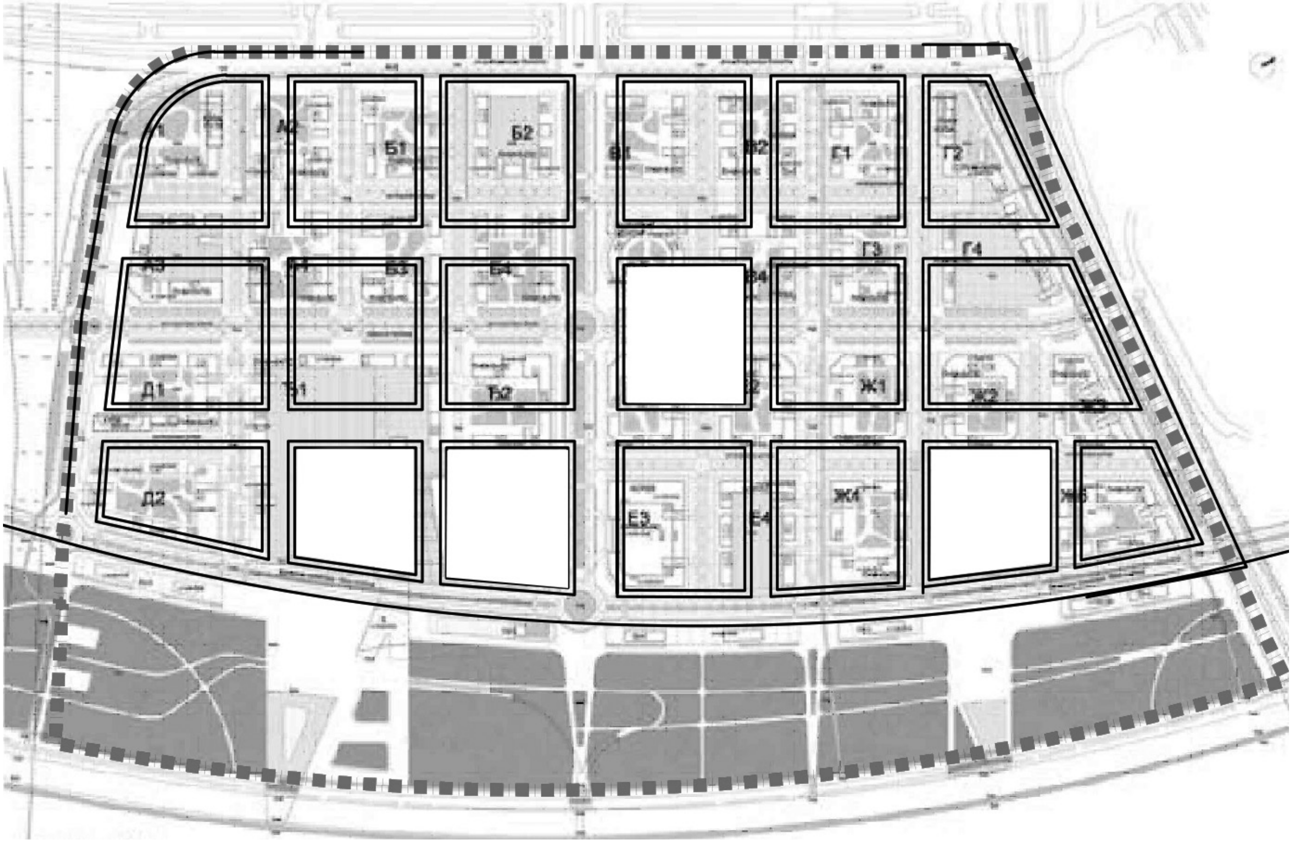


Diagram 27. Optimized block matrix to accommodate the mixed use developments, a matrix of 19 blocks is proposed (blocks in white remain reserved for public functions) based on the average size from the overview of competition entry (Diagram 26).

As previously elaborated, several awarded entries provide different block sizes within the same urban density input from the brief based on the parameters from the plan of general regulation. They are merged in a synthesized proposal with an average number of 18–19 blocks, based on the main traffic principles from the winning entry – the directionality of one primary street towards the river, surrounded by primary streets on the borders of the area, and adding two more transversal primary streets which will enable more moments of distance to the inside zone of the area. Public buildings proposed by the winner are kept in similar positions as proposed. In this synthesized solution to be further elaborated on, the typical block size is 105x120 m, aimed to achieve a more optimal land use which will later be demonstrated through the quantitative analysis.

212 Background images used from: Direkcija za gradjevinsko zemljište i izgradnju Beograda, Katalog radova - otvoreni anketni jednostepeni anonimni urbanističko-arhitektonski konkurs za Blok 18 u Novom Beogradu, (Belgrade: City of Belgrade, 2016), https://www.beoland.com/aktuelnostidgz/273-rezultati-urbanisticko-arhitektonskog-konkursa-blok-18.html.

4.1.9 Hierarchy of the urban plans and comparative analysis of planned capacities

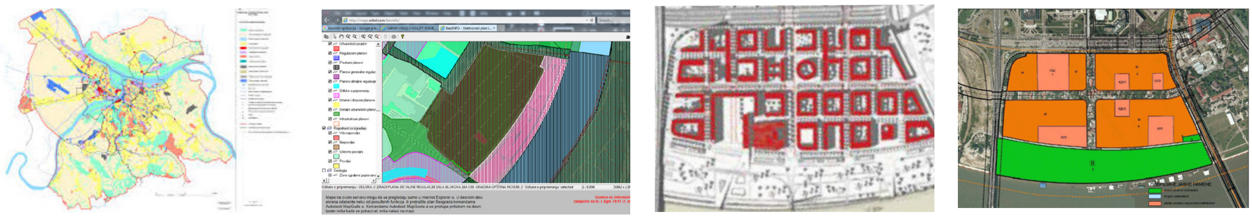


Diagram 28. Hierarchy of the urban plans

There are four principal stages of planning for the cities in Serbia, GUP (General Urban Plan) – a strategic document developed for a 20-year period, the first operational plan is PGR (Plan of General Regulation), for an important city area like Block 18 urban competitions are obligatory as a base for a most operational PDR (Plan of Detailed Regulation). A capacity overview of the last three planning stages will be performed to understand the way that projected location capacities change and to anticipate the possible reasons for that..

- Capacities - Plan of general regulation PGR (from the competition brief, Table 12)

In the table below we can see the capacities of housing and commercial functions for a mixed use city centers envisioned by this plan (700 000m2) and the urban parameters (FAR 5, COV 60%, HEI - unlimited, H 0-80%, O+R 20-100%, 10% green).

Potential real estate value (PGR):

H 343 000 m2 and O/R 357 000 m2.
H avg. 2500 eur/m2 and O/R 3500 eur/m2 (rough est.)
Housing real estate value: 857 million Eur
Office/ retail real sale value: 1 249 million Eur
Total potential real estate value: ~2.2 Billion Eur

Table 12. Capacities of Block 18, suggested by the competition brief[213]

ПРЕГЛЕД КАПАЦИТЕТА ИЗГРАДЊЕ У ОКВИРУ КОНКУРСНОГ ОБУХВАТА ЗА БЛОК 18 - ПРИМЕР

УРБАНИСТИЧКИ ПАРАМЕТРИ	**ПОСТОЈЕЋЕ СТАЊЕ**	**ПЛАНИРАНО СТАЊЕ** (оријентационо)
Конкурсни обухват **Land surface**	46.8 ha	**46.8 ha**
БРГП становања **Housing** **(повећањем учешћа становања расте потреба за капацитетима социјалне инфраструктуре)**	83190 m^2	343 000 m^2 **700 000 M2**
БРГП комерцијалних и пословних садржаја **Office & Retail**		357 000 m^2
БРГП јавних садржаја	0	50 000m^2
БРГП укупно		**750 000 m^2**
бр. стамбених јединица (просечан стан 80 m^2, 2.9 становника/стану)	630	4 300
бр. запослених (повећањем учешћа становања опада број запослених)		10 630

бр. становника	2 140	**12 470**
зап. + стан.		**23 100**
индекс изграђености		4.0 за зону мешовитог градског центра
Комерцијлани и пословни садржаји / становање		51% : 49%
густина становника	64 st/ha	373 st/ha
густина корисника простора	63 st/ha	670 st+zap/ha

Урбанистички показатељи за парцеле и објекте	**Зона центра Новог Београда**	
Максимални индекс изграђености (И)	5	**FAR 5**
Максимални степен заузетости (З)	60%	**COV 60%**
Максимална висина венца и спратност	није ограничена	**HEI - unlimit.**
Однос становања и комерцијалних и пословних садржаја у зони мешовитог градског цента	0 - 80%: 20% - 100%	**H 0-80%** **O+R 20-100%**

213 Direkcija za gradjevinsko zemljište i izgradnju Beograda u saradnji sa Udruženjem Arhitekata Srbije, PROGRAM za otvoreni anketni jednostepeni anonimni urbanističko-arhitektonski konkurs za Blok 18 u Novom Beogradu, (Belgrade: City of Belgrade, 2016), http://dab.rs/images/21.2.%20-%20Program%20konkursa%20K-1-16.pdf., 18-19.

- Achieved capacities / winning competition entry

In the table below we can see the achieved capacities of the mixed use city centers in the winning competition entry. The surface of the mixed use city center decreased significantly for 200 000m2 to the final GFA of 500 000m2. According to the summary of the competition from the Plan of Detailed Regulation 50% of all the land is dedicated to traffic (streets and parkings) which is a lot and probably one of the main reasons for reducing the overall GFA (Table 13).

<u>Potential real estate value (Competition):</u>
Mixed use city center GFA 500 000 m2.
Average 3000 eur/m2 (rough est.)
Total potential real estate value: ~1.5 Billion Eur
Real estate value reduced (comparing to PGR): 700 000 000 Eur

Table 13. Achieved capacities of the winning proposal[214]

ratio of public vs. other functions, 50% off all are traffic areas
- однос површина јавне и остале намене, блок 18 = 60% : 40% (од чега око 50% саобраћај)
- однос стамбене и пословне намене = 50% : 50% **ratio of housing vs. (office+ retail)**
- БРГП мешовитог градског центра 500,000 m^2 **surface area of mixed use city center**
- БРГП јавних објеката 67,700 m^2
- број становника: 9,161
- број станова: 3,159
- величина комплекса јавних служби: ОШ+КДУ=0.43 ha, СШ=0.46 ha
- зелене површине: јавна површина приобалног парка + унутрашњост блокова

Figure 53. Aerial perspective of the winning proposal 2[215]

214 Ana Graovac and Ana Lazovic, Plan detaljnje regulacije bloka 18 - Elaborat za rani javni uvid, (Belgrade: Direkcija za gradjevinsko zemljiste i izgradnju beograda, 2017), http://www.beograd.rs/lat/gradski-oglasi-konkursi-i-tenderi/1732006-rani-javni-uvid-u-plan-detaljne-regulacije-bloka-18/,13.
215 A complete project documentation of the winning competition proposal is acquired from the author (Vanja Panić) for the purpose of this research, on 24.09.2019

- Achieved capacities /Early preview plan of detailed regulation (PDR)

In the table below we can see the achieved capacities of the mixed use city centers after the competition in the first preview of the Plan of Detailed regulation. Compact blocks are envisioned. The overall surface of the mixed use city center decreased even more significantly for another 110 000m2 to the final GFA of 390 000m2. Urban parameters are also decreased (FAR 3, COV 60%, HEI - 7.5 /22m, H 0-60%, O+R 40-100%, 20% green, high-rise may be allowed after studies in particular areas) (Table 14).

<u>Potential real estate value (PDR Plan of Detailed Regulation):</u>

Mixed use city center GFA 390 000 m2.
Average 3000 eur/m2 (rough est.)
Total potential real estate value: ~1.17 Billion Eur

Real estate value reduced (comparing to PGR): 1 030 000 000 Eur

Table 14. Urban capacities suggested by the Plan of Detailed Regulation(2016)[216]

7.1.2. Површине остале намене

Планиране површине за мешовите градске центре - М

Планирана површина за мешовите градске центре износи око 20.15 ha.
Планира се потпуна трансформација постојећих објеката и катастарске парцелације.
По типологији ова зона припада компактним блоковима.
Однос стамбене и комерцијалне намене: макс 60% : мин. 40%.
Максимални индекс заузетости на парцели/блоку: 60 %
Максимална спратност објеката: П+6+Пс
Укупна процењена БРГП: макс. 390,000 m^2
Минимални проценат зеленила на парцели/блоку: 20%
Потребе за паркирањем неопходно је обезбедити на парцели/блоку.

	ПОСТОЈЕЋЕ (оријентационо)	**УКУПНО ПЛАНИРАНО** (пост.+ново) (оријентационо)
површина плана	46.85ha	46.85 ha
БРГП мешовитих градских центара	58,400 m^2	390,000 m^2 (390 000m2)
БРГП објеката и комплекса јавних служби	0 m^2	40,000 m^2
БРГП укупно	**58,400 m^2**	**430,000 m^2**
бр. станова	664	2,987
бр. становника	1836	8,663

Табела процењене планиране БРГП

PDR plan ПЛАН ДЕТАЉНЕ РЕГУЛАЦИЈЕ					PGR plan ПЛАН ВИШЕГ РЕДА			
Намена	Зона	FAR/COV "И" / "З" индекс изграђ. / заузетости блока	HEI "С" макс. спратност / "Н" макс. висина	Green мин. % зелених незастрт. површина	FAR "И" макс. индекс изграђ. парцеле	COV "З" макс. индекс заузетости парцеле	HEI "С" макс. спратност	Green мин. % незастрт. зелених површина
Мешовити градски центар	М	3.0/60%*	П+6+Пс** /22 m	20%***	5.0	60%	П+8+Пк (П+12+Пс	10%
Површине за објекте и комплексе јавних служби	КДУ	0.38/30%	П+1	40%	0.42	44%	П+1	22%
	ОШ	0.3	П+2	20%	0.33	-	П+2	-
	СЗЗ	0.6	П+2	30%	1.0 – 2.0	50%-70%	П+2 -П+4	30%
	КУ	0.2 – 1.3	П+1-П+2	25%	-	-	-	-

FAR 3
COV 60%
HEI - unlimit.
H 0-60%
O+R 40-100%

Табела предложених основних урбанистичких параметара и параметара ПГРа

* Индекс изграђености и заузетости дефинисани су као просечни на нивоу блока, док на појединачним парцелама током даље планске разраде могу бити и различити.
** У овој фази израде плана максимална висина објеката у компактним блоковима мешовитог центра је сагледана као П+6+Пс, у току израде нацрта плана биће преиспитане локације за евентуалне високе објекте.

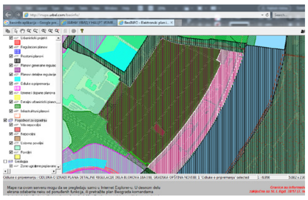
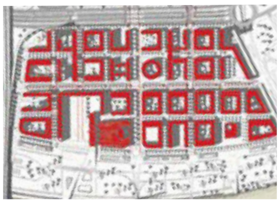
216 Ana Graovac and Ana Lazovic, Plan detaljnje regulacije bloka 18 - Elaborat za rani javni uvid, (Belgrade: Direkcija za gradjevinsko zemljiste i izgradnju beograda, 2017), http://www.beograd.rs/lat/gradski-oglasi-konkursi-i-tenderi/1732006-rani-javni-uvid-u-plan-detaljne-regulacije-bloka-18/,46-47.

- Comparative capacity analysis for different planning stages and possible consequences

Comparative capacity analysis shows a significant decrease of the overall GFA of the zone of mixed use city center of Block 18, followed with the decrease of urban parameters.
The reasons for the first decrease of GFA in the competition phase seems to be an inappropriate dimensioning of the blocks and proposing the wrong typologies for a mixed use city center, which resulted that almost 50% of the land is dedicated for traffic areas. This decrease of the land use could have been compensated by proposing high-rise buildings, but the zoning laws are a limiting factor and, so a separate high-rise study is obligatory but this studies is an insufficiently transparent processes.

As the capacities proposed in the competition were a guideline for the PDR Plan of Detailed Regulation, and the Urban department of Belgrade decided to decrease the GFA even more to 390 000m2 of the mixed use city center (with FAR 3), partially because of increase of obligated green space from 10 to 20% which makes sense, since it was initially very low. The rest is remains unclear since the share of areas for public buildings and social infrastructure actually decreased (Table 15).

Table 15. Urban parameters and capacity comparison within different planning stages

		
PLAN OF GENERAL REGULATION	COMPETITION PLAN	PLAN OF DETAILED REGULATION
GFA 700 000m2	GFA 500 000m2	GFA 390 000m2
FAR 5	FAR 5	FAR 3
COV 60%	COV 60%	COV 60%
HEI - unlimit.	HEI - 7.5	HEI - 7.5
H 0-80%	H 0-80%	H 0-60%
O+R 20-100%	O+R 20-100%	O+R 40-100%
GREEN 10%	GREEN 10%	GREEN 20%
REAL ESTATE VALUE: 2 200 000 000 EUR	REAL ESTATE VALUE: 1 500 000 000 EUR	REAL ESTATE VALUE: 1 170 000 000 EUR

Consequences are:

- decrease of mixed use city center GFA through planing phases
- decrease of FAR and HEI parameters
- decrease of projected real estate value
- proposed block matrix will be neglected, as it is not efficient and economically viable
- the only probable intervention will be building two boulevards with the location

- possible land and speculations and land price devaluation, the private property owners already know it since there are already sale announcements for land claiming that 9.5 levels are allowed to be built - which is impossible with current Plan of Detailed Regulation which allows 7.5 levels - potential investors will most probably ask for a new PDR plan for their particular micro locations - something called "investor urbanism" in and it remains publicly unclear under which conditions these "purchased" detailed plans get accepted or rejected (Figure 54).

What now? The solution which maximizes land use of the area may be the following: creating the urban infrastructures capacitated for the old high parameters, abandoning the compact low-rise block and densifying by allowing high-rise under transparent rules. Gaining high revenue from taxes and developing a high quality public spaces and social infrastructure.

Figure 54. Plot in block 18 for sale [217]

4.1.10 Examining the typological diversity, spatial efficiency and land use potentials of a typical block in different planning stages

This study aims to show what could be the alternatives to a closed (or semi open) perimeter proposed (in the winning competition entry) or to detail plan - PDR. Looking for the typological diversity, functional neutrality, and spatial efficiency, the three sizes of the block are examined together with their prospective urban parameters and including or excluding high-rise buildings (Table 16).

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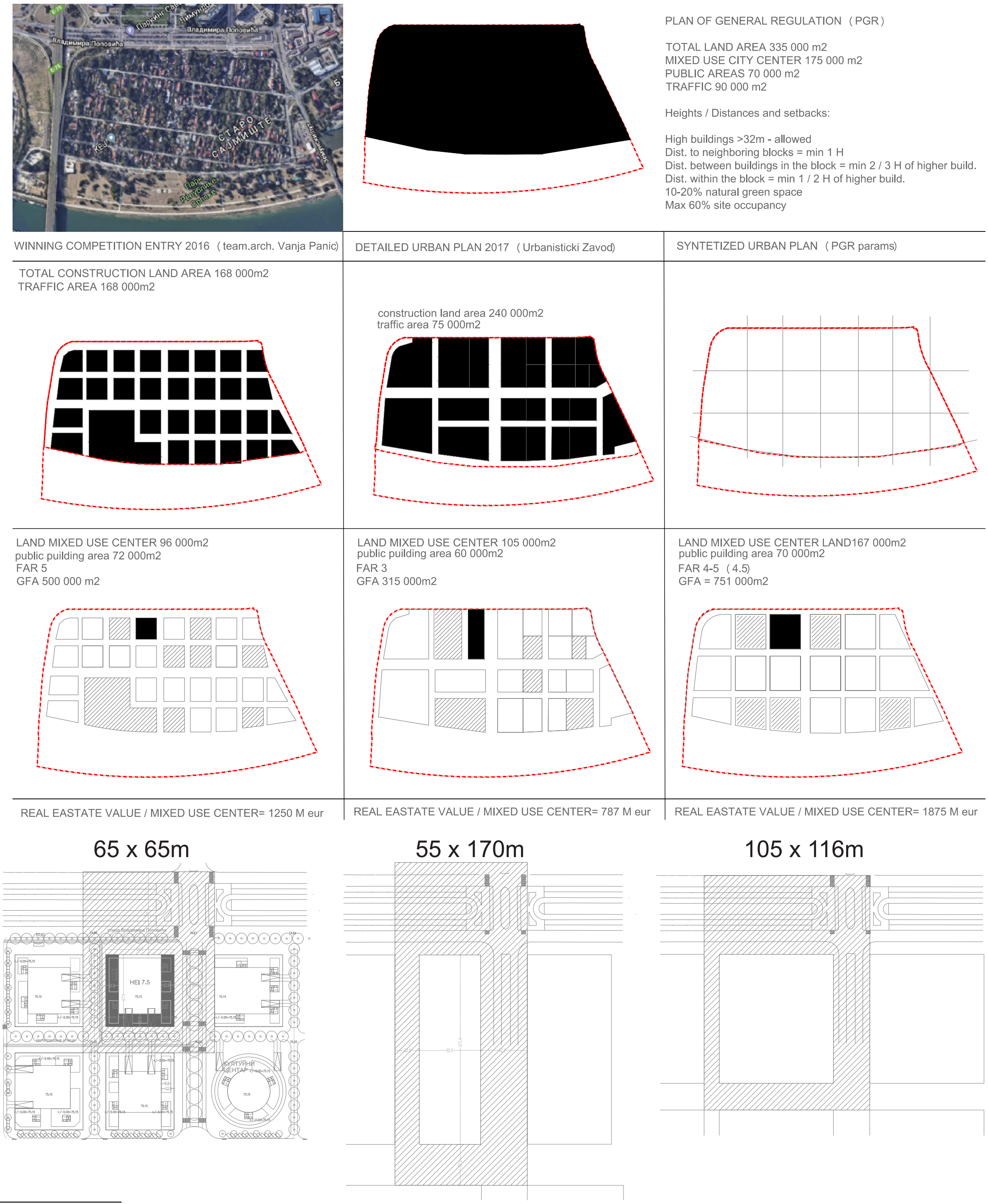
217 A screenshot from 2019 local real estate website. 900m2 plot in is offered for 1Mio Eur, while the description says it is possible to build 9.5 levels like indicated in the general plan PGR. (much more than the latest PDR plan actually allows).Image obtained from: "Plot in Block 18," HaloOglasi, 2019, https://www.halooglasi.com/nekretnine/prodaja-zemljista/beograd-novi-beograd-blok-18-staro-sajmiste.

The high-rise is allowed by the higher-ranked Plan of General Regulation, so potential investors could ask for creating a new Plan of Detailed Regulation for their particular block, which includes a study that could allow high-rise buildings (over 32 m.) Allowing high-rise buildings in a mixed-use city center could result in lower site occupancy and more open spaces, with higher quality and more accessible public spaces, which increase retail values on the ground levels and increase the overall land use.[218]

Table 16. Comparing the capacities of three options of block matrix and sizing: 1)Competition phase 2) Matrix based on PDR 3) Synthesized plan - 19 blocks (based on PGR)



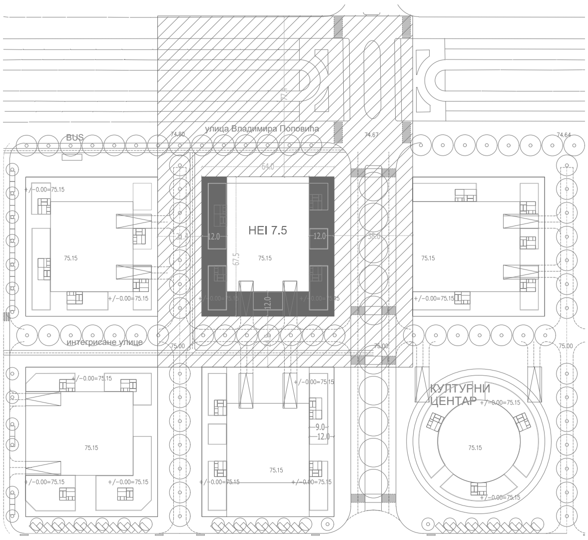
218 NOTE: The massing studies have been performed with the assumtion that maximum GFA should be developed within a block.

TYPICAL BLOCK - COMPARATIVE ANALYSIS / Implementation of efficient volume typologies (winning competition entry block)

** footprint dimensions are based on the repository of functionally neutral plans (Diagram 20)*

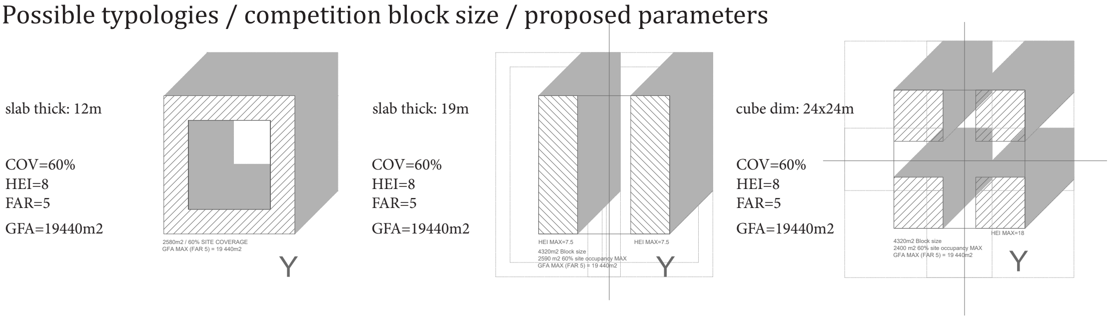
PROPOSED URBAN PARAMETERS (COMPETITION):
FAR 5 / Footprint max.60%
HEI 7 - 8
dist. to neighboring block = H
dist. within the block = 2/3 H of higher building.
10% green space

Typical block situation



The brief capacity analysis show the limitations and potentials of the typical block proposed on the competition. The proposed options of an semi open city block don't work, because of low GFA. While the perimeter block with 12m thick slab is inefficient in terms of GLA, offers a limited semi enclosed semipublic or no public space in the case of perimeter block. The only two remaining options that respect 7-8 HEI are deep slabs and cubes. Introducing high-rise brings diversity to the overall urban block and offers more public and green spaces.

Possible typologies / competition block size / proposed parameters



Alternative typologies / competition block size / PGR with highrise

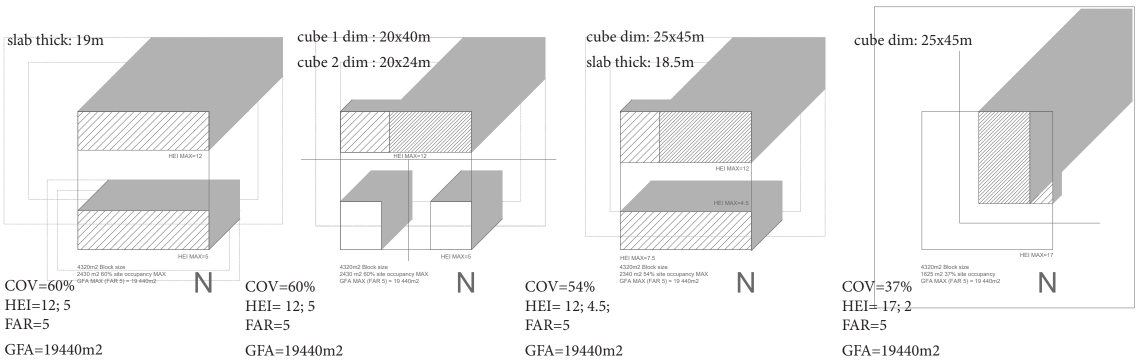


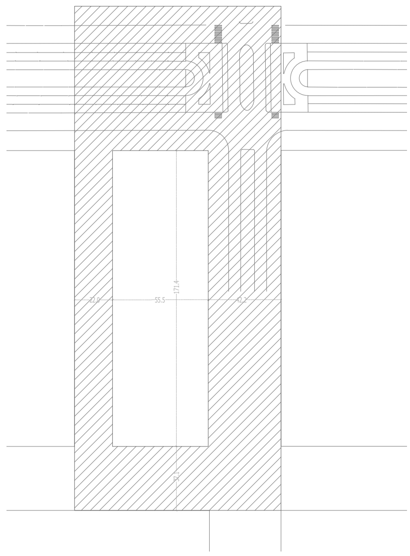
Diagram 29. Typical block - comparative analysis 1/3

TYPICAL BLOCK - COMPARATIVE ANALYSIS / Implementation of efficient volume typologies (PDR block)

** footprint dimensions are based on the repository of functionally neutral plans (Diagram 20)*

URBAN PARAMETERS (Plan of Detailed Regulation):
FAR 3 / Footprint max.60%
HEI 7 - 8
dist. to neighboring block = H
dist. within the block = 2/3 H of higher building.
20% green space

The anticipated block from the early preview Plan of Detailed regulation is dimensioned 55x170m, has reduced FAR to 3 and limits the HEI to 7.5. This suggests a compact city block, no public space with an inefficient slab thickness and low mixed use ability of the block. The alternative solutions neglect the suggestions for a closed block work with multiple smaller and deeper and efficient buildings but also smaller public spaces which may be more suitable for the areas of lower density. Allowing high-rise could bring urban qualities to the block, lower building footprint large public and green spaces.



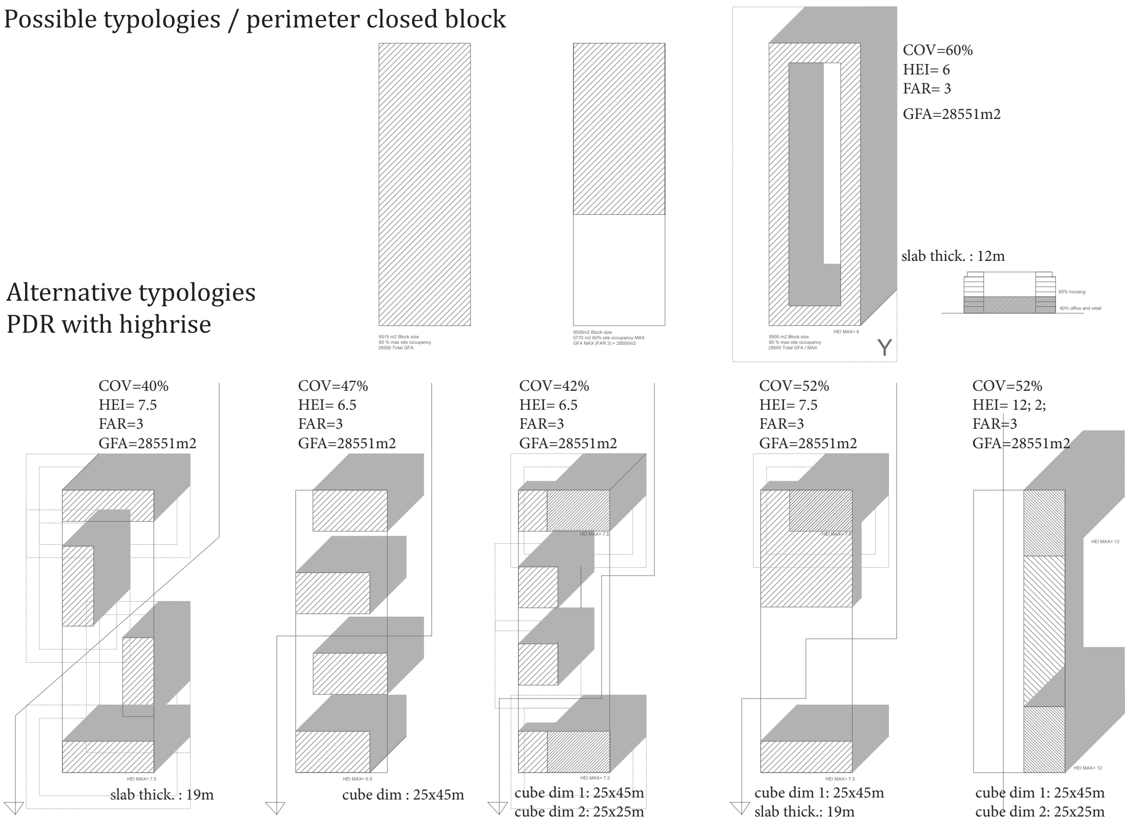
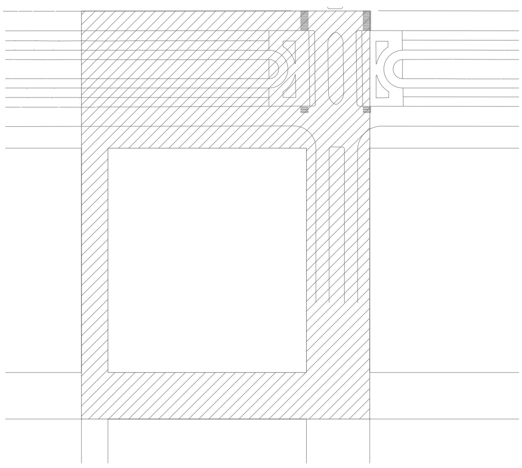


Diagram 30. Typical block - comparative analysis 2/3

TYPICAL BLOCK - COMPARATIVE ANALYSIS / Implementation of efficient volume typologies (PGR block)

** footprint dimensions are based on the repository of functionally neutral plans (Diagram 20)*

URBAN PARAMETERS (Plan of General regulation):
FAR 5 / Footprint max.60% , MAX GFA=51 500m2
HEI - not limited
dist. to neighboring block = H
dist. within the block = 2/3 H of higher building.
10% green space



The synthesized typical block dimensioned 105x120m, including high-rise buildings, offers a largest scope of typologies which can be implemented, including the options with a better quality of pubic spaces that enhance the circulation through the block and increase the % of open and green spaces and the retail potential of the area.

Possible typologies / synthesized block size / PGR with high-rise

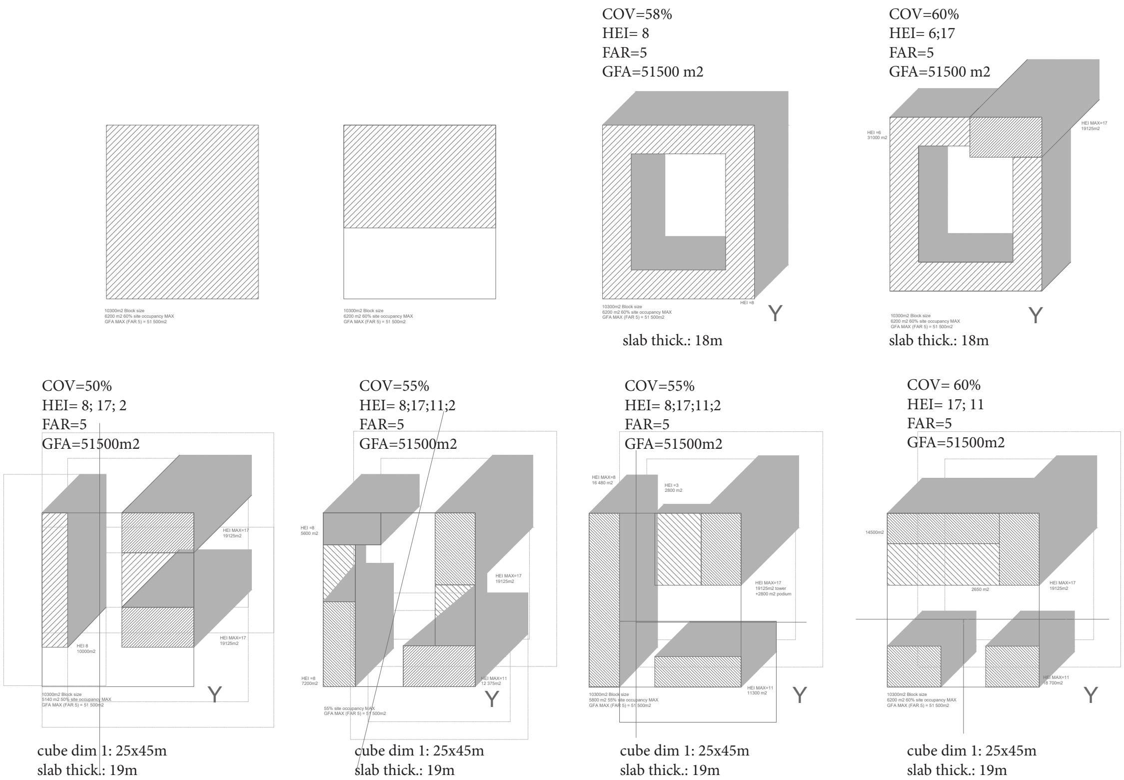


Diagram 31. Typical block - comparative analysis 3/3

The study implies the three principal conclusions (summarized through Diagram 32):

- if high-rise buildings are included there are more efficient options, high-rise are allowed by the higher ranked Plan of General Regulation, so potential investors could ask for a study that could allow high-rise buildings (over 32m, defined in Serbian law.) Allowing high-rise buildings in a mixed use city center could result with larger and more accessible public spaces, which increase a retail values on the ground levels and increase the overall land use.[219]

- the larger block size offer larger degree of typological diversity and therefore a more mixed use city block configuration

- as the third block based on the initial PGR parameters with FAR 5 shows the largest typological diversity, it will be chosen for further demonstration of the urban automation process

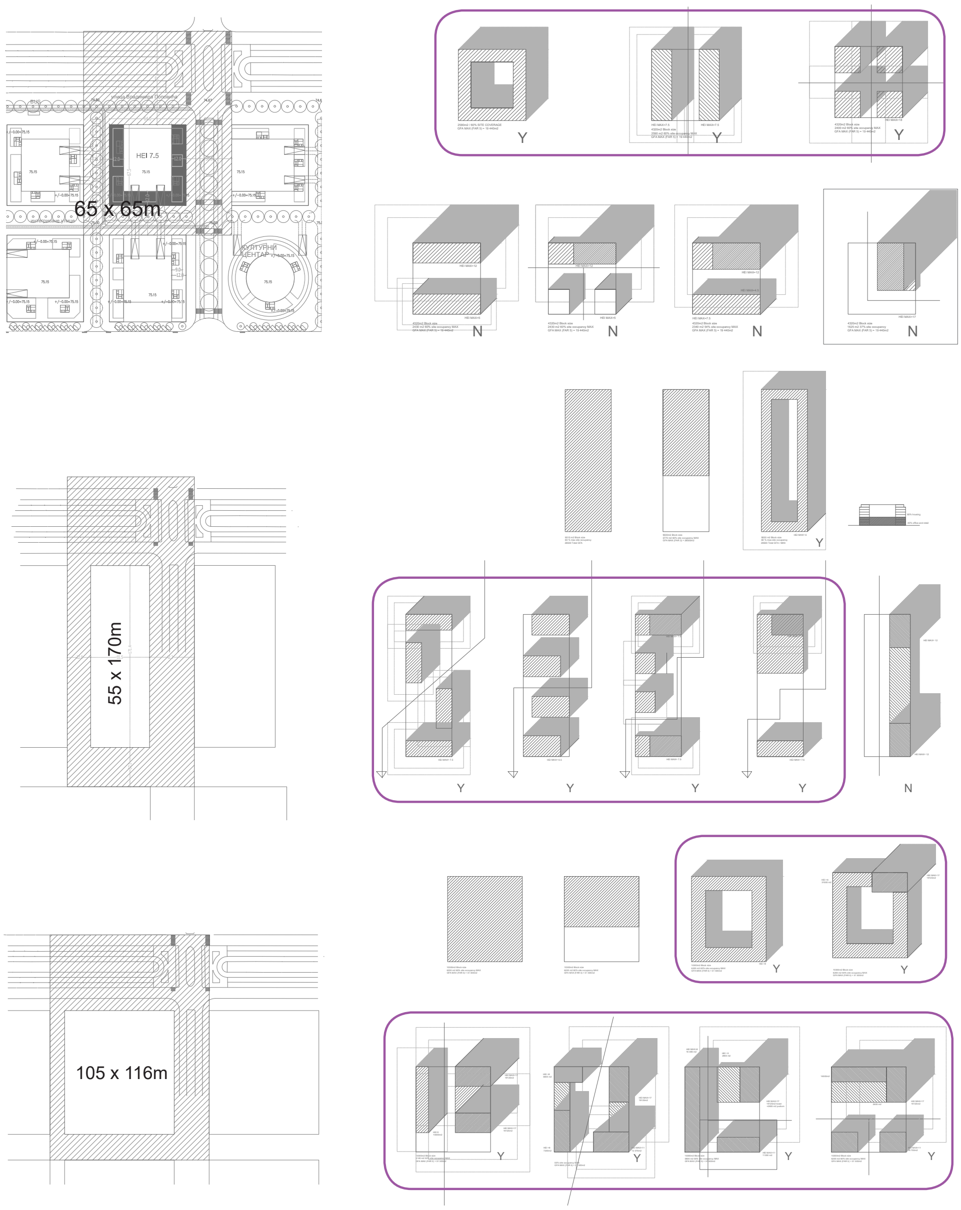


Diagram 32. Typical block – comparative analysis: overview of feasible massing options

219 NOTE: The massing studies have been performed with the assumption that maximum GFA should be developed within a block.

4.2. URBAN AUTOMATION TOOL - DEMONSTRATION/ DESIGN & EVALUATION ALGORITHM SEQUENCES - (BLOCK 18)

4.2.1 Urban Automation Tool - core component sequences

The previously elaborated urban massing capacity analysis (performed manually) is a actually a first step of the urban automation tool which can be used to generate and the massing studies using a repository of spatially efficient and functionally neutral typical plans developed for the urban context of mixed use city centers. A *Grasshopper* script has been developed to support and automate some of the steps. (Which are operational segments of UAT (Phase 2 - 3, Diagram 21, Chapter 3)

- **STEP 1** - AUTOMATED / Incorporates the locally specific zoning laws by creating a boundary - a virtual cage of setbacks, generated depending on the distances to neighboring blocks. <u>Observations:</u> Zoning law data as a fixed category could be automatically visualized for the newly defined urban plans, but a problematic point that both the laws and the algorithm automates them by defining spatial boundaries don't give enough autonomy for the individual development of the blocks. For example corner plots can have FAR increased 15% to achieve more GFA than the other but there is no clear direction how this is accomplished, either by enlarging site coverage or enlarging HEI index and allowing more levels (Diagram 33).

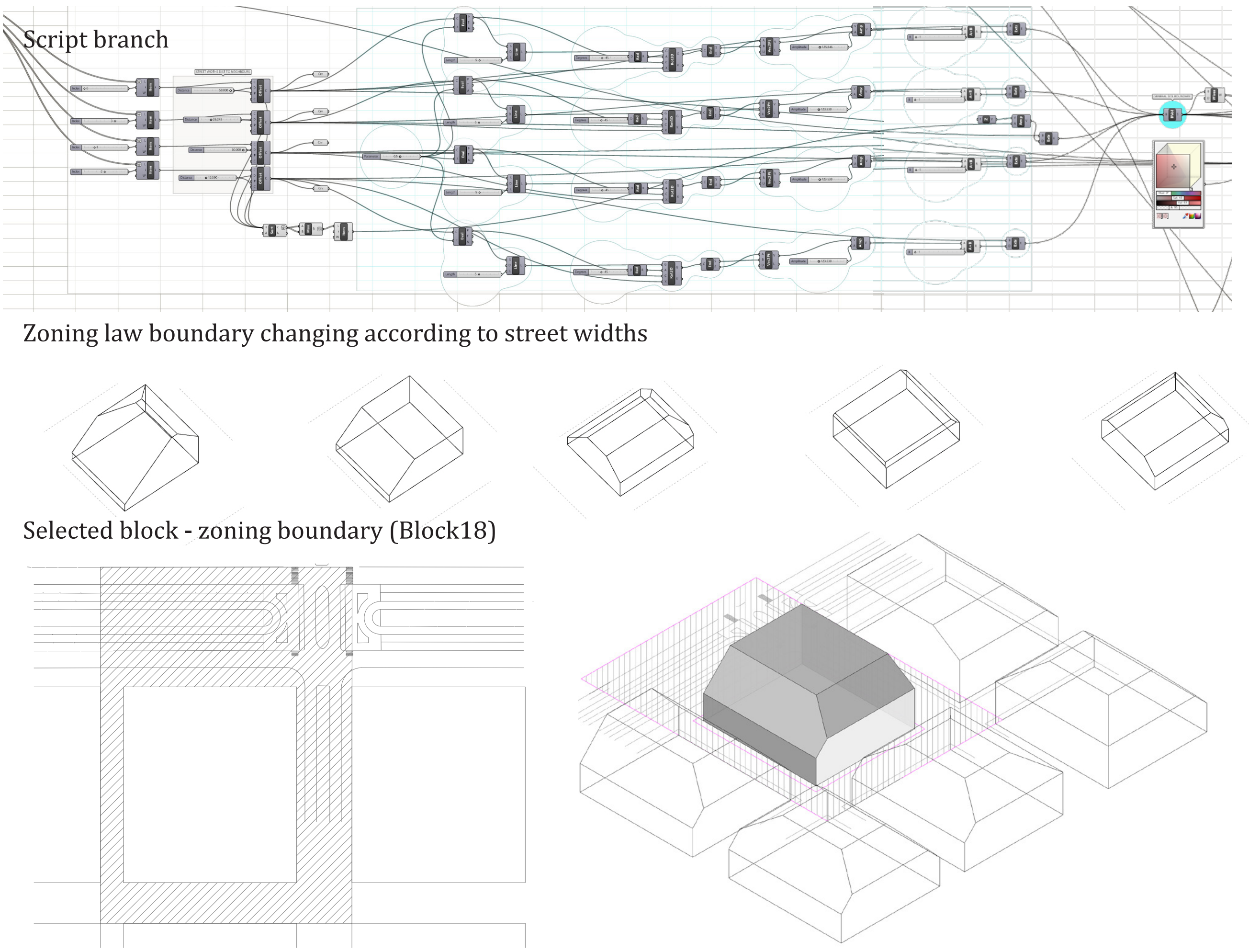


Diagram 33. *Grasshopper* script branch - incorporating the zoning laws to generate a volumetric boundary for a chosen block

- **STEP 2** - GENERATED & SELECTED (supervised machine learning) / The process of generating a set of massing configurations within previously generated zoning law boundary showed that there is a limited number of viable typologically determined massing options. The selection process which follows the generative design could be automated and be based on quantitative criteria such as GLA/GFA, % green space, compactness, etc. But, the complete evaluation should also include the qualitative criteria and relate with the quantitative; therefore, a degree of human interaction is necessary, which could possibly be recorded and applied using supervised machine learning techniques. Three options are selected for further evaluation based on their typological diversity (A=perimeter block – compact, B=two dominant high-rises and one slab – homogeneous, C=open block with mixed typologies high-rise and low-rise – heterogeneous (Diagram 34)).

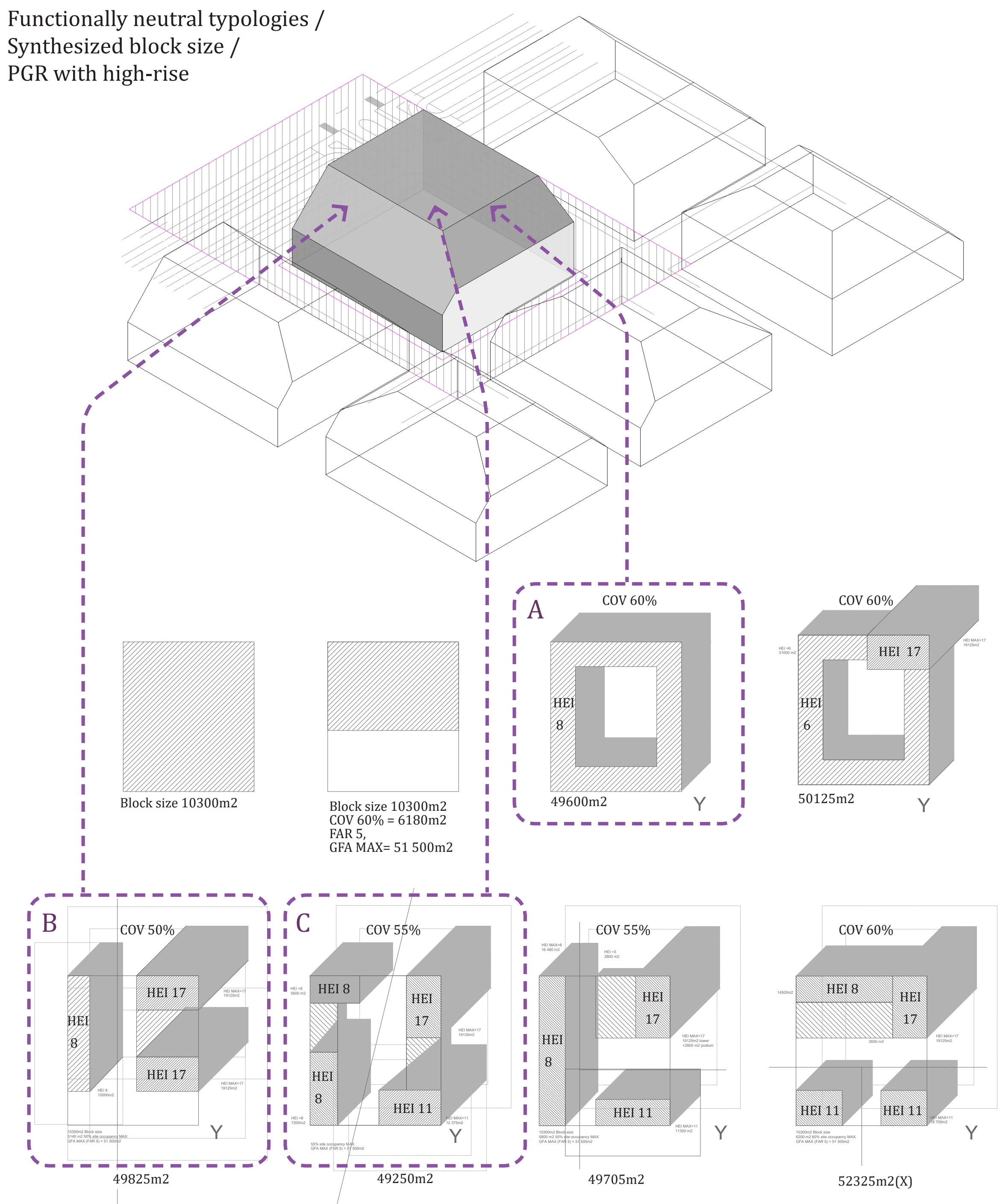


Diagram 34. Selection of desirable massing options for further analysis

- **STEP 3** - PROGRAMMING – (anticipated & user-defined, supervised machine learning) / This step deals with programming within the block massing options; program distribution can happen on two levels: 1) mono-functional and mixed, 2) rental or sales. Again a degree of human interaction is necessary, which could possibly be recorded and applied using supervised machine learning techniques. This process of selection is exemplified with the three massing options: compact, homogeneous and heterogeneous, each of them zoned according to the positions towards the main streets, but also to show the possible different degrees of program flexibility and mixed-use (Diagram 35).

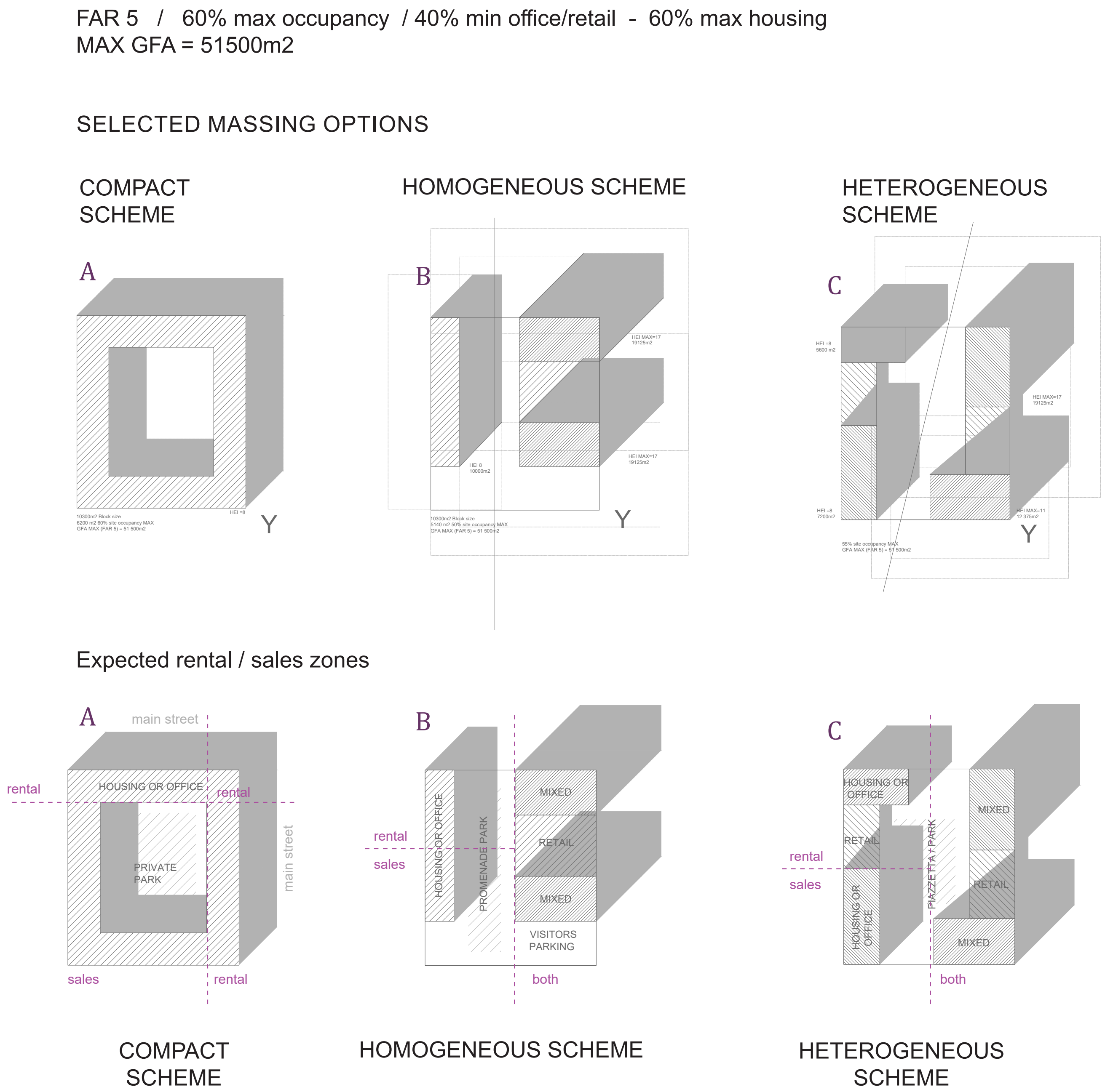
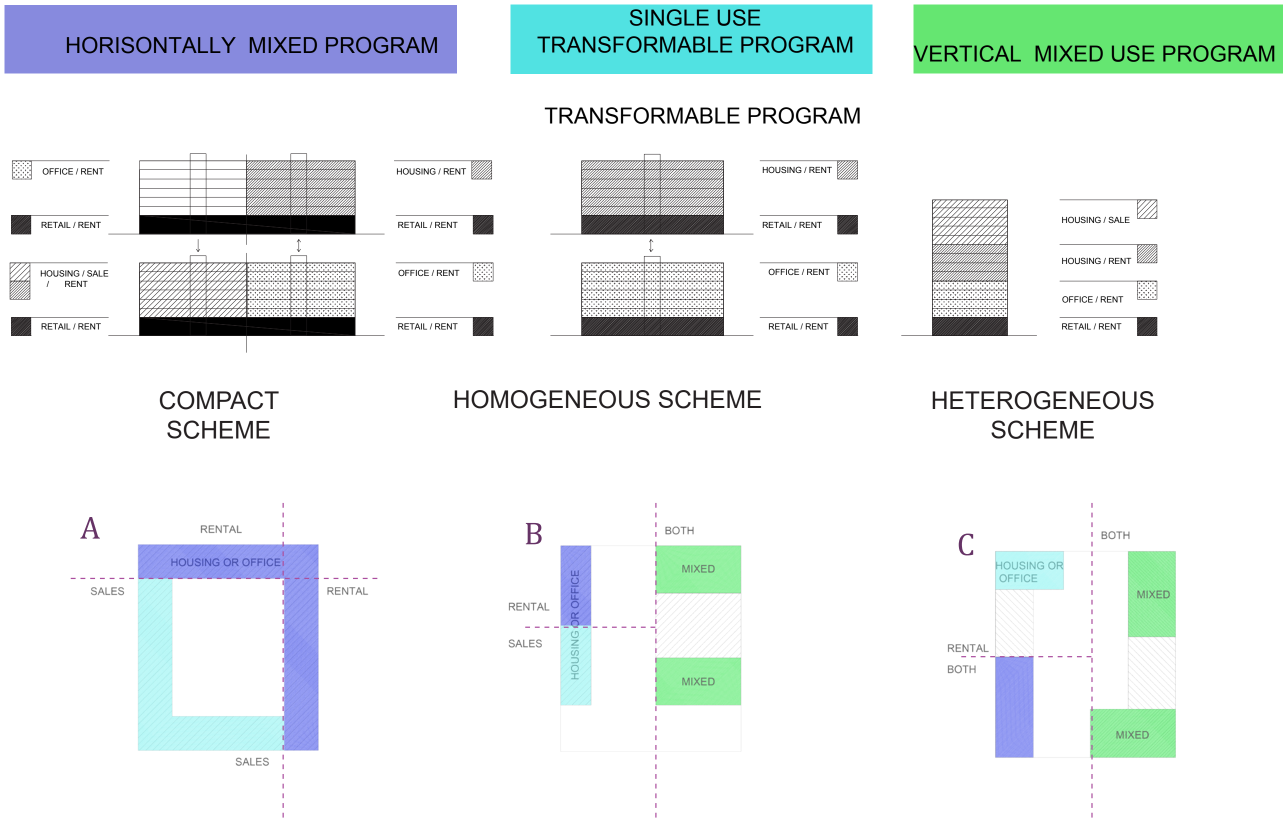


Diagram 35. Programming the chosen massing options according to the urban context

- **STEP 4** - CHOOSING THE VOLUMETRIC CONFIGURATION – (user-defined) / Based on the chosen massing solution, the programmatic distribution can be anticipated according to the zoning laws and interests of the users or developers. According to assumed the real estate strategy and desired program mix, this step elaborates on the massing options that can accommodate 50% housing and 50% retail+office programs. Option C is chosen for further elaboration as the most typologically diverse and heterogeneous (Diagram 36).

Mixed use principles



NOTE: Rental and sale zoning is determined by the proximity of the highly intensive traffic routes, as well as the program distribution meaning that more permanent housing program will be located in the calm zones within the block.

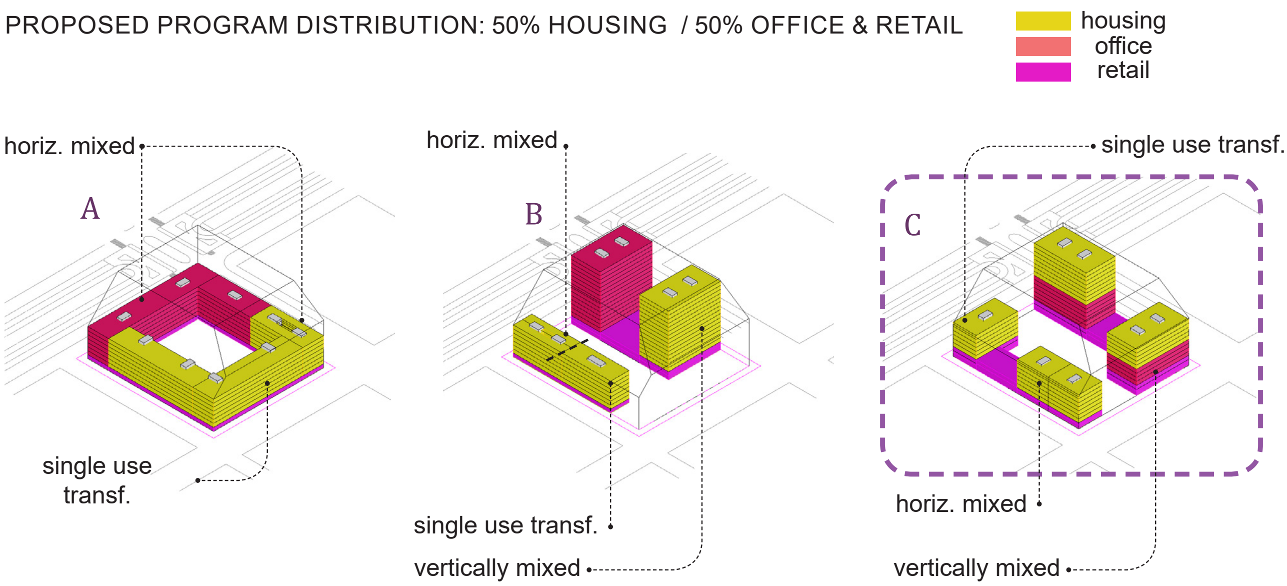


Diagram 36. Choosing the type and degree of mixed program within massing options

- **STEP 5** - APPLYING THE FUNCTIONALLY NEUTRAL AND SPATIALLY EFFICIENT TYPICAL PLANS – (automated) / Based on the building proportions (A x B x H), the algorithm calls and applies the infrastructural layouts defined with this proportional domain (according to their similarity) from the repository of typical plans to generate the architectural compositions on a schematic level (Diagram 37).

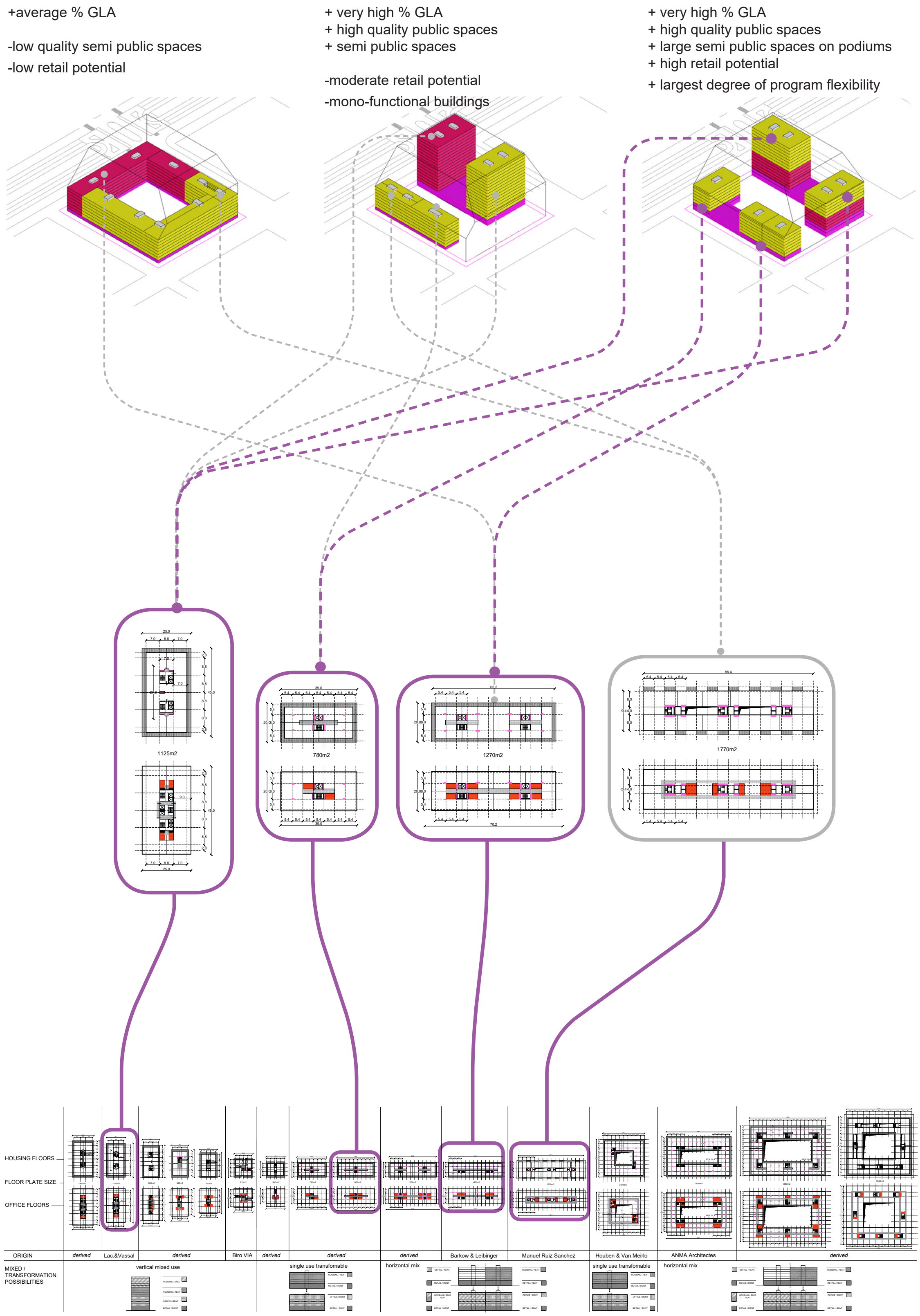


Diagram 37. Applying the library of functionally neutral plans to the massing options

- **STEP 6** - TUNING THE PROGRAM MIX – (user-defined) / Through an interactive process, it is possible to set the desired program mix depending on the typologies. Within the selected option, it is possible to balance and evaluate the ratio between office and housing (the slab buildings are functionally neutral and ready for a horizontal mix, while the extended cubes (towers) are vertical mixed-use typologies) (Diagram 38).

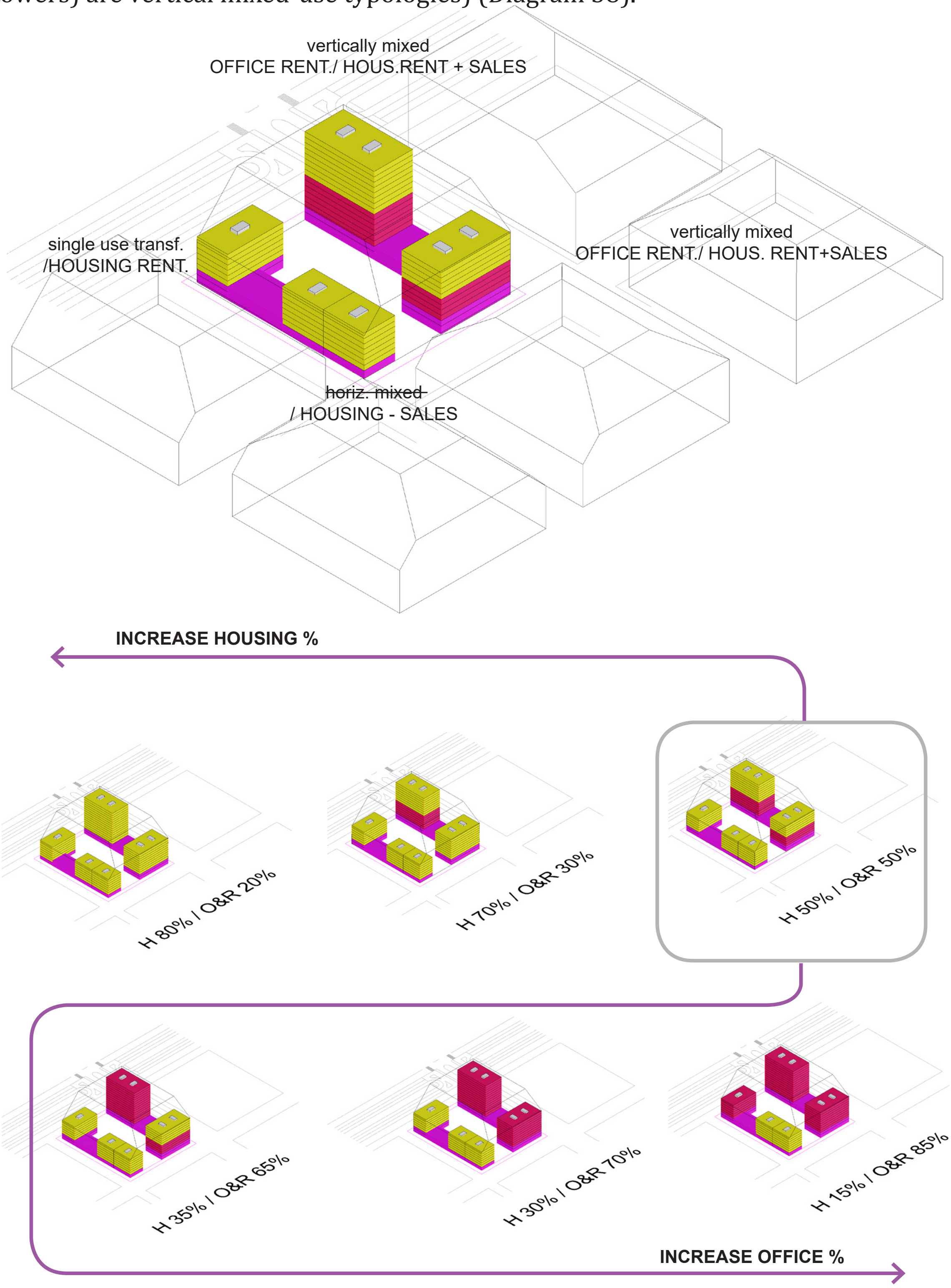


Diagram 38. Tuning the program mix

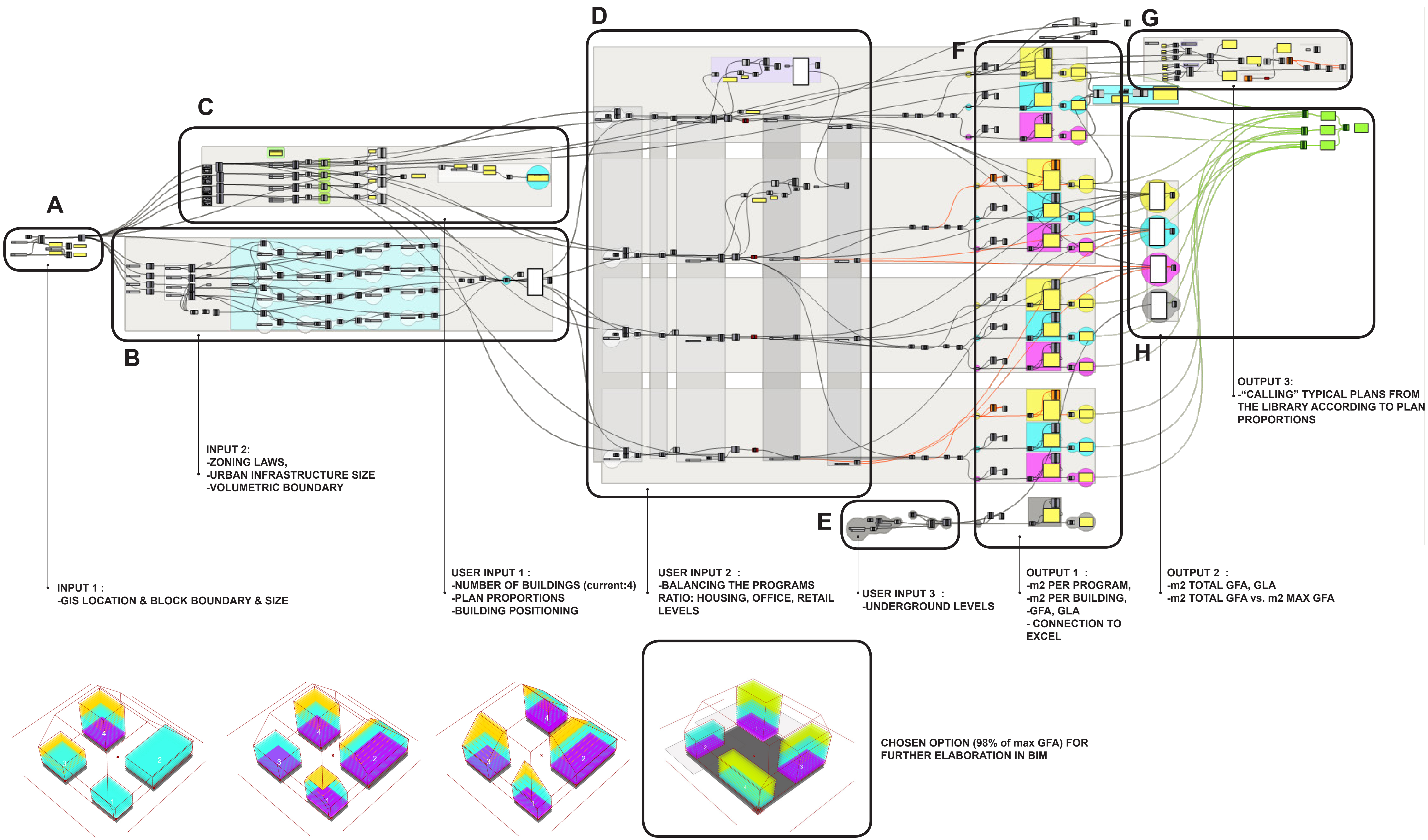


Figure 55. A screen-shot from a developed segment for the Urban Automation Tool - a *Grasshopper script* definition v1.0, that generates a volumetric boundary cage based on zoning laws generates the desired number of buildings, which can be moved withing boundaries defined by local zoning, it is possible to balance the program mix in each of the segments, and automatically “call” and map a typical functionally neutral plan according to the building proportion, program, and mix. Quantitative outputs can be multiple: 1) GFA, GLA 2) Surface of facade 3) Volume.... The m2 data can be used for rough cost estimations projections

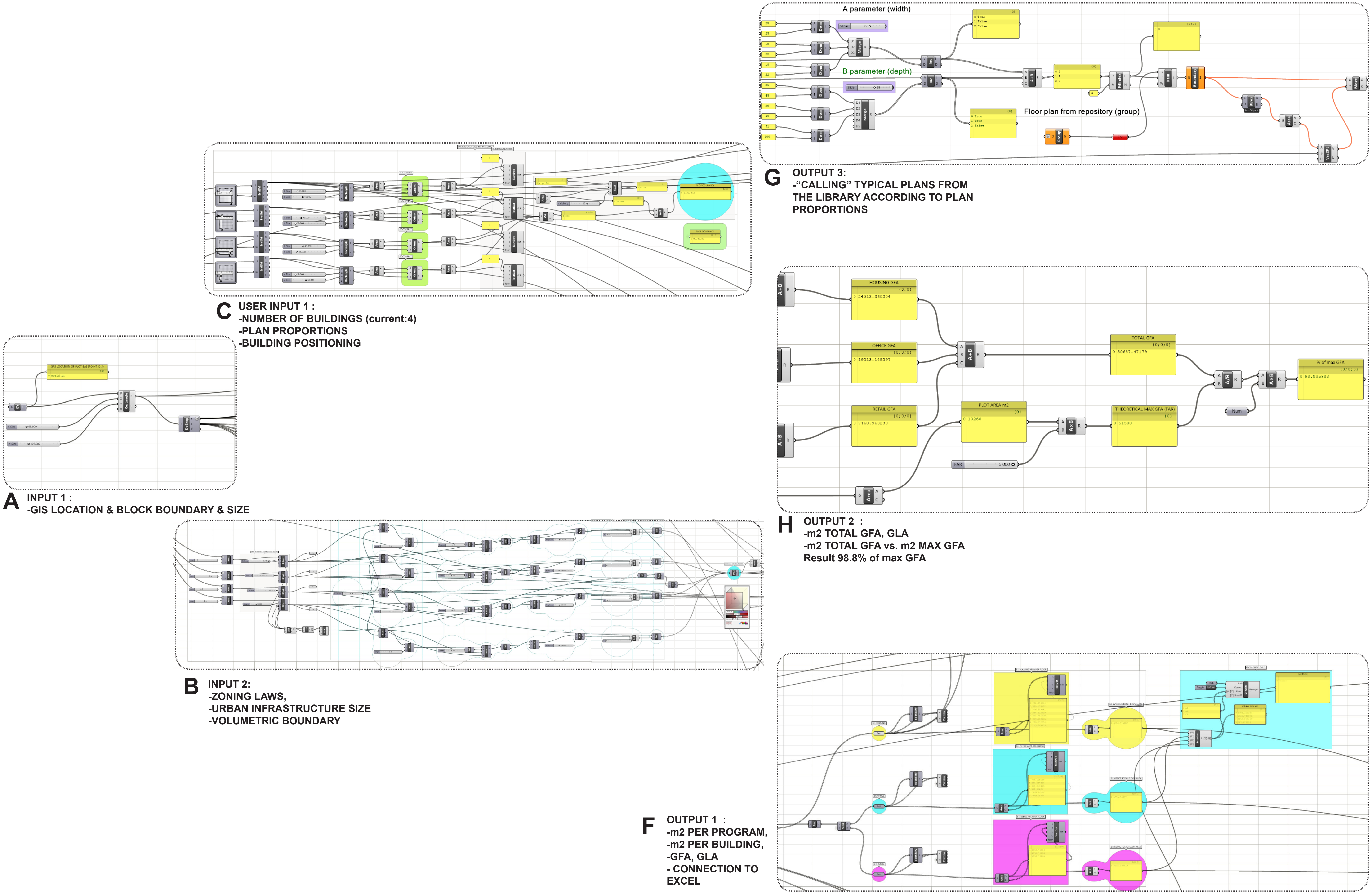


Figure 55a. A screen-shot from a developed segment for the Urban Automation Tool - zoomed segments

- **STEP 7** - CHOSEN OPTION - SITE ANALYSIS INFORMS GENERIC DESIGN INPUTS : DEPTH, FACADES, ORIENTATION - (automated or user defined) - Based on the site orientation, climate zone, budget, or other user defined inputs, a facade system can be chosen and applied according to the defined level of transparency, depth and thermal requirements (Diagram 39). The parametric model is converted into a Building Information Model (Diagra 39a).

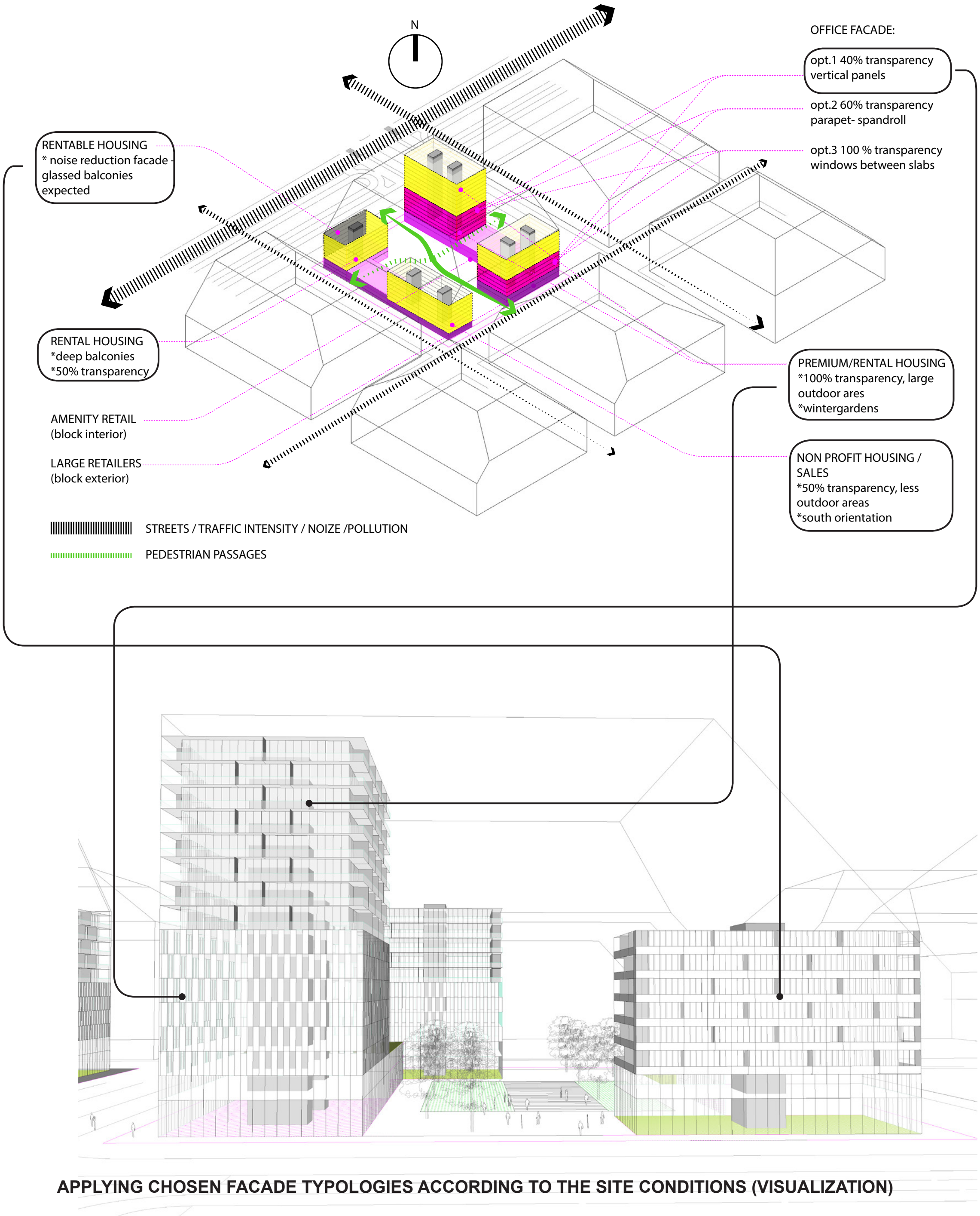


Diagram 39. Informing the chosen generic massing options with the context sensitive data

- **STEP 8** - BUILDING INFORMATION MODEL AS AN OUTPUT

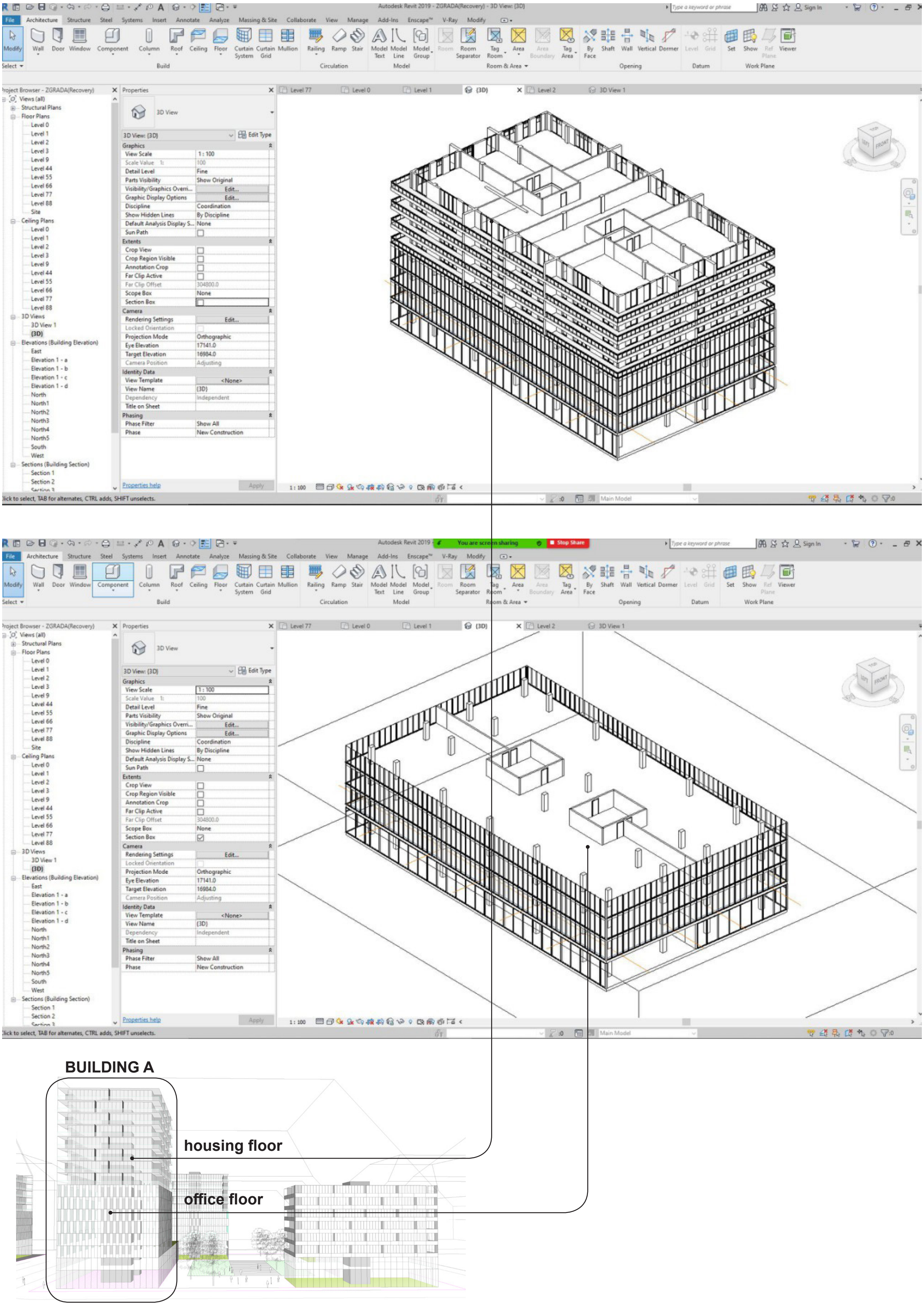


Diagram 39a. A self corrected and updated BIM model - with *Rhino inside Revit*

- **STEP 9 -** COST MODELING **-** feasibility study level profit calculation, presented here : Experience based cost modeling[220] providing a reference for a crosscheck with BIM based design supported cost modeling (Table 17).

Table 17. Experience base cost model - Input table for plot profitability [221]

UAT INPUTS	ИЗВЕДЕНИ ПОДАЦИ		Шифра		
Plot size	Површина парцеле		ПП	2500	м2
COV. max	Максималан индекс заузетости	0-100	СЗ	50%	0-100%
FAR	Максималан индекс изграђености	0,3-4	И	2,0	нум
HEI	Максимална спратност	>0	С	4,5	(П+3+Пк) П+...+Пк
MIX (H%:O%)	Однос намене становање/пословање	x : y	ОСП	80%	%
Zone	Зона	1 - 8	З	2	од 1 до 8
Exhisting struct.	Постојећа структура		ПС	500	м2
EXPERIENTAL	ИСКУСТВЕНИ ПОДАЦИ		Шифра		
Location factor	Фактор локације	искуствено	ФЛ	0,75	0-1 реал. проста - реал. сложена
Sales factor	Фактор продаје	искуствено	ФП	0,75	1-0.75-0.5-0.25-0 лака продаја - не продаје се
Housing eur/m2	цена м2 стамбеног простора	из процене	ЦСП	1800	€ / м2
Office/Ret eur/m2	цена м2 пословног простора	из процене	ЦПП	2800	€ / м2
Rent Ret. eur/m2	рента по м2 локала	из процене	Р	17	€ / м2
Parking spot cost	цена паркинг места	из процене	ЦПМ	10000	€ / ком
Project start (mts)	Почетак пројекта	иза анализе времена	ПРП	10	месеци
Building (mts)	Изградња	иза анализе времена	ПИ	13	месеци
Sales	Продаја	иза анализе времена	ППП	22	месеци
Bank share %	Проценат учешћа банке у пројекту	искуствено		70%	50%-70%
Interest rate %	Каматна стопа на учешће банке	искуствено		7%	3%-12%
GENERATED	ГЕНЕРИСАНИ ПОДАЦИ		Шифра		
Timeframe	Временски оквир пројекта	из гантограма		29	месеци
Land city tax	Цена накнаде за земљиште	по правилнику	ЦНЗ	180	€ / м2
GFA overgr.	БРГП надземна	ПП × И	БРГП	5000	м2
GFA undergr.	БРГП подземно	ПП × 1,75 или	БРГПподз	3900	м2
GLA undergr.	НЕТО подземно	БРГПподз × 0,8	НЕТОподз	3132	м2
Parking no.	**Број паркинг места**	(БРГПподз × 0,8) / 27	БПМ	116	ком
GLA net H.	НЕТО стамбеног простора	ОСП × БРГП × 0.8	НЕТО СП	3200	м2
GLA net. O/R	НЕТО пословног простора	ОСП × БРГП × 0.8	НЕТО ПП	800	м2
GLA	НЕТО	НЕТО СП + НЕТО ПП	НЕТО	4000	м2
Housing units no.	Број стамбених јединица	НЕТО СП / 60	БСЈ	53	ком
Quality	Квалитет објекта	(ЦСД / ЛЦИ) x ФП	КО	2,33	
Cons.cost/m2 **BIM model input**	Јединична цена грађење	420€/м2 x КО	ЛЦИ	978	€ / м2
Land cost / m2	Усвојена процењена јединична цена земљишта	из тока новца	Куповина и исплата договорене цене	388,8	€ / м2
Invest. cost/ m2	Трошак инвестиције по квм БРГП	из тока новца	СУМ Трошкова / БРГП	1763	€ / м2
Sales cost/ m2	Средња продајна вредност БРГП	из тока новца	СУМ Прихода / БРГП	1832	€ / м2

PROFITABILITY OUTPUTS

220 Design supported cost modeling vs. Experience based cost modeling

221 A formula based table from the research of Danilo Furundzić is used as an experiential model convenient to use with the UAT script, Danilo S. Furundzić, "Defining model of profitability evaluation for planned urban parameters of residential-business zones in Belgrade." PhD diss., University of Belgrade, 2016, 221.

- **STEP 10** - BUILDING INFORMATION MODEL AS AN OUTPUT - A self corrected and updated BIM model (Diagram 40).

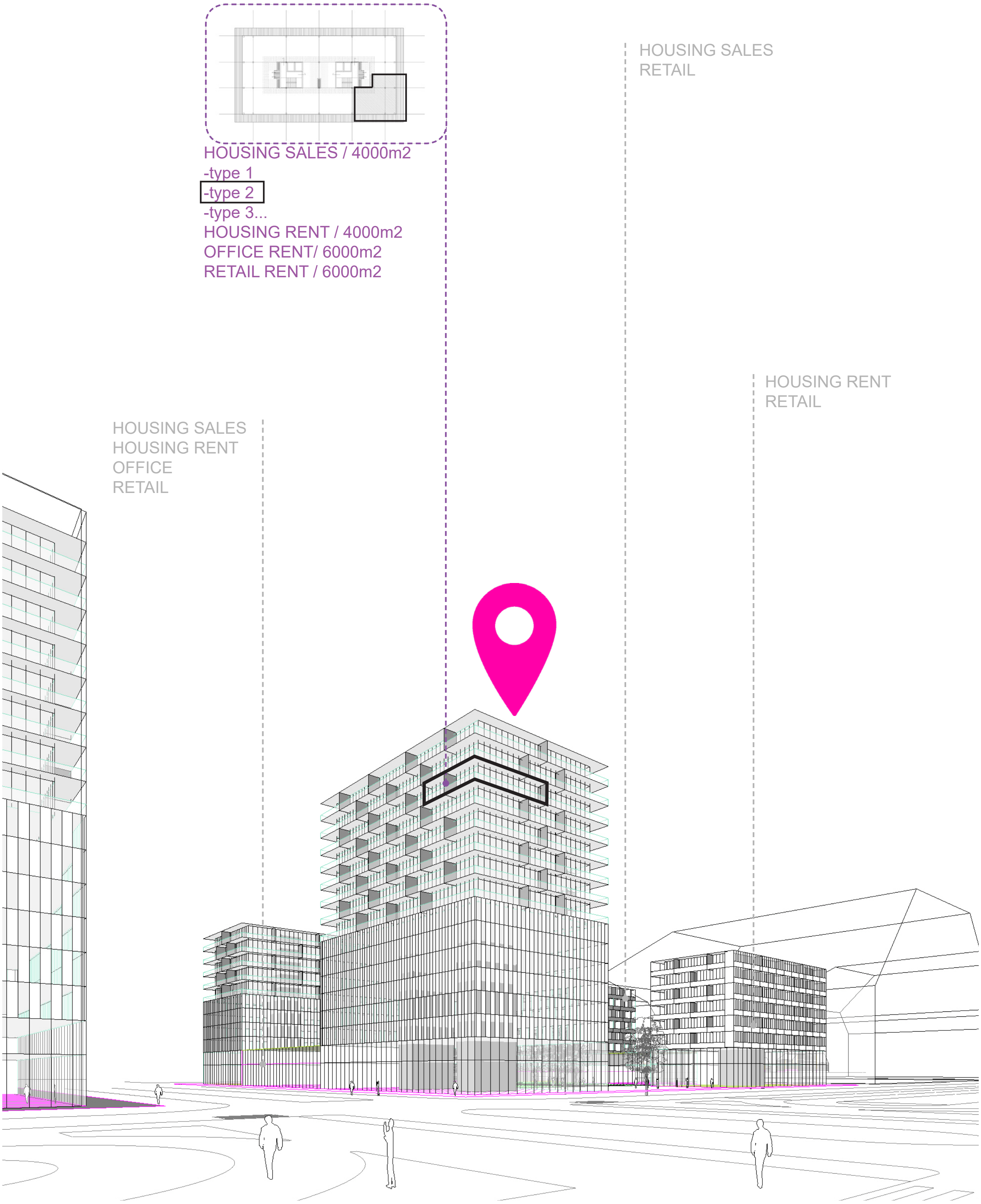


Diagram 40. BIM model as final output

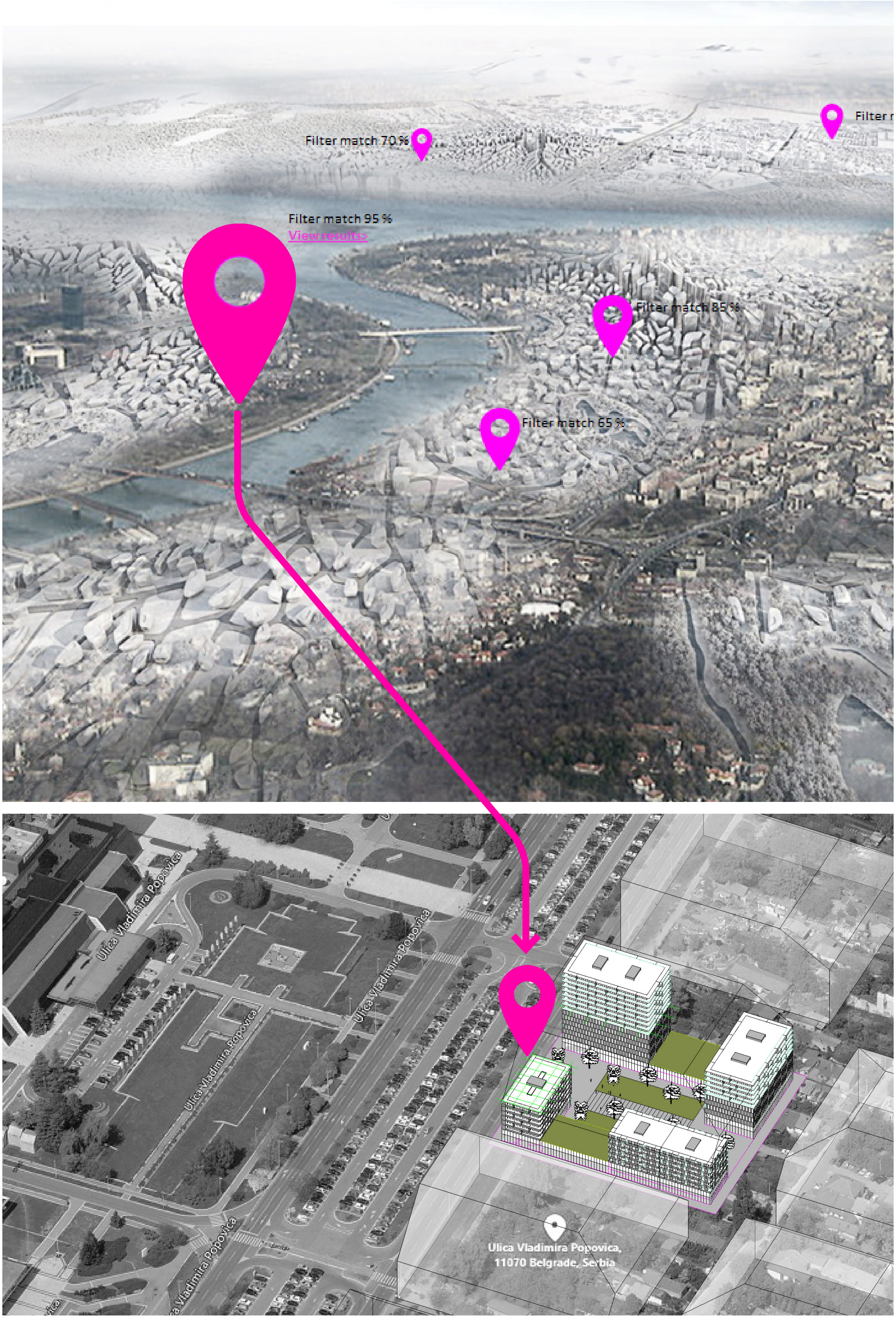


Diagram 41. Positioning a generated urban block as a BIM model back into GIS

VR EXPLORING THE GENERATED MASTER-PLAN AREA (ILLUSTRATION)

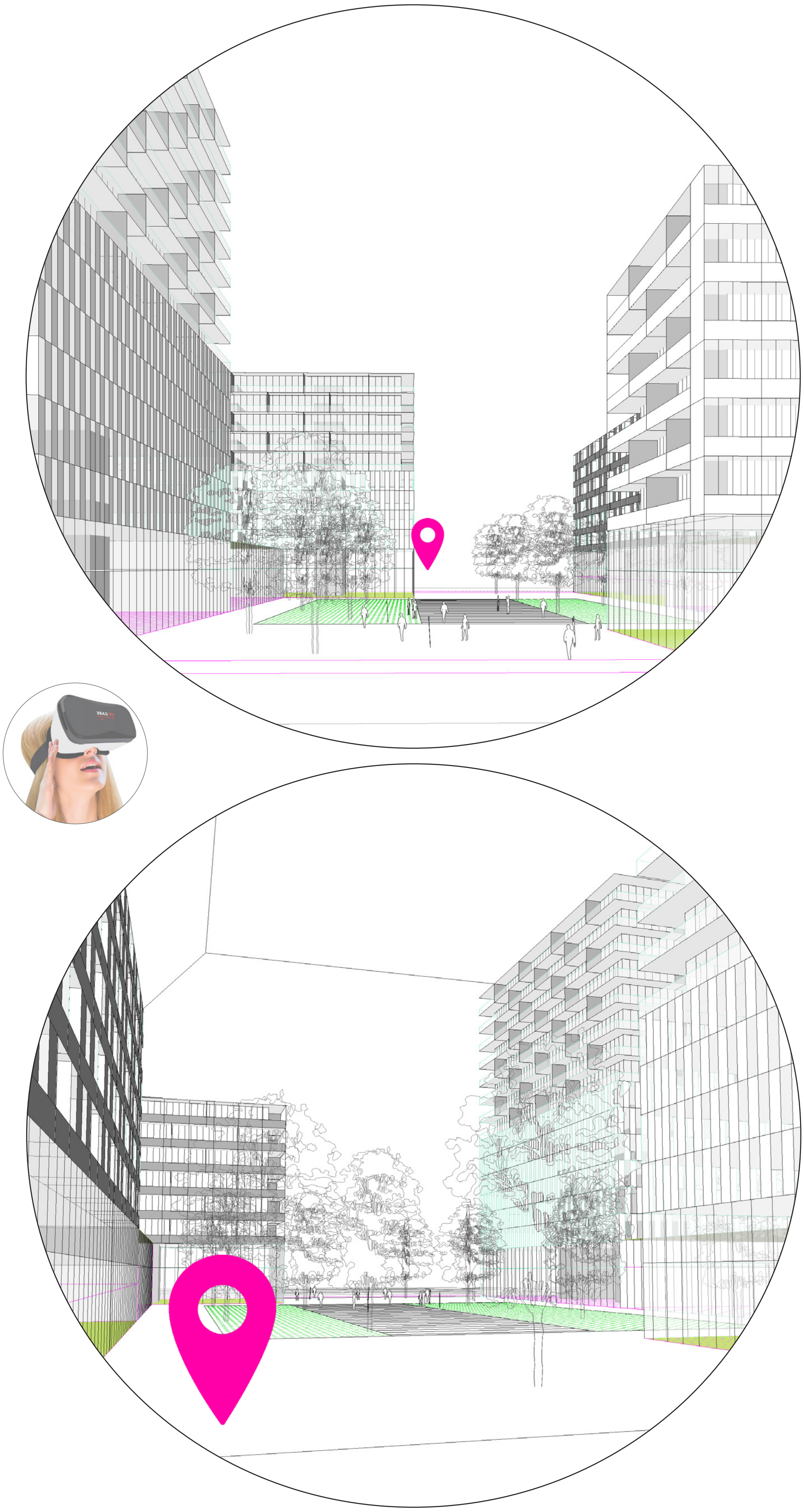


Diagram 42. A possibility to explore the generated 3d model in VR

PUBLIC SECTOR:

CITY GOVERNMENTS

PLANNING AGENCIES

PRIVATE SECTOR:

PENSION & INSURANCE INVESTMENT FUNDS

REAL ESTATE DEVELOPERS

HOUSING COOPERATIVES

COMMERCIAL TENANTS

CIVIL SECTOR:

LOCAL COMMUNITIES

INTERFACE 1

INTERFACE 2

INTERFACE 3

DIALOGUE

AVAILABLE VISUALIZED DATA (GIS BASED PLATFORM):

1) VISUALIZED ZONING LAWS 2) MASSING OPTIONS AND RELATION TO THE URBAN PARAMETERS 3)PROGRAMMATIC STRUCTURE DATA 4)LAND COST & INVESTMENT COST 6) PROFITABILITY OF THE PLOTS 7) ZERO DESIGN VISUALIZATIONS

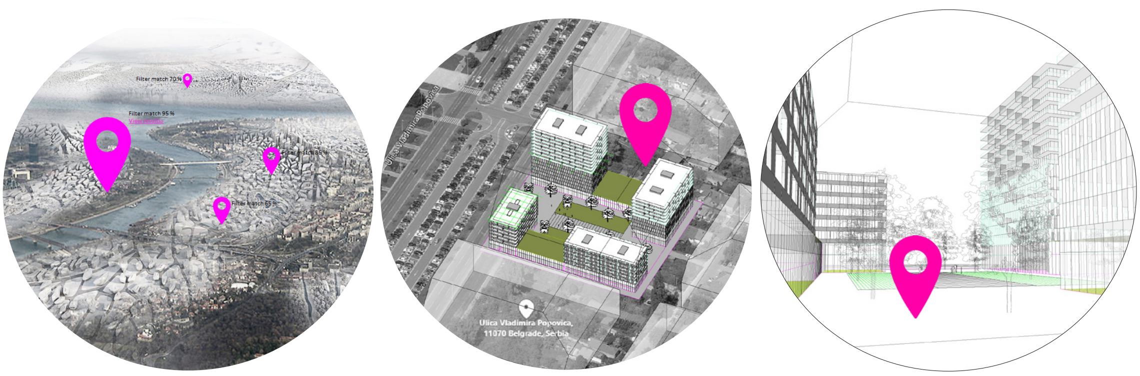


Diagram 43. Urban Automation tool - a platform for stakeholder dialogue

4.2.2 Urban Automation Tool demonstration - summary

This chapter has demonstrated a scenario where the use of algorithmic design procedures have employed the infrastructural tenets of functionally neutral typologies to answer the need for maximizing the land use potentials in the mixed-use city centers, not only in the spatial sense by maximizing the build-up of the plot but also in the temporal dimension by partially assuring the time resilience of the proposed city block with the competence to change its content.
This chapter introduced a locally specific problematic area as a test-ground and analyzed its potentials and obstacles, and gave proposals according to the “ideal scenario” and “ideal client” who seeks long-term ownership and maximal programmatic flexibility within his development. There are several logical questions that could be asked: Who decides and how to decide on the design options prompted several times during this process? And what are the evaluation criteria for these decisions?
Surprisingly, during the volumetric and capacity analysis following the zoning laws, there were no infinite numbers of logical and land-use efficient design options (from the perspective of the trained eye of an architect, backed up with graphical and numeric data), but actually quite a few directions (which AI, through supervised machine learning can learn from professionals and the larger number of reference projects). There could be, of course, many nuances between the options based on functional neutrality, but this demo used the most suitable ones from the scope of the established design repository. The process of narrowing down the design options until the “final option” was based on the intentions to: 1) choose the most heterogeneous and flexible option in terms of typology – low-rise and high-rise, 2) apply a diverse real estate concept: combining rental and sales zones, 3) use both mixed-use types: horizontal and vertical, 4) to match the maximum FAR. The latter (maximum FAR) may not be the ideal one in every case in order to achieve profit together with social and ecologic equilibrium, but it could be considered as a reliable reference guideline prior to the full process of architectural design.
Demo applied on a particular plot in Block 18 in Belgrade gives the following outputs: (1) maximal build-up, (2) massing options, (3) program flexibility options, (4) options for single-use or mixed architectural compositions, (5) high efficiency in plan and section (6) indication of the applied infrastructural layouts through typical plans, (7) envelope/facade typology indication, (8) rough GFA and GLA areas, (9) rough cost indications and investment profitability studies based on the experiential model.
The current outputs of the UAT demo are limited to the scope of the previous research, which do not claim to give the ideal and finished solutions, so it rather represents an open-source upgradeable tool. UAT is anticipated with the awareness that the decisions could only be made (possibly with the assistance of the AI) based on the data collected through the feedback of the end-users from the market and actors from the private, public, and civil sector, gathered around a GIS-based platform with an interface customized towards each of these stakeholder groups (Diagram 41, 42, 43).

5.CONCLUSION

5.1 REFLECTION ON THE RESEARCH THEME

As stated in the introduction chapter, with the global capitalist consensus, the architectural composition of the 21st century is guided with profitability, spatial efficiency, performative & time-resilient (transformative) capacities. The rapid development of an information-based society affects the architectural composition not only in terms of necessity for its programmatic flexibility, but also in terms of the informational tools that regulate and manage the processes within since its conception. The new take on the architectural composition integrates the physical and informational infrastructures of a building is oriented towards a new time-resilient/ user-oriented – process-based architecture with integrated transformational capacities.

The time resilient concept of an architectural composition is used here to ensure the long-lasting building and well-being of its users and take the programmatic transformation and evolution within its boundaries as a permanent and inevitable condition. The time resilience of a building could also be understood as an ecological concept since it implies more reconstruction than new buildings, reducing the need for greenfield developments.

On the architectural scale, the infrastructure of a building can be observed as a tool that instrumentalizes the architectural composition, just as it regulates the urban composition on the urban scale. Assuming that an architectural composition is conceived from three aspects: formal, functional, and structural, and that all three are bundled with building infrastructures, it can be expected that the infrastructure can be observed as a spatial layout of interrelated elements which can determine the architectural composition and its transformational potentials.

Infrastructural elements are essentially located within the difference of the Gross Floor Areas (GFA) and (GLA) Gross Leasable Areas and volumes of a building. These ratios vary with different programs; they also vary within different classes of the same program. Changes within the buildings of the 21st century are in a way inevitable because of the necessity to always maintain the use of land in the city maximally efficient and adequate, which is a design prerequisite, especially in the zones of mixed-use city centers. Therefore, in order to perform reprogramming or improving the buildings to follow the evolving standards of the same programs, the infrastructure of architectural composition must be designed in such a way so it can facilitate these changes more easily than in the present time or it can be upgraded to do so. Within the scope of the presented research, this intention has been demonstrated for a chosen scope of buildings typologically determined in terms of the program – office/housing or mixed-use between the two, and volume proportions – cubes and slabs, and finally the urban contexts – mixed-use city centers.

According to the research findings, the role of infrastructure in (determining) the architectural composition in the 21st century could be: to maintain spatial efficiency, obtain functional neutrality (with a degree of transformational capacity or mixed-use ability) while maintaining an economical, ecological and social equilibrium of a building.

5.2. CONCLUSIONS ACCORDING TO THE HYPOTHESIS

This section summarizes the research findings according to the hypothesis set in the introduction, so all three hypotheses are repeated and followed by related conclusions.

5.2.1 First hypothesis

Changes in socio-economic conditions initiate the new methodological concepts of infrastructure in the process of architectural design, oriented towards intensifying land use and spatial efficiency.

The first hypothesis is elaborated using the method of multi-variational analysis of the historical research context. This method was applied to the four historical periods, which were defined within the research and named after some of the architectural movements relevant for the topic of infrastructure (Chapter 1, Section 1.3). These are: I) Prehistory (Modern period): 1900–1989, II) New pragmatism 1989–2000, III) Parametricism 2008–2015, IV) Contemporary period: 2015 – present.

The research on this hypothesis offers four achievements to support it:

- The causally – consequential connections related to the topic of infrastructure within the field of architectural and urban design with the historical social-economic changes

This was proven by intersecting three timelines (that mapped the events, seminal theoretical essays, and concepts, and published regulations and policies) related to the previously mentioned periods and drawn connections between 1) the evolving understanding of the role of infrastructure within the fields of urban and architectural design (from urban infrastructures to infrastructural elements as infrastructure of the architectural composition), 2) social and economic changes that trigger the evolution of spatial and ecologic norms and regulations, 3) the evolving design tools, technologies, and methodologies (Diagram 1, Diagram 2, Diagram 3).

- Introducing infrastructural ground as a term that integrates the understanding of infrastructure on the architectural and urban scale and determines the land use potential

During all the mentioned periods, the way the land is used was a subject of discussion and different ways of understanding. In architectural theory and practice, the figure-ground condition has been gradually more and more infrastructurally charged from the liberated ground of modernism to the podiums of today, when the land is treated as the most valuable resource in densely populated cities and maximizing its potential is a must. As an extended area of building footprint, a plot is saturated with infrastructures densified and intensified to achieve greater performativity. This indeed results in the thick ground (thick 2d) as Allen named it, often hosting multiple underground and overground levels with circulations, services, technical spaces, car parks, lobbies, vertical cores, green space, and commercial functions. As the urban density is higher the ground is thicker, and the building capacities enlarged.

Therefore, positioning the term infrastructural ground within the field of architectural design can be observed as a first theoretical contribution of the research. It connects the topic of the infrastructure of architectural and urban scale using the method of logical argumentation. This term integrates and bridges the theoretical positions of Allen (understanding of the field intensities – a thick 2d), Delalex (architectural objects as extensions of urban infrastructures), and Kipnis (extending urban infrastructures into the building as infrastructural tenets).

Infrastructural ground is the space where capacities of urban infrastructures provided by the city converge into the architectural composition determining its potentials and boundaries, including the scopes and possibilities for its future transformations. A plot can be seen as ground that relies on the capacities of infrastructures of a larger scale (urban, social, and territorial) indexed through zoning laws and urban planning regulations. The larger a potential development is, the more infrastructures are allocated both in and outside of the plot.

- An overview of the evolution of a typical architectural plan and its relation to infrastructure in terms of land use and spatial efficiency of an architectural composition

In parallel with the treatment of land, changes were made to typical plans brought by new architectural discourses that have influenced the conception, evaluation, and distribution of infrastructure. Different urban densities and land-use intensity imply different volume typologies and, therefore, specific design approaches to their plans. Although all major volume typologies analyzed (there are four, defined by Zaera Polo) coexisted since the beginning of modernism, the developments of their plans matched certain technological advancements within the four periods previously elaborated and carried a particular potential for programmatic transformation (Chapter 1.5, Table 1 and Table 2):

- Tight-fit plan (I Modern period, Keynesian economic context, constrained with the FAR parameter, typical volume is a flat vertical (slab), low flexibility and transformational potential for reconfiguration),

- Loose-fit plan, Relaxed-fit plan (II New Pragmatism, Neo-liberal economic context, Kyoto Protocol & LEED, typical volume is flat horizontal/vertical, polyvalence, high degree of flexibility),

- Slim-fit plan (Parametricism, III World economic crisis, Spatial efficiency guidelines, Vertical volume type, High performance),

- Functionally neutral – process plan (IV Contemporary period, Crisis of Neo-liberalism, BIM standards, Cubic and Slab volumes (theoretically all typologies), Functional neutrality).

- An overview of the relations between different transformational strategies (flexibility, performativity, process) and the role of infrastructure within them

This overview was achieved using the method of critical analysis of primary and secondary sources related to the three transformational strategies and logical argumentation. One of the main conclusions that all the transformational strategies analyzed (Chapter 2) are infrastructure-based. As they evolve, they do not substitute the previous but rather include it and become more precise and typology related.

From the 21st century and the return of the typical plan, architectural compositions host vague accommodations in terms of the program as the rental real estate concept started prevailing in the Western cities. It can be observed that the building developments are more and more defined in a time-based bottom-up fashion following the projective supply and demand chains, overriding the typical design according to the current state of the market. Therefore, the design methods evolve hand in hand with the approaches to the design of infrastructure within the architectural composition. As building standards have brought some of the program-related spatial requirements closer to each other (with respect to the spatial efficiency, energy, and health requirements), functionally neutral – process plans (evolved from the typical plans) are being developed capable of accommodating different functions with projectively designed and distributed building infrastructures. This is something that promises that the land-use potential can be maintained high during the lifespan of a building (also one of the promises of BIM technologies and standards).

This research segment has established infrastructure as a driving engine of the contemporary architectural composition oriented towards programmatic transformation. Following different design models (plan types) showed that the role of infrastructure is being customized to the evolving economic and spatial constraints to achieve the most from the space available by using evolving plan models: from tight-fit to loose-fit, typical, and, finally, a functionally neutral (process-based) plan. Contemporary architectural composition is based on infrastructural tenets, which are typologically determined with its volume type and possible "program range," and organized with its infrastructural layouts and suitable transformational strategies (Hypothesis 2).

5.2.2 Second hypothesis

The typological relations between volume and program can determine the infrastructural layouts and the possible strategies and scopes for programmatic transformations.

The second hypothesis is elaborated using the following methods:1) analysis of the research context for the functionally neutral and mixed-use buildings (Chapter 2.1), 2) case studies and 3)comparative analysis (Chapter 2.3). Programmatic transformations based on infrastructural tenets were determined by introducing the concept of spatial efficiency and setting a list of spatial efficiency criteria (quantitative and qualitative). Then, the typological relations between volume and program have been explored through case studies for the two chosen volumetric typologies (cubes and slabs) and two program typologies (office and housing) with the aim to look for the architectural compositions which could house both programs within the same volume.

Three principal achievements support this hypothesis:

- An intersecting range of urban parameters for the two programs with the two-volume typologies is determined, locating the functionally neutral and mixed-use developments within the context of mixed-use city centers

The analysis of the basic urban parameters (FAR, COV, HEI) for the 22 selected case study projects (4 groups: Cubes (office/housing), Slabs (office/housing)) has resulted in a series with comparative charts indicating the urban densities where these typologies appear.

To understand to see how the two different programs relate to the volumetric/density tendencies, charts associated with the same volume typologies were overlapped, so a set of urban density parameters could be determined. In general, office building requires a higher density urban context, but significant overlap with housing typology can be observed (Chapter 2.3.3, Diagram 9), meaning that there are volume typologies that can facilitate both housing and office programs.

Therefore, there is a typological hierarchy where there is: (1) urban plan that indexes density through FAR, COV, HEI (2), a Volume typology, and then (3) a program typology. This has been used to focus the research towards the particular urban contexts (mixed use city centers, with high FAR parameters 2+ (Chapter 2.4) and to explore possible applications of the spatially efficient, functionally neutral (and mixed-use) architectural compositions within (Chapter 4.1).

- An intersecting range of spatial efficiency parameters is determined for the two programs with the two-volume typologies locating the infrastructural elements and their possible layouts that satisfy the functional standards for both programs within the same volumes

The analysis of the basic spatial efficiency parameters in plan and section (GLA/GFA, FTF, FTC, PACK, Depth Ratio...) for the 22 selected case study projects (4 groups: Cubes (office/housing), Slabs (office/housing)) has resulted in a series with comparative charts which were overlapped for the two programs within the same volume typologies (Chapter 2.3.3, Diagram 9). The comparative charts have shown a mutual range of the planar and sectional proportions and a range of spatial efficiency parameters that satisfy both programs (Chapter 2.4.2.). This proves that volumes of the similar proportion do have the potential to house both programs, which resulted with establishing the design parameters for functional neutrality (the program can be changed) or mixed-use ability (the program can be mixed, vertically or horizontally).

- Infrastructural tenets for functionally neutral architectural compositions written as infrastructural layouts (functionally neutral typical plans), and sets of design recommendations

In order to understand the infrastructural tenets for the functionally neutral compositions, it was necessary to understand the process of programmatic transformation and mixed-use composition. Common problems, design principles, and characteristics of such typologies have been extracted from the research context (Chapter 2.1), which helped to formulate criteria (topics) for qualitative evaluation. From the four groups of projects analyzed with spatial efficiency indicators, four projects have been selected for a more detailed quantitative and qualitative analysis which elaborated different project conditions: 1) transformation office to housing, 2) refurbishment – an unfinished HQ office building converted as a multi-tenant office, 3) a vertically mixed-use building (new-built), 4) and mixed-use interpolation within a dense city block (new-built). The analysis of the reconstructions has shown opportunities, methods, difficulties, and constraints of architectural compositions originally designed for single use. The analysis of new-built mixed-use buildings clearly indicated the design strategies for a process-based design approach. In general, office buildings require slightly higher spatial standards: slightly bigger plan depth, and ceiling height, a larger degree of facade transparency, but less dense vertical ducts, while the density of the structural grid is often similar for both programs. However, these differences could be overcome by creating facade setback for the loggias for housing to reduce depth, having exposed horizontal HVAC conduits to reduce the ceiling packages and keep the FTC height within the standards, creating a dense provisional grid of vertical installation ducts integrated with the structure suitable for housing... The transformational and mixed-use design strategies have been abducted from the typical plans of the analyzed projects and applied on a gradient of volume typologies to create infrastructural layouts written within a repository of typical – functionally neutral (and mixed-use) plans (Chapter 2.4, Diagram 12).

Volumetric and program typologies qualified with urban density parameters and zoning laws determine the land use potentials of a plot. As the land in cities gains and loses value or changes purpose over time, the volumetric and, more often, program typologies of buildings prove to be inappropriate. Therefore, the architectural composition in the 21st century tends to become projective and process-based. A degree of functional neutrality determined within the scope of the research opens possibilities of programmatic transformations that could improve the time resilience of a building. According to the conducted research, areas with increasing urbanity and urban parameters in mixed-use city centers are mainly suitable for such building typologies, which is demonstrated using a semi-automated (scenario – based) on an algorithmic design that employs the findings presented while proving this hypothesis: urban parameters, spatial efficiency based infrastructural tenets, and a repository of functionally neutral plans.

5.2.3 Third hypothesis

The use of algorithmic design procedures to apply infrastructural layouts within volumetric typologies can result in spatially efficient, functionally neutral, and therefore time resilient architectural compositions that maximize and maintain the land use potentials of plots.

The research addresses the infrastructure throughout algorithmic thinking on two levels: informational and physical. Informational is multidisciplinary, oriented towards design and development procedures, and drawn as a schematic algorithm for a speculative software tool UAT (Urban Automation Tool). The algorithm is process-based and integrates inputs from different disciplines (urban planning, real estate, IT) and stakeholders and uses different available informational technologies and design software (GIS, Rhino & Grasshopper, BIM) to define the brief (site, volume, program, and infrastructures). The informational macro level is speculative, and it is not intended to be proven within the research. Instead, it provides a framework for its possible application.

The previous results of the research (infrastructural tenets of functionally neutral architectural composition) are partially implemented within the algorithmic design procedure in the central part of the proposed software tool (UAT). As most of the basic information about the spatially efficient and functionally neutral typologies is contained within the repository of typical (scalable) plans as "infrastructural layouts," the algorithm uses them and assigns the typical plans to desired volume typologies. Through a semi-automated interactive process, several spatial configurations are offered and evaluated to investigate the relations between the optimal and maximal land use potential of a particular plot (a city block size plot is used to demonstrate this as a part of the Block 18 case study in Belgrade).

Several points support this hypothesis (some only partially):

- A critical analysis of the planning procedures on a case study location (mixed-use center location in Belgrade – Block 18) showed discrepancies between the capacities envisioned by different stages of urban planning and failed to approach maximum build-up indexed with FAR, which implies the necessity for an algorithmic approach to the planning procedures

The urban plans for this location, zoning laws, and urban parameters acquired from GIS were a base for critical planning documentation analysis. The analysis showed that the urban zoning laws are both restrictive and ambiguous and show the tendency for reduction as they offer a more detailed level. The analysis of a winning entry of a public competition does not nearly approach the capacities envisioned by the brief based on the Plan of General regulation, but also show the problem of the block size – too small blocks result in minimal typological diversity and low spatial efficiency, which is paradoxical that the block matrix in a mixed-use city center almost dynamic city area does not support the tested mixed-use and functionally neutral typologies, and remain rigid on the proposed perimeter block as an only possible solution. The detailed plan level is only partially based on a winning competition entry, leaving the block matrix as an open question, but using the achieved capacities from the competition to define new lower parameters, which might lead to the under-use of costly land or disruptions and speculations on the real estate market knowing that the "purchased detailed urban plans" will be based on the higher parameters from the plans of higher level (Chapter 4.1). This raises questions about the expediency of the current planning system and the possible necessity of algorithmic evaluations of the stages of planning procedures.

- A possibility to interpret zoning laws algorithmically proved to be possible and have resulted in the "volumetric boundaries" in which the relation between the size and capacity of urban infrastructures and the capacity of building volumes can be tested in order to find a balanced volume-based master-plan configuration.

The necessity to perform this step appeared with the analysis of the typical block sizes that showed very limited numbers of possible configurations within; the conclusion was that to be able to test blocks of different sizes, the zoning laws would need to be drawn with algorithmic design tools as volumetric boundaries which was performed with a Grasshopper script (Chapter 4.1.10 and 4.2.1).

- It is possible to implement the infrastructural layouts as functionally neutral plans within the semi-automated process of generating and evaluating different volumetric configurations (urban massing)

This process was started manually using the typological proportions from the repository of typical functionally neutral plans on the scale of one typical block within a volumetric boundary, which is automatically generated with the zoning laws parameter inputs. This urban massing analysis showed a limited number (only 6) reasonable solutions which approach the maximum build-up determined with FAR. Typologies with the base (A x B) proportions closest to the ones in the current massing options are the ones automatically imported within the volumetric boundary and extruded until the height boundary cage (or their height could be adjusted with sliders). The available typologies are limited to the current scope of the repository; otherwise, there may be more massing options. The current typical plans from the repository should be parametrically defined and adaptive/stretched in fine gradients (with respect to their functional and infrastructural limitations); this is currently not done but is feasible (exemplified with Finch 3d, adaptive planning project). It is possible to customize and evaluate the program structure within each configuration (horizontally and vertically) with the sq. meter output for each program, building volume, or total program structure within the chosen volumetric configuration (Chapter 4.2.1).

- Maximizing and maintaining the land use potentials of the plot (partially proven)

Land use potential of a plot is only partially determined in the UAT demo, in terms of approaching the maximal GFA values (3 out of 6 options reach 95%of GFA, while the last chosen option reaches 98.8% of GFA's theoretical maximum) using the functionally neutral and efficient typologies. The numeric data values can be followed in real-time as the adjustments are performed (Chapter 4.2.1, Figure 55a).

The social and ecologic as important components of the use of land have not been proven within the case study (the scope of the UAT demo showed a simple and commercial segment of the overall platform). They are only envisioned and suggested through the possibility for stakeholder interaction within the UAT (Chapter 3.1.4, Chapter 4.2.1, Diagram 35).

- Applying functionally neutral infrastructural layouts to ensure time resilience and maintain the appropriate land use

The time resilience of functionally neutral typologies based on infrastructural tenets is not proven. There are no or not enough such developments with a sufficient time distance, so this cannot be evaluated yet. But the research shows that theoretically, it could be possible due to the integrated capacity that allows the adjustments of the program structure within the chosen block over time – which can be considered as one of the aspects of maintaining appropriate land use in the mixed-use city centers.

A proposed algorithmic procedure (presented through 10 steps, Chapter 4.2), where one can simulate and evaluate the spatial impact of infrastructural layouts applied to particular volumetric typologies and proposed programs, is the first partially developed stage of the UAT. This procedure could demonstrate its real powers when with the use of Building Information Modeling (BIM) and parametric design tools to test a larger number of spatial configurations determined by urban parameters and zoning laws. They can be evaluated in a generative way, and specific scenarios can be distinguished, achieving optimal relations between the capacities for programmatic change and adaptation on the one hand, and spatial and energy efficiency, and social components, on the other.

5.3. RELATION OF THE RESEARCH WITH ITS THEORETICAL FRAMEWORK

Architecture as an extension of urban infrastructures

As stated in the introduction chapter, Allen's identifies infrastructure as a primarily urban device that supports and sustains changes in the urban context and the buildings within. Delalex has determined the relation between infrastructure on the urban and the architectural scale, saying that buildings can be observed as extensions of the urban infrastructures. This research indirectly confirms both suggestions by bringing in the urban density parameters as a multiplier in the equation, which also defines the capacities of urban infrastructure concerning the expected and planned capacities of buildings. However, nowadays, another direction of influence is present since the dynamic forces of the real estate market often influence expansions or intensifications of urban infrastructures to boost the construction.

Figure-ground

As previously mentioned, a new figure-ground condition has been suggested to supplement the three principle ground conditions (appropriation, staging, and elevated ground) that originate from modernism. Infrastructural ground is the space where capacities of urban infrastructures provided by the city converge into the architectural composition determining its potentials and boundaries, including the scopes and possibilities for its future transformations. It is a zone that multiplies the flows and intensities of use. It exists when the existing urban infrastructure cannot be further intensified or expanded in a very dense context, so the necessary urban infrastructures are sometimes developed on-site and within a building. This is a method that Kipnis describes as infrastructural tenets (exemplifying it through OMA projects), meaning – importing the urban infrastructure into buildings.

Infrastructural tenets

During the research process, it became evident that the infrastructural tenet[222] is actually not a singular methodological procedure. Multiple tenets integrate infrastructural ground and infrastructural elements into typological architectural compositions[223] qualified by its volumes and program scopes. Therefore, they distribute the infrastructures within architectural compositions according to the qualitative and quantitative criteria of spatial efficiency aiming towards different performative effects and transformational outcomes.

222 A term originally coined by Kipnis to explain how OMA brings urban infrastructure into the building

223 The research partly relies on the theoretical standpoint of Alejandro Zaera Polo (2008) *A Politics of the Envelope – A political critique to materialism* (2008), where he discusses four envelope typologies in terms of their socio-economic and political influence to a public space, their spatial and technological characteristics which imply certain infrastructural regularities.

Typologies

The infrastructure of architectural composition in the 21st century is typology-related. There are three hierarchical levels of understanding typologies: volume (nonspecific), program (programmed volume), and building (site-specific programmed volume).

The volume typologies rely on Zaera Polo's research on the political, environmental, and infrastructural implication of the building envelopes have served as an important framework for choosing the case studies. Zaera Polo is discussing the building envelopes using the signature buildings as examples for this manifestation. In contrast, this research used repetitive and more common buildings both in terms of program and volume complexity. Most of the case studies have confirmed his statements on the infrastructural specificities of volume (envelope) typologies. However, this division into four principle typologies is proven to be rough. As the research was dealing with spherical (cubic), flat vertical (slab), and partially vertical (smaller high-rises) typologies, the main finding is that within different urban densities, we are dealing with a subtle gradient of volumetric proportions.

When programs are applied to volumes, typologies become more specific. Zaera Polo indicated the conceptions on typical plans concerning the volume. However, when programs are introduced, plans become more program-related. The plan concepts range from tight-fit and slim-fit (for housing) in all the volumetric typologies, while for offices, relaxed-fit is also included for deeper cubic volumes. Using the method of overlapping program-related plans of the same volume typologies, functional neutrality or vertical mixed-use can be achieved to introduce a process plan.

The most specific – a building typology is qualified by the previous two (volume and program), and its composition is determined with its site-specific ground condition (infrastructural ground) and its time-oriented real estate strategy (rental, sale, functionally neutral, or mixed-use).

Transformations

Within this research, three transformational concepts have been considered: flexibility, performativity, and process model that integrates the first two. As suggested by Till and Schneider, flexibility strategies do exist in today's production of space, indeed hierarchically, as hard (predictive) and soft systems (uncertain). The performative strategies were elaborated following the three paradigms: device and topographical (Leatherbarrow 2005, 16–19) and biological (Hensel 2010, 36–56). The topographical paradigm that actively lives on within the "mainstream" building typologies using the materials and systems to provide durability through the static equilibrium between an architectural object and the environment using the active and passive infrastructural systems (ex. thermic insulation and HVAC), biological however focuses more in the passive context-sensitive systems. The relation between object and the environment, which Leatherbarrow and Hensel addressed, can be interpreted in terms of active and passive infrastructures, the ones that consume and the ones that do not consume energy during the building exploitation.

Process based architecture and programmatic transformation

What is a process-based architecture? It is an architecture whose content is transforming since its conception through design, construction, and exploitation. An architecture ready to grow and diversify its functional units as the user groups change their needs through time – a resource equally important as space. Programmatic transformations are explored throughout this research in two ways:

1) During the process of design – in order to achieve the optimal program mix and spatially efficiency according to the volume typologies determined by the zoning laws of a particular site,

2) After the building completion – in order to achieve functional neutrality and the easy and cost-effective transformation towards maintaining maximizing land use potentials in a time resilient manner.

The programmatic transformations are more feasible in the rental real estate concept than in sales. In housing especially, rental gives more flexibility for the developer/owner and, in the long-term, brings more revenue, while sales get faster investment return. Also, in the present time, they are more feasible when offices are converted to housing than vice versa because the current offices have higher spatial standards and can be in a way "downgraded" to accommodate housing, which is the case often analyzed when existing office buildings are converted. Since the design of functionally neutral buildings is a relatively new thing, time will prove the opposite practice of converting housing to offices. Theoretically, if a building is carefully designed as functionally neutral, the opposite should be feasible too.

5.4. IMPLEMENTATION OF THE RESEARCH WITHIN THE FIELDS OF ARCHITECTURAL DESIGN, REAL ESTATE, URBAN DESIGN AND PLANNING

The research could be implemented within a wider range of practices dealing with the built environment: architectural design, urban design, real estate management and prop tech industry, and urban planning.

In the field of architectural and urban design, a set of methodological procedures is established for the design of functionally neutral buildings and mixed-use building typologies. In a particular context of mixed-use city centers, a developed library of functionally neutral and spatially efficient architectural compositions could help the investors start large developments bit by bit. It could help them adjust the program structure following the market needs throughout the planning procedures, even during and after the construction, following the boundaries defined by urban regulations (even providing a transparent way of pushing those boundaries).

In the field of urban planning, the research provides a transparent way of reading current urban plans through data visualization (what can be built, spatial impacts and profitability).[224]This is something that may trigger the feedback of the potential investors and users, which can be a corrective factor that opens the potentials for the urban planning to become more bottom-up. It could help the real estate investors and developers quickly find suitable land for construction and have the investment opportunities visualized and quantified to a certain extent.

A proposed Urban Automation Tool (UAT) uses the results of the research to demonstrate its potential as a software platform. Since few years back, few similar software platforms have emerged worldwide, developed both by architectural/urban and real estate consulting practices. It is just a matter of time when such informational systems will be embedded into official planning and regulation procedures.

224 Determining whether the given urban parameters and zoning laws are economically feasible and wheather they correspond to the desired use of land in a particular context

Implementation in the context of Serbia

Within the context of Serbia, the thesis and its results could improve the implementation of planning procedures of the mixed-use city centers. Update the design guidelines and standards in such a way so the buildings could be built in a more sustainable way by including the possibilities for their upgrading, expansion, reuse in order to reduce vacancy and obsolescence. The latter will be more feasible once the Building Information Modeling has been integrated into local planning and design procedures, which is a currently ongoing process worldwide.

The proposed concept for software product (Urban Automation Tool) could improve the functionality of GIS (Geographic Information Systems) by providing a transparent reading of urban plans and regulations with the use of BIM technology for modeling and data visualization, which could empower local governments to attract diverse investors and therefore faster, more transparent and sustainable urban development. The cities could be managed with a greater degree of control over the use of their land and a greater degree of following the planning regulation and procedures.

The tool could be used by local governments to collect data about the land possibilities which have not yet been regulated with Plans of Detailed Regulations (PDR). It could empower the landowners and local communities to be aware of the ongoing investments and construction and to become active participants in the planning processes.

5.5. DIRECTIONS FOR FURTHER RESEARCH

Within this research, the role of infrastructure in the architectural composition in the 21st century has been determined using the infrastructural tenets driven by the economy, spatial efficiency, performativity, functional neutrality, and time resilience. The scope of this research is limited by three boundaries: morphological, programmatic, and urban. Consequently, expanding each of these may be a new direction for further research.

Morphological – currently, two particular volume typologies are selected together with their gradients: a spherical (cube) and a flat vertical (slab). Expanding the research to high-rise typologies or flat horizontal low-rise typologies could provide a new framework for further research.

Programmatic – currently, two dominant programmatic typologies (which are most likely to be mixed) are selected: office (administrative) and housing buildings. Expanding the research to other program typologies which may or may not be mixed could provide different insight on the role of infrastructure as the program typologies elaborated here are characterized by a large degree of repetition and rationality.

Urban – the urban setting studied within this research is the one where the chosen programmatic typologies most often coexist – mixed-use city centers – high-density city areas indexed with high Floor Area Ratio parameters and the higher value of the land. However, with the change of the urban context and urban densities, another set of typologies may be applied, so exploring the urban settings of different densities may complement this research.
Further research could also be directed towards the feasibility evaluation for the programmatic transformation of existing buildings in terms of their spatial efficiency, functional neutrality, and mixed-use ability.

Another direction for further research could be oriented towards expanding the repository of the functionally neutral typologies, which is developed here using a limited number of case study projects and limited to the typical plans and sectional information. Using a larger number of projects, this repository could be expanded and defined more precisely. Ideally, a repository of projects developed with BIM could provide greater precision and significantly more detailed building-related data.

The work on the development of the Urban Automation Tool software is another direction of the research, and it requires the involvement of different disciplinary expertise. The current research has developed algorithmic procedures for a narrow scope towards creating a so-called minimum viable product to demonstrate the principle where a lot of data is anticipated. In order to have the software platform fully operational, this research would need to be supported from several different fields: real estate and urban economics, IT, data science, urban planning, law...

The principal foreseeable problems which could become subject of research within these fields refer to data collection and automated data processing, interface design, establishing software protocols between BIM and GIS (Diagram 44), machine learning (IT), real-time cost modeling, investment management (real estate economics), software mediated and flexible planning procedures and zoning regulations (urban planning, law) ...

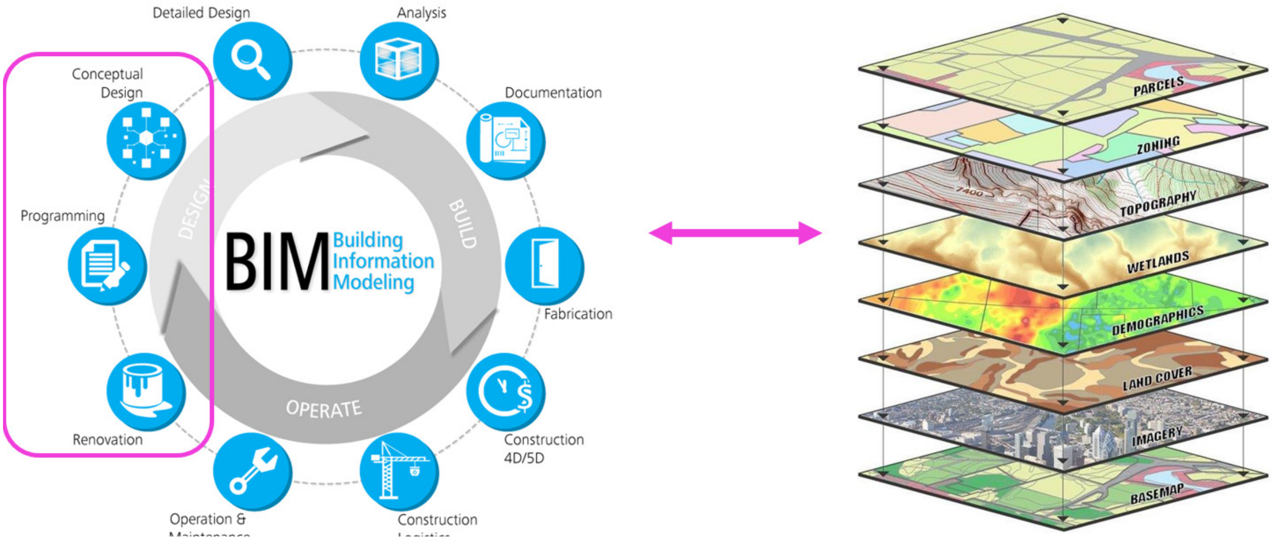


Diagram 44. Implementing automated BIM urban design models as a new GIS data layer.[225]

225 The diagram uses two web images:
Advanced solutions Inc., "BIM Project phases," , 2017, https://www.letsbuild.com/blog/recognising-bim-roles-project-cycle. Ontario County, NY, "GIS Data layers," , 2016, https://www.usgs.gov/media/images/gis-data-layers-visualization.

6 APPENDIX

Case studies

6.1 Case studies 1: Determining the spatial efficiencies and infrastructural layouts within the four groups of selected projects: office and housing programs , cubic and slab volume typology (22 projects)

6.2 Case studies 2: Determining the possibilities for programmatic changes and mixed use ability within the architectural compositions of four chosen projects

Table 18- Overview of chosen projects - cubic building typologies

HOU SING

VOLUME TYPOLOGY: CUBE
PROGRAM TYPOLOGY: HOUSING

IBA / 1957
Otto Heinrich Senn /
Berlin

Escherpark / 2014
E2A / Zurich

Manresa Housing / 2008
/ Nothing Architects /
Barcelona

Hotel Centar / 2015
MITarh / Novi Sad

Hunziker Aeral / 2015
Duplex Architekten /
Zurich

Tour Opale, Chene Bourg/
2019 / Lacaton Vassal /
Geneve

OFF ICE

VOLUME TYPOLOGY: CUBE
PROGRAM TYPOLOGY: OFFICE

Citibank Canary Wharf
/ 1996 / Foster & Part-
ners / London

Tour Opale, Chene
Bourg/ 2019 / Lacaton
Vassal / Geneve

UNStudio tower /
2013/ UNStudio/
Amsterdam

TAZ HQ / 2018
E2A / Berlin

Roaming HQ/ 2018
Biro VIA /Belgrade

IMPLICATIONS OF TYPOLOGY AND SCALE

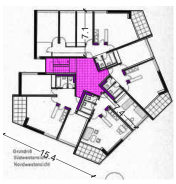
Typologically the buildings are chosen in ascending scales ranging from small point buildings with central or ex-centric cores with direct natural light.

As the floor-plate grows the void space is being introduced around the central core as a source of light and ventilation, in the case of a high-rise cores are set centrally without natural light and air.

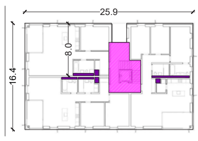
On smaller floor-plates a smaller % of openings can satisfy the light standard and therefore reduce the heat losses. While the deeper floor-plates are characterized with more transparency, and therefore are more expensive in construction and during its operation.

Table 19. Housing / cubes – implications of typology and scale

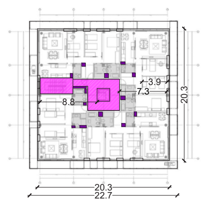
Floor plate size: S
central/excent. core
LOW OPEN %



Floor plate size: S
central excenter core
LOW OPEN %

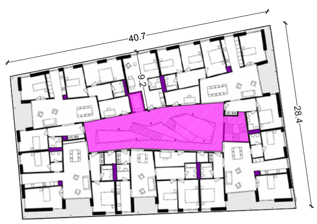


Floor plate size: M
central /excent. core
HIGH OPEN %



Floor plate size: M
excentric core / void
HIGH OPEN. %

Floor plate size: L
central core / void
MED. OPEN %



Floor plate size: L
double central core/
HIGH OPEN %

URBAN PARAMETERS, DENSITY AND LAND VALUE

The first chart establishes the relation between the urban density and FAR, height index HEI (number of levels), site occupancy %, and a land cost estimation in order to determine the characteristics of the urban contexts where project are developed. Average housing projects of a cubic volume typology are developed on a medium density city ares FAR 1.5 -2, HEI 5-7. The extremes are characterized with high land occupancy or a high-rise ability so the the FAR of their plots reaches over 6, therefore their land is highly expensive, as they are located in the city center areas.

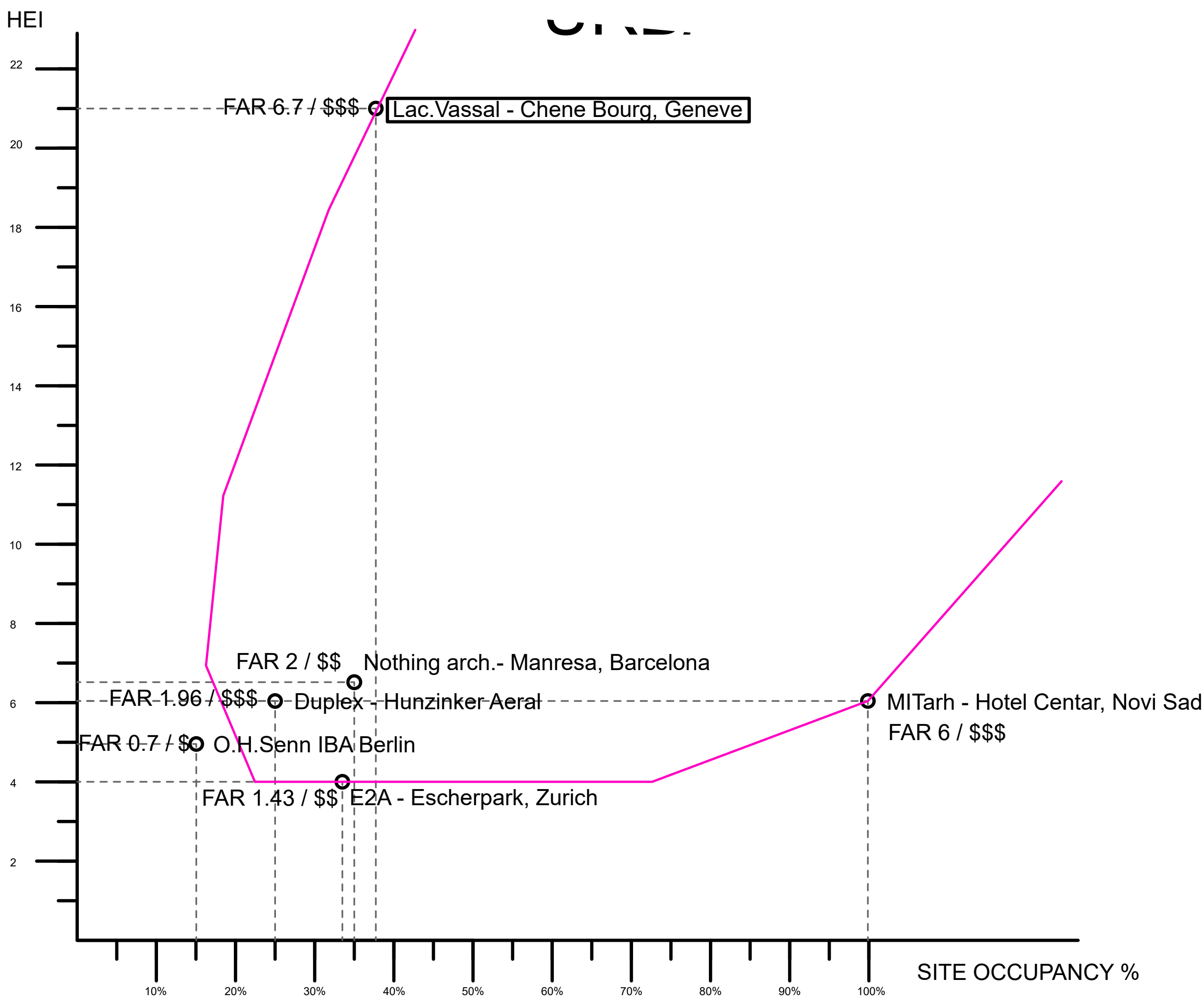


Chart1. Housing / cubes – comparative chart showing urban parameters, density and land value

PLANAR EFFICIENCY / The planar efficiency chart relates core to facade depth to the GLA%/ GFA determining the efficiency of the plan.

CONCLUSIONS:

Since the chosen plans have the ascending scale it is possible to draw a curve that shows that the plans less deep than 6.5m are on the lower limit of efficiency ~85%, while the typical ranges from 7.2-8.5, the deeper plans loose efficiency again by having introduce voids or loggias to meet the housing standards.

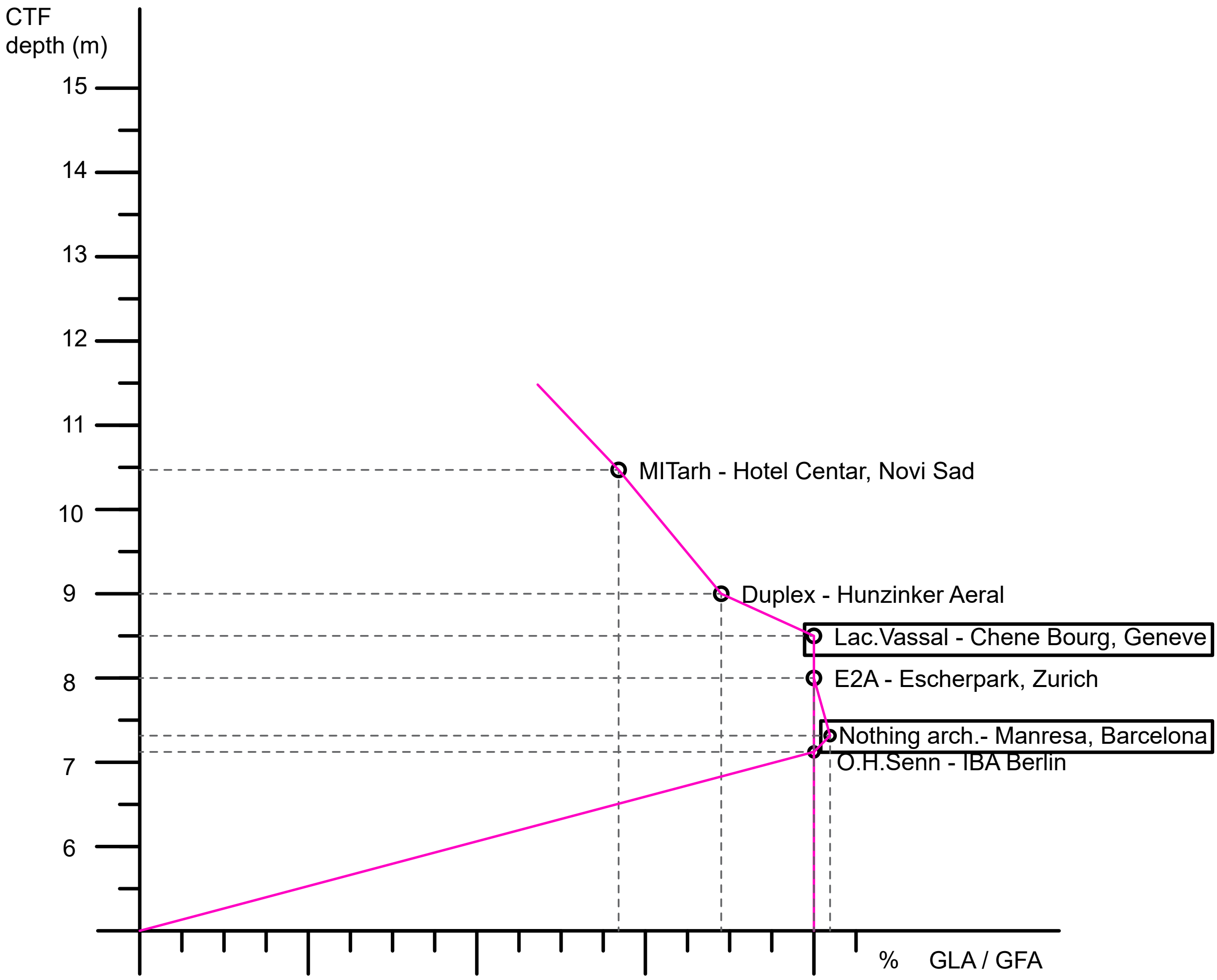


Chart 2. Housing / cubes – Planar efficiency comparative chart: CTF vs. GLA%/ GFA

PLANAR AND SECTIONAL EFFICIENCY / This chart relates the planar efficiency with the share of all floor packages in the overall height determining the structural and sectional efficiency indexed with floor package %.

CONCLUSIONS:

Most efficient projects in plan have 10-15% of floor packages /overall height. The larger and deeper floor-plates have also a larger floor-package due to larger structural spans.

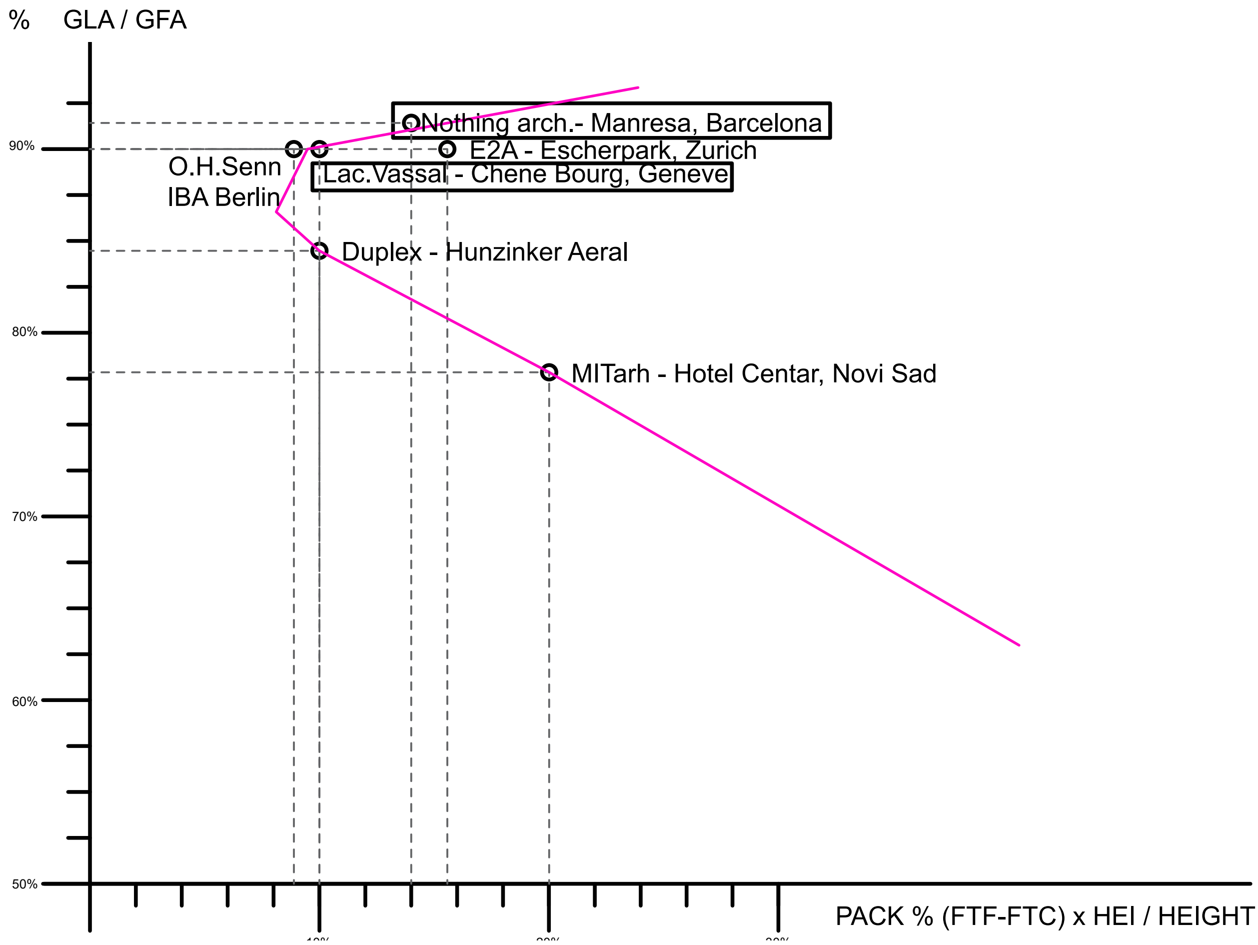


Chart 3. Housing / cubes comparative chart - Planar and sectional efficiency

DEPTH VS. PACK / Shows the interrelation between the core to facade depth CTF and the thickness of the floor package.

CONCLUSIONS:

The general tendency showed in this chart that the depth of the floor-plan is generally characterized with the increasing thickness of the floor-package. However two projects have managed to keep the floor packages very thin due to the use of smaller spans and integrated installations.

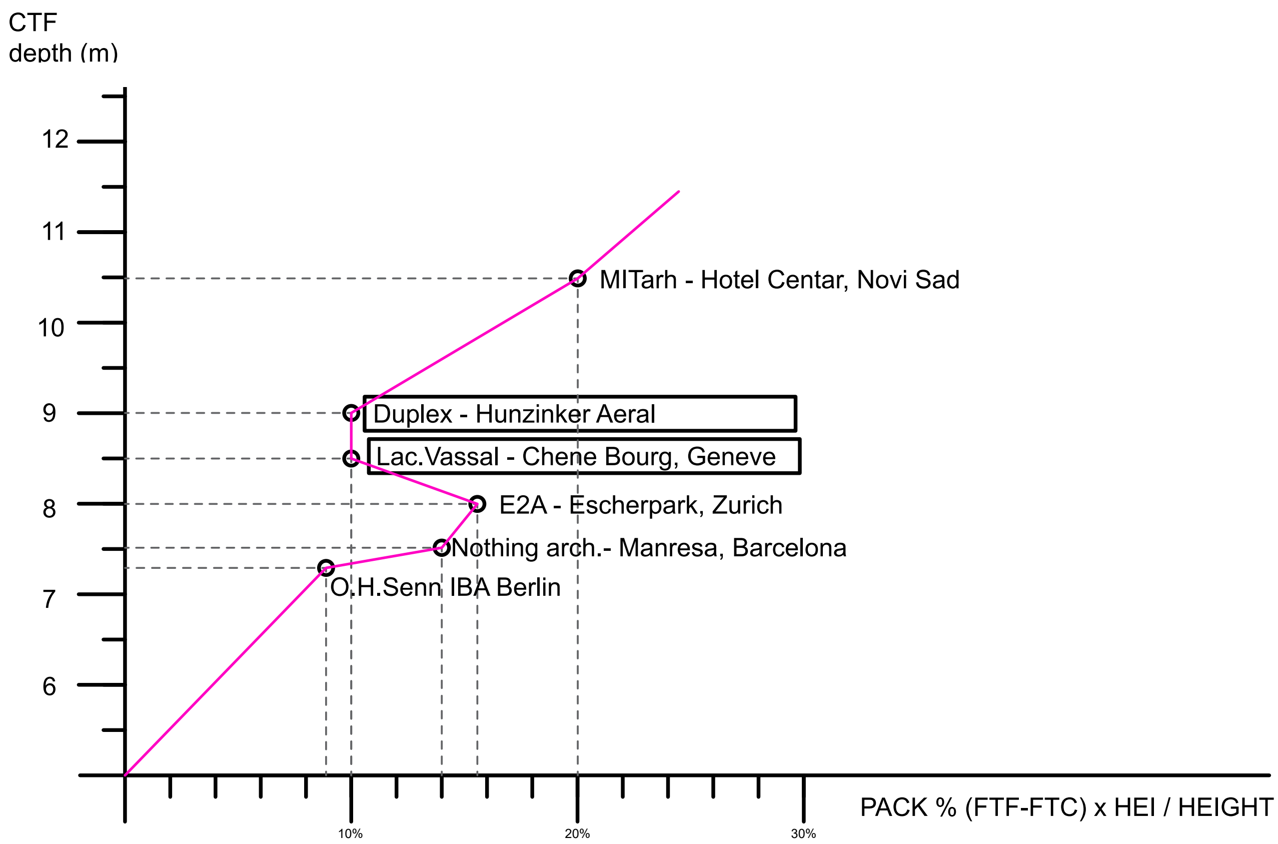


Chart 4. Housing / cubes comparative chart – CTF depth vs. Floor package

DEPTH RATIO VS. OPENINGS % / Shows the interrelation between the core to facade depth CTF and the FTC floor to ceiling height. With the indications about the % of openings on the facade and the applied thermal / light related devices.

CONCLUSIONS:

The depth optimal depth ratio for housings is between 2.8 -3.6 which is quite deep, the deeper floor-plates are usually solved with high degree of facade openings which demand an answer for light/ thermal /privacy devices dependent of the climate zone: winter-gardens, shading panels.

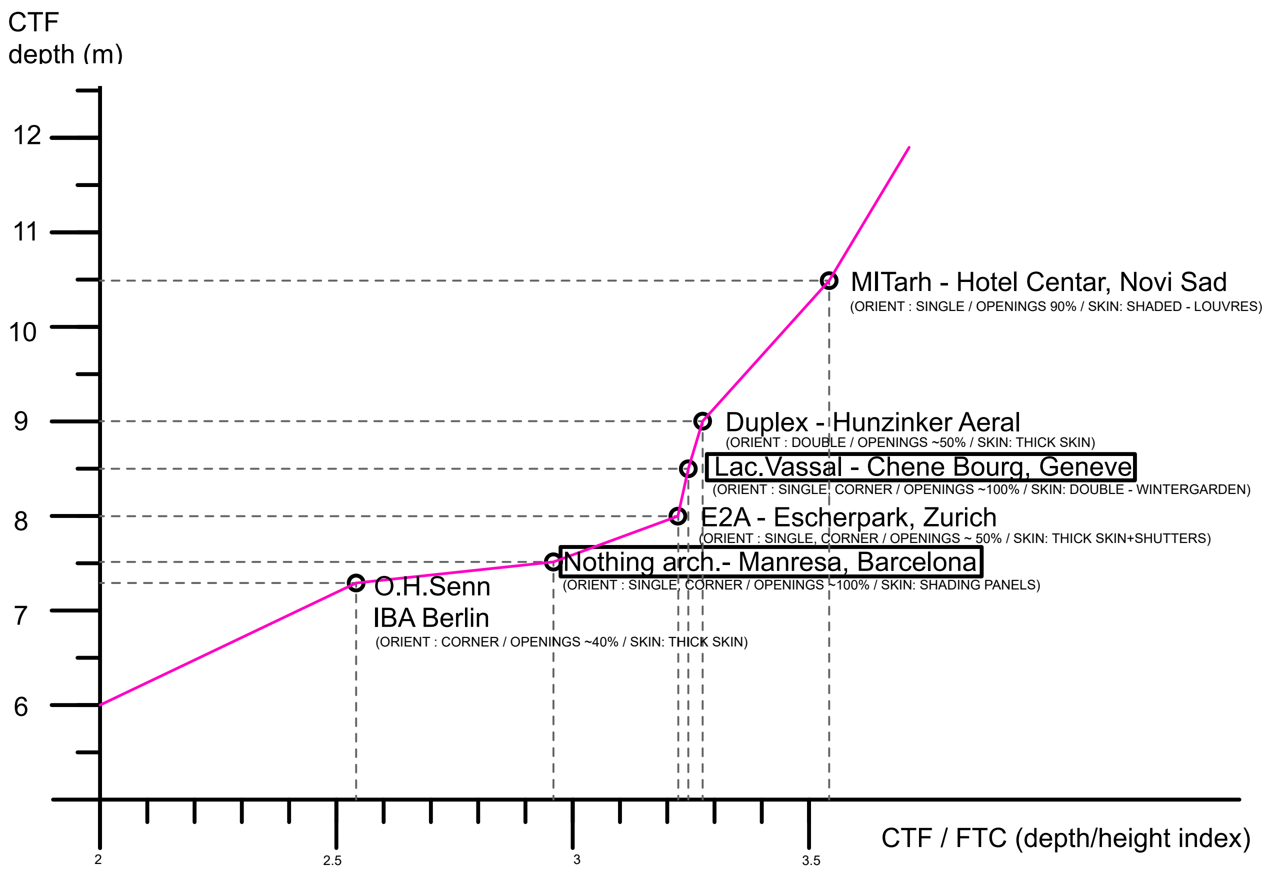


Chart 5. Housing / cubes comparative chart - Depth vs. Openings %

URBAN PARAMETERS, DENSITY AND LAND VALUE

The first chart establishes the relation between the urban density and FAR, heght index HEI (number of levels), site occupancy %, and a land cost estimation in order to determine the characteristics of the urban contexts where project are developed. Office projects of a cubic volume typology are developed in high density city ares mixed use city centers FAR 2.8 -6.7, HEI 6-8 to 20. The extremes are characterized with high land occupancy or a high-rise ability so the the FAR of their plots reaches over 6, therefore their land is highly expensive, and such extremely big building are located in the CBD areas (UNstudio tower and Citibank).

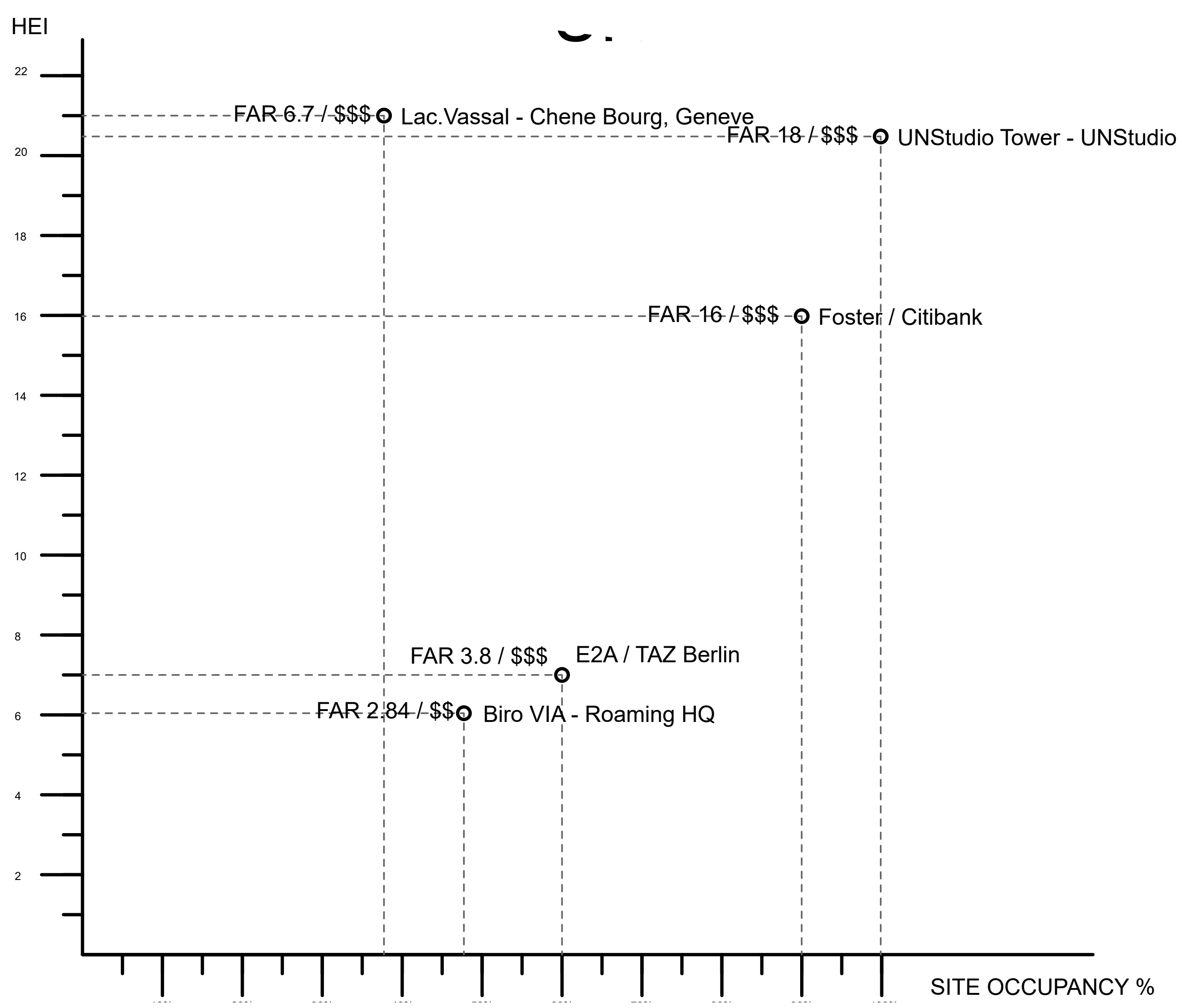


Chart 6. Office / cubes – comparative chart showing urban parameters, density and land value

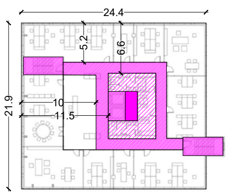
IMPLICATIONS OF TYPOLOGY AND SCALE

Typologically the buildings are chosen in ascending scales ranging from small cubic buildings with central / ex-centric cores. As the floor-plate grows the void spaces are introduced as ex-centric as a source of light and ventilation, but also increasing the perimeter of the facade and therefore the number of workplaces.

Since most of the office floor-plans are relatively deep besides introducing voids there is a need for a high level of facade transparency, which increases the heat gains and losses and therefore requires artificial conditioning.

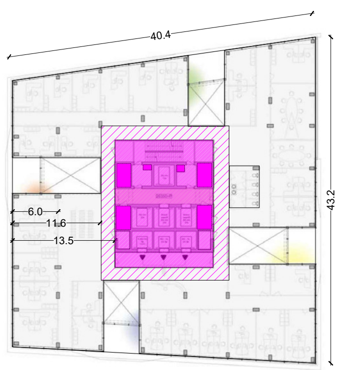
Table 20. Office / cubes – implications of typology and scale

Floor plate size: S
central/excent. core, no voids
100 % opening



Floor plate size: M
central core, no voids
100 % opening

Floor plate size: M
excent. core + excent. void
80 % opening



Floor plate size:L
central core + excenter. voids
80 % opening

Floor plate size: XL
central + excentric cores, excentric void
100 % openining

PLANAR EFFICIENCY / The planar efficiency chart relates core to facade depth to the GLA%/ GFA determining the efficiency of the plan.

CONCLUSIONS:

Since the chosen plans have the ascending scale it is possible to draw a curve that shows that the most efficient plans are 8-10m deep, the deeper plans loose efficiency again by having introduce voids and more vertical circulations and service areas, in general deep plans provide more spatial comfort but loose on the spatial efficiency.

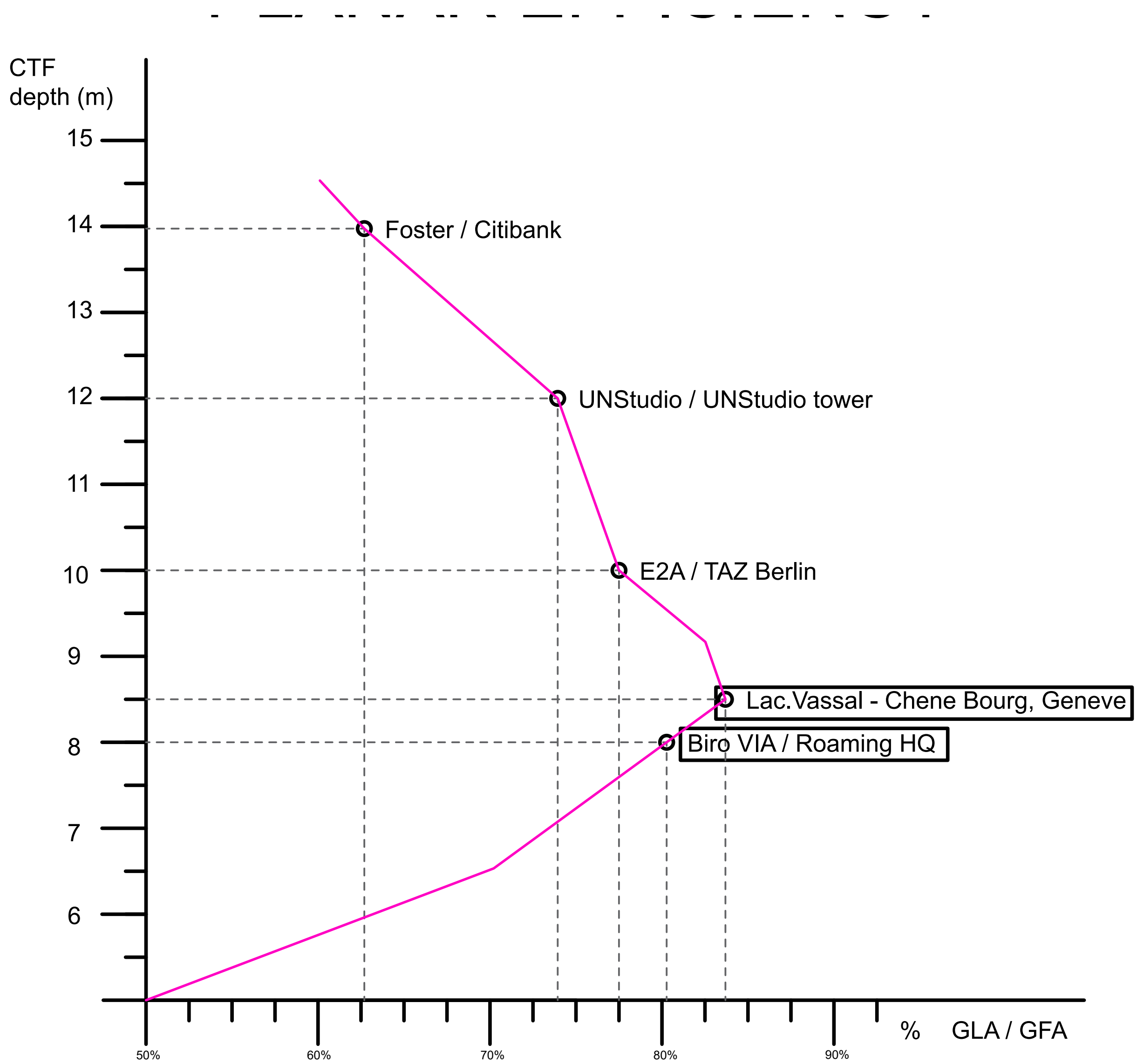


Chart 7. Office / cubes – Planar efficiency comparative chart: CTF vs. GLA%/ GFA

PLANAR AND SECTIONAL EFFICIENCY / This chart relates the planar efficiency with the share of all floor packages in the overall height determining the structural and sectional efficiency indexed with floor package %.

CONCLUSIONS:

Most efficient projects in plan have 12-16% of floor packages /overall height. The larger and deeper floor-plates of high-rise buildings (Foster and UNStudio) have also a larger floor-package due to larger structural spans and increased HVAC capacities.

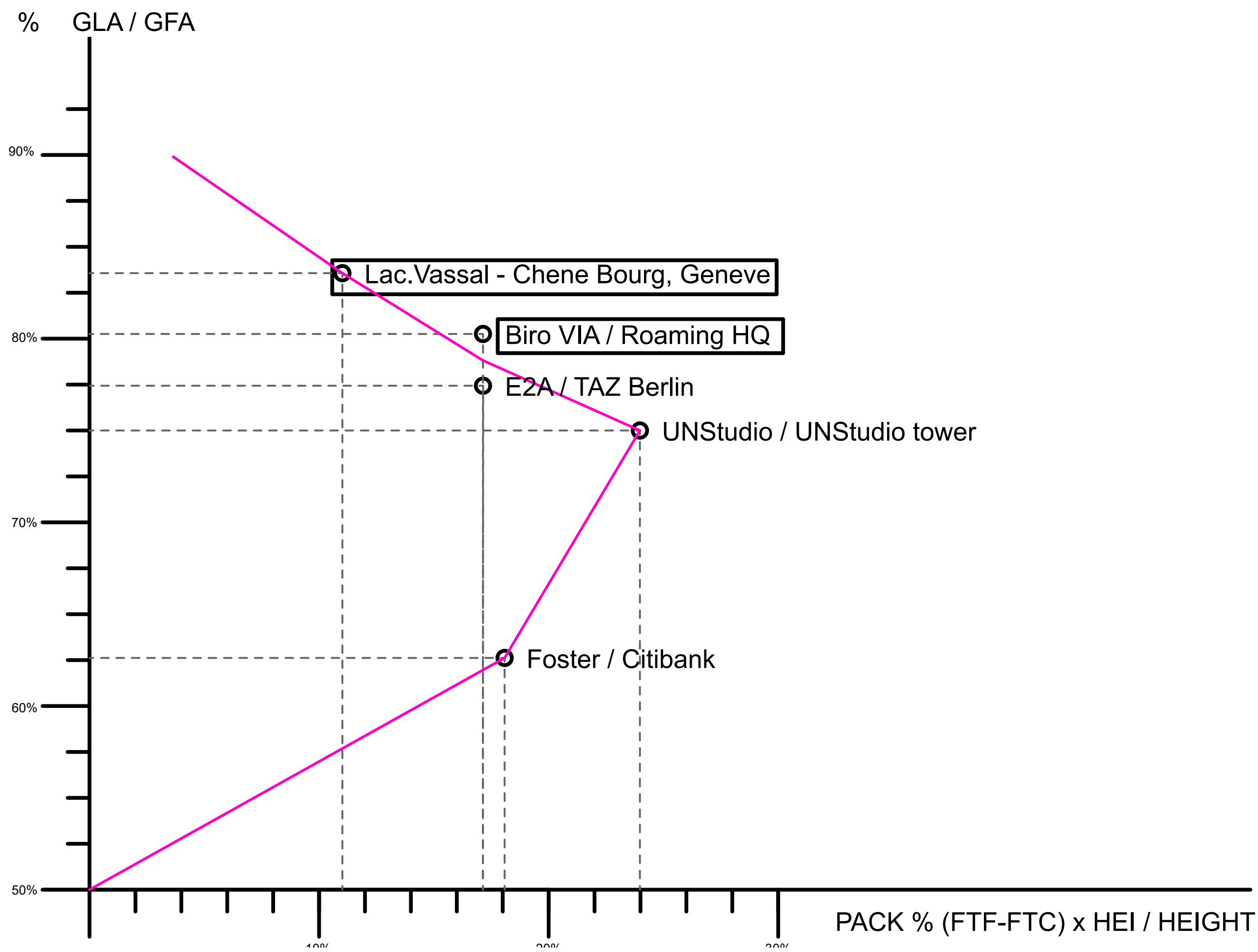


Chart 8. Office / cubes comparative chart - Planar and sectional efficiency

DEPTH VS. PACK / Shows the interrelation between the core to facade depth CTF and the thickness of the floor package.

CONCLUSIONS:

The general tendency showed in this chart that the depth of the floor-plate is generally characterized with the increasing thickness of the floor-package. However one project (Tour Opale by Lacaton & Vassal) have managed to keep the floor packages very this due to the use of smaller spans and use of natural ventilation and integrated installations.

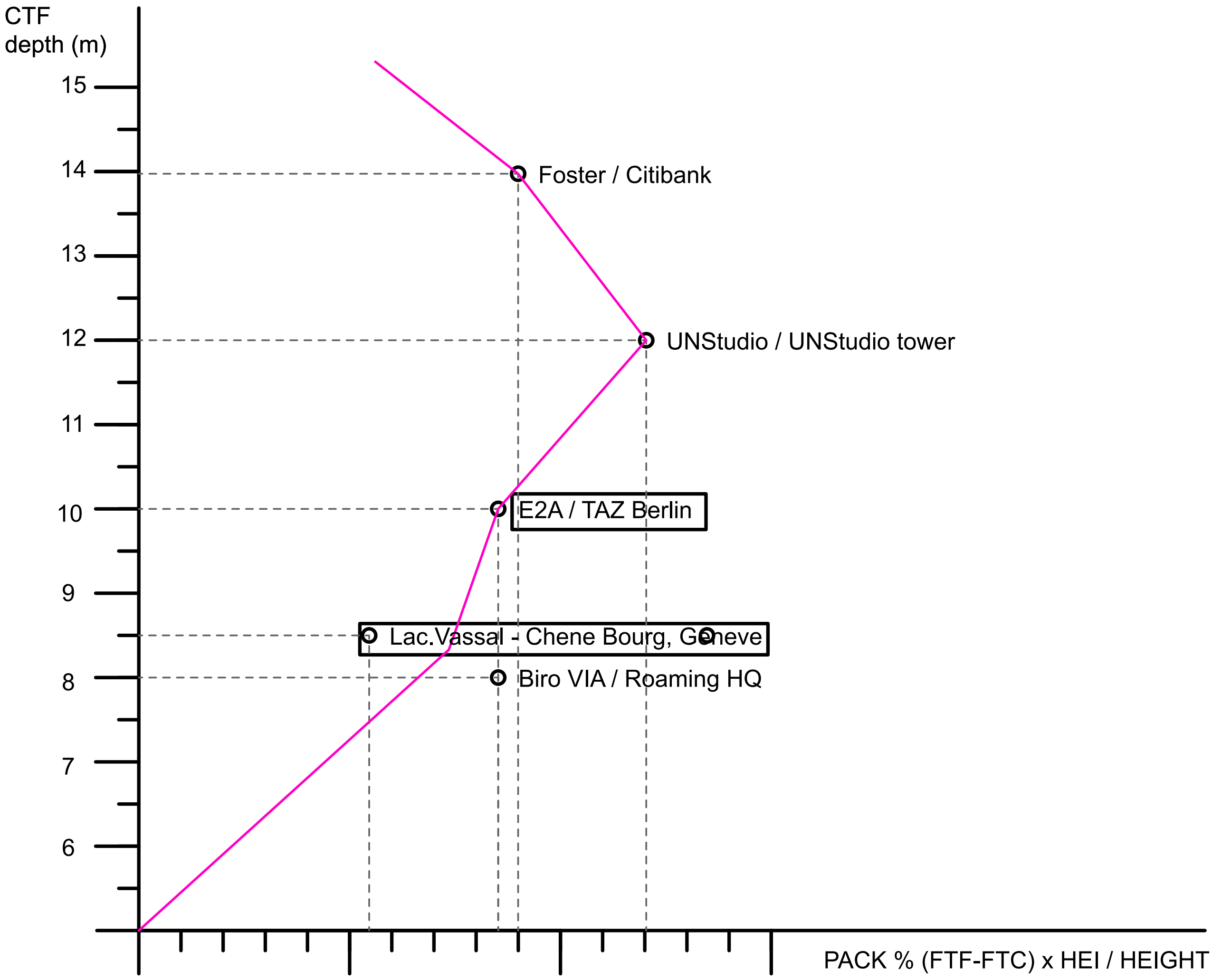


Chart 9. Office / cubes comparative chart – CTF depth vs. Floor package

DEPTH RATIO VS. OPENINGS % / Shows the interrelation between the core to facade depth CTF and the FTC floor to ceiling height. With the indications about the % of openings on the facade and the applied thermal / light related devices.

CONCLUSIONS:
The scalar relation of CTF and depth ratio is almost linear for ascending scale, average for office is between 3 -3.5 which is quite deep, the deeper floor-plates are usually solved with high degree of facade openings which demand an answer for light/thermal devices such as type of glazing, shading and HVAC.

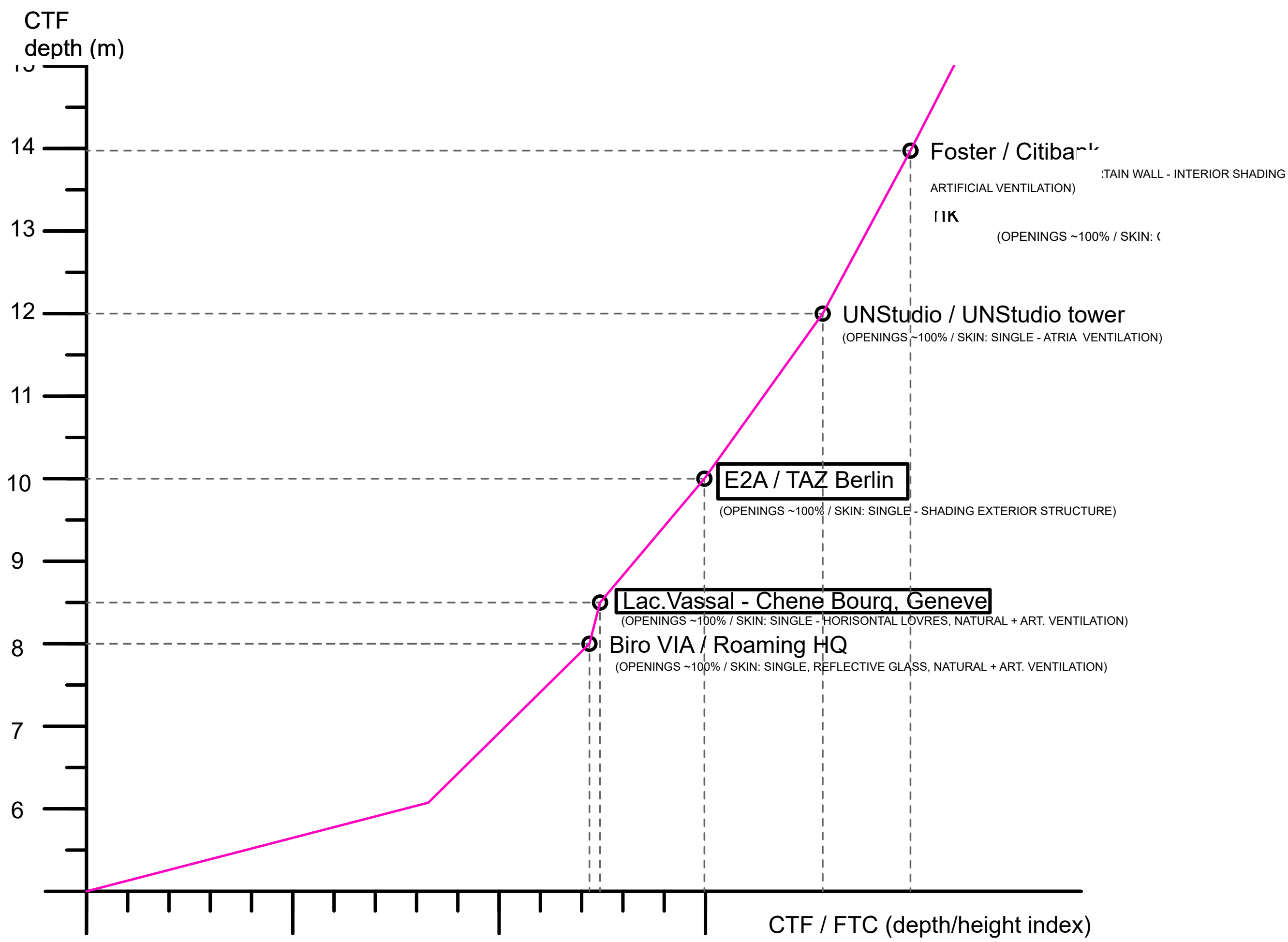


Chart 10. Office / cubes comparative chart - Depth vs. Openings %

Table 21 - Overview of chosen projects slab volume typologies

HOUSING VOLUME TYPE : SLAB
PROGRAM TYPOLOGY: HOUSING


IBA Hansaviertel/ 1957
Alvar Aalto /Berlin


Kamendin social housing / 2015/ MART Architecture / Belgrade


Gouverment sponsored housing/ 2008 /Manuel Ruiz Sanchez /Barcelona


Carree de Flot / 2014 /Nicolas Michellin / Bordeaux


Schubertsingel / 2019 /Houben Van Mierlo / Den Bosch


Block 1b / 2019/NL Architects/Utrecht


Villaverde housing / 2014 /David Chipperfield /Madrid

OFFICE VOLUME TYP.E :
PROGRAM TYPOLOGY: OFFICE


Ministry od Education / 1943 / Corbusier, Niemeyer, Costa / Rio de Janeiro


Aufbauhaus 84 / 2015 /Barkow Leibinger /Berlin


Siemens HQ / 2012/NL Architects/Hengelo


Guldenoffice / 2018 /KSP Juergen Engel /Braunschweig


Pulse office building / 2019 / BVF Architectes / St.Denis

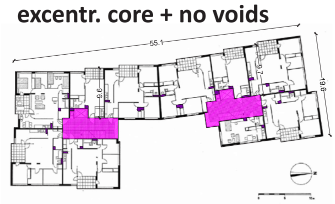
IMPLICATIONS OF TYPOLOGY AND SCALE

Typologically the buildings are chosen in ascending scales in terms of the slab thickness ranging from connected cube buildings, central double loading corridor typology, towards thicker slab with void introduced such as double bay housing atrium building all the way up to a perimeter block which is actually a folded slab.

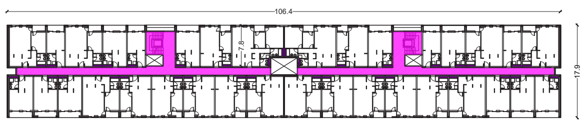
As the floor-plate grows the void spaces is introduced and gradually a double orientation is enabled. As the building grow to a block scale single orientation can be potentially reintroduced.

Table 22. Housing / slabs – implications of typology and scale

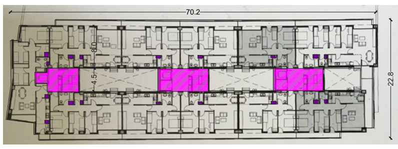
Double, corner orient.
excentr. core + no voids



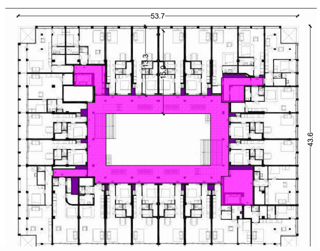
Single orient.
excentr. core + no voids



Double, corner orient.
central core + light shafts



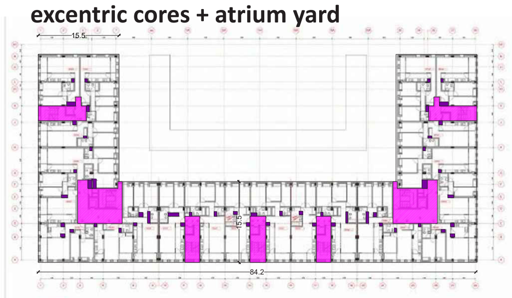
Double, corner orient.
cores along atrium



Double orient.
cores along atrium

Double orient.
cores along atrium

Double orient.
excentric cores + atrium yard



URBAN PARAMETERS, DENSITY AND LAND VALUE

The first chart establishes the relation between the urban density and FAR, height index HEI (number of levels), site occupancy %, and a land cost estimation in order to determine the characteristics of the urban contexts where project are developed. Average housing projects of a slab volume typology are developed on a medium density city ares FAR 1- 3.8, HEI 5-8. The projects with higher site occupancy are developed closer to the city centers on a more expensive land.

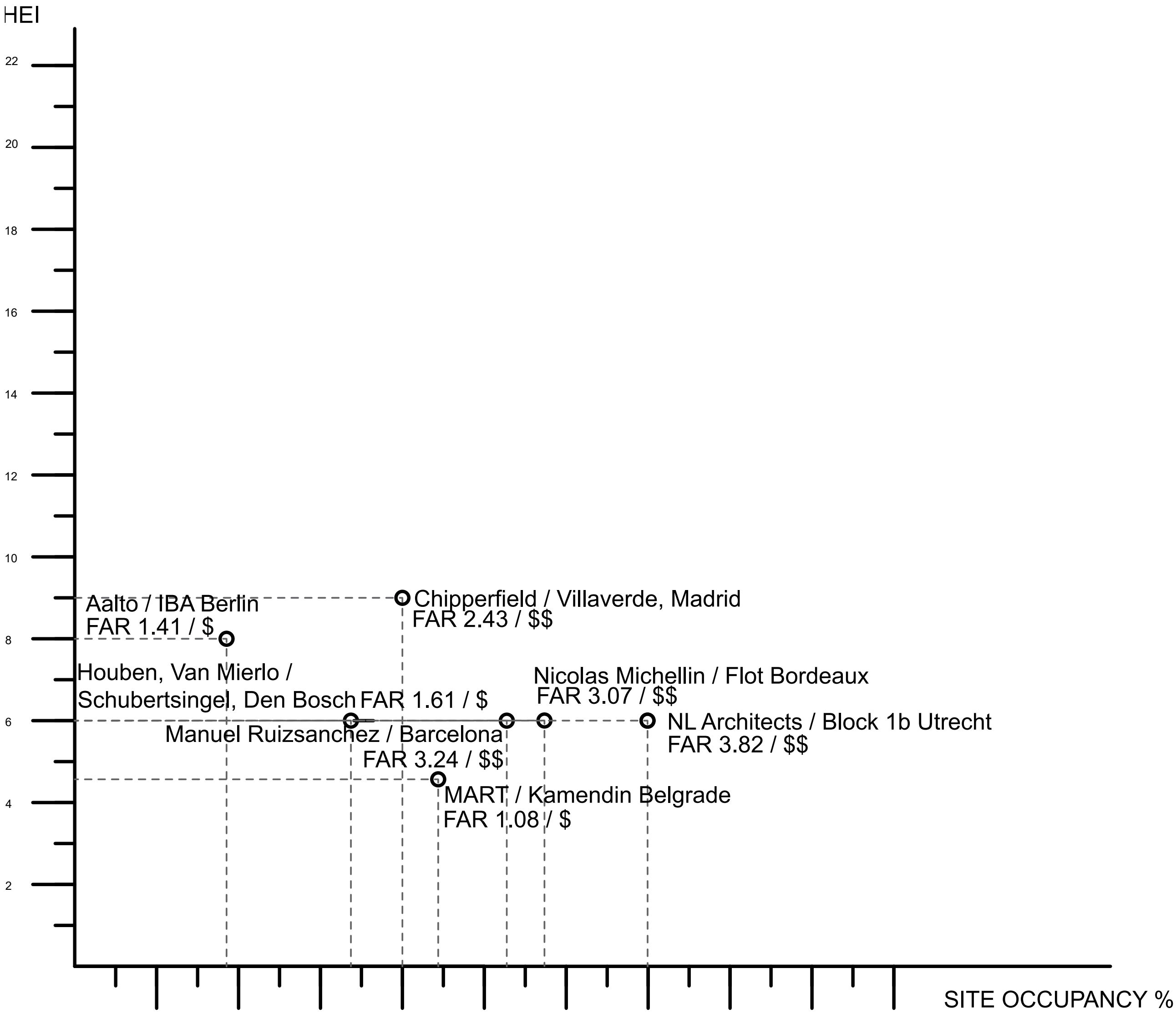


Chart 11. Housing / slabs – comparative chart showing urban parameters, density and land

PLANAR EFFICIENCY / The planar efficiency for the slab buildings relates the total slab thickness to the GLA%/GFA determining the efficiency of the plan.

CONCLUSIONS:

Since the chosen plans have the increasing thickness dimension it is possible to draw a curve that shows that the most efficient plans are the ones belonging to thickest slabs such as double bay or double loading corridor typologies. The typologies that work with real double orientation apartments such as gallery housing or multiple cores (Chipperfield, Villaverde) loose slightly on the efficiency in plan but gain the higher standard of housing.

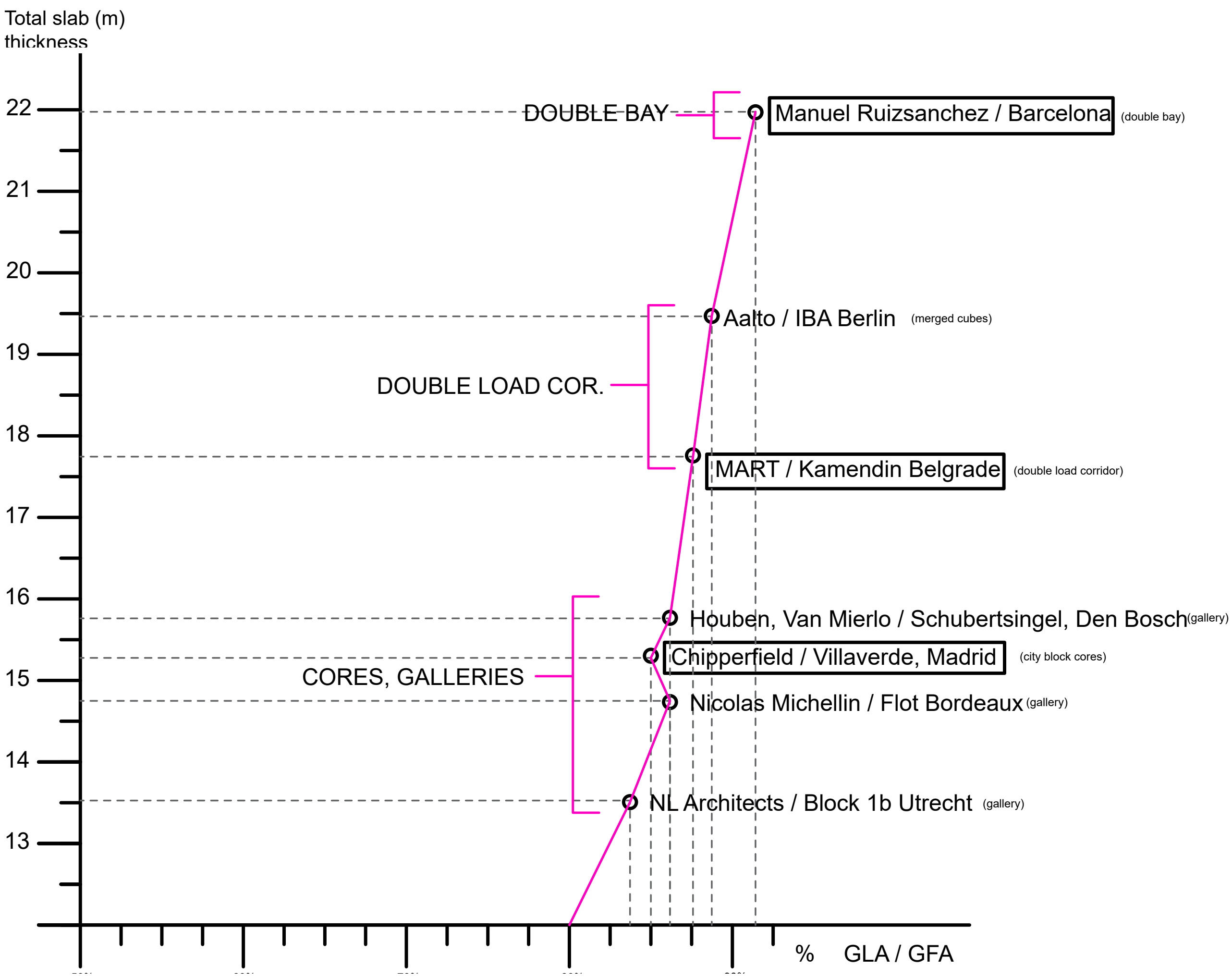


Chart 12. Housing / Slabs – Planar efficiency comparative chart: Slab thickness vs. GLA%/ GFA

PLANAR AND SECTIONAL EFFICIENCY / This chart relates the planar efficiency with the share of all floor packages in the overall height determining the structural and sectional efficiency indexed with floor package %.

CONCLUSIONS:

Most efficient projects in plan have 8-12% of floor packages /overall height. In housing the thickness of the floor-slab package is mainly determined by the span of structural grid as they don't use the ceiling HVAC conduit for heating and cooling. The social housing projects seem to be most efficient in section and use the most rational grids. A project with least package efficiency is a former office building in Den Bosch.

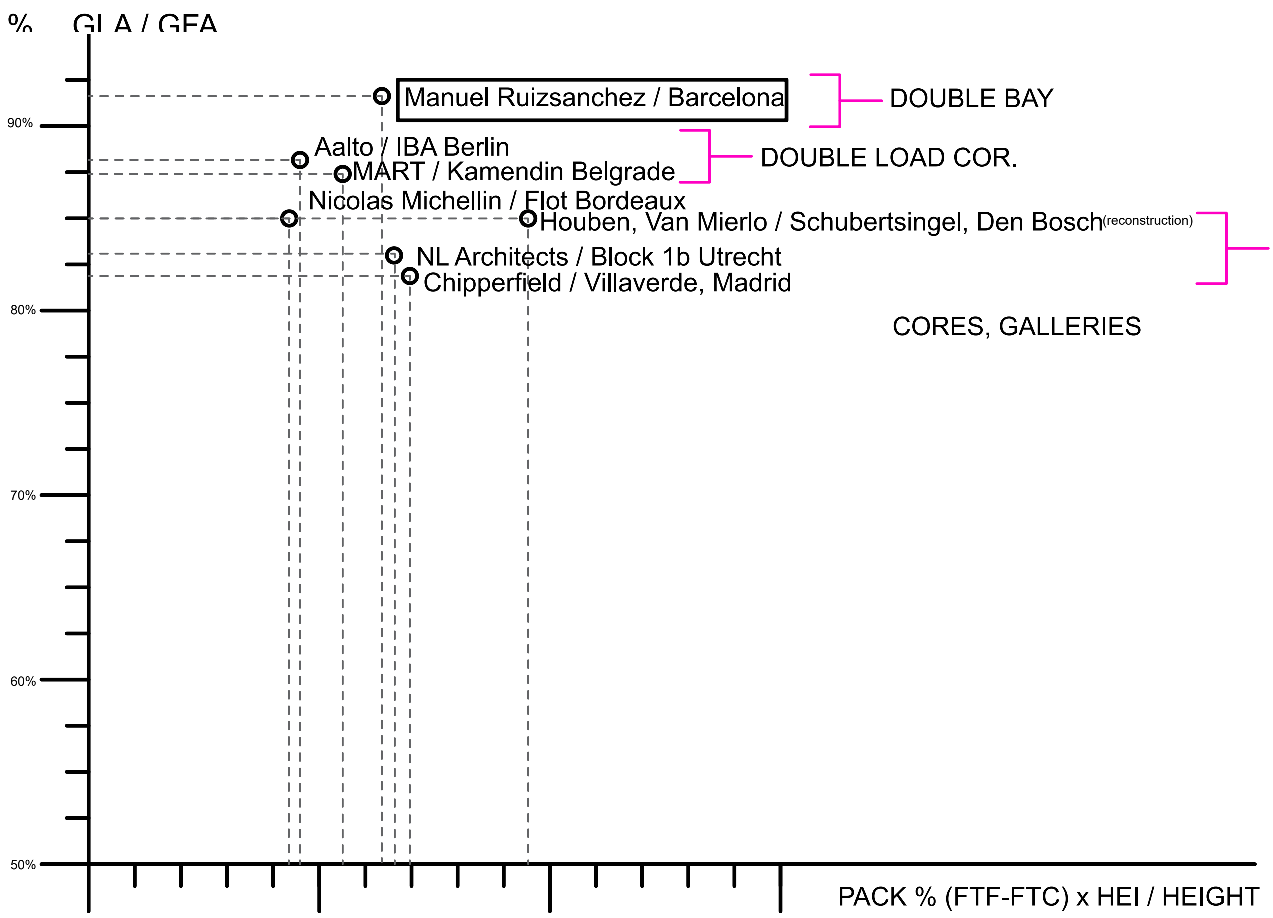


Chart 13. Housing / slabs comparative chart - Planar and sectional efficiency

DEPTH VS. PACK / Shows the interrelation between the depth of slab buildings (total slab thickness) and the thickness of the floor package.

CONCLUSIONS:

The general tendency showed in this chart that with the increase the slab depth does not affect very much the floor-package, the deeper slabs use the smaller spans (usually social housing), while the slabs built less deep a bit smaller but single spans and are therefore more flexible and with a thin floor-slab package.

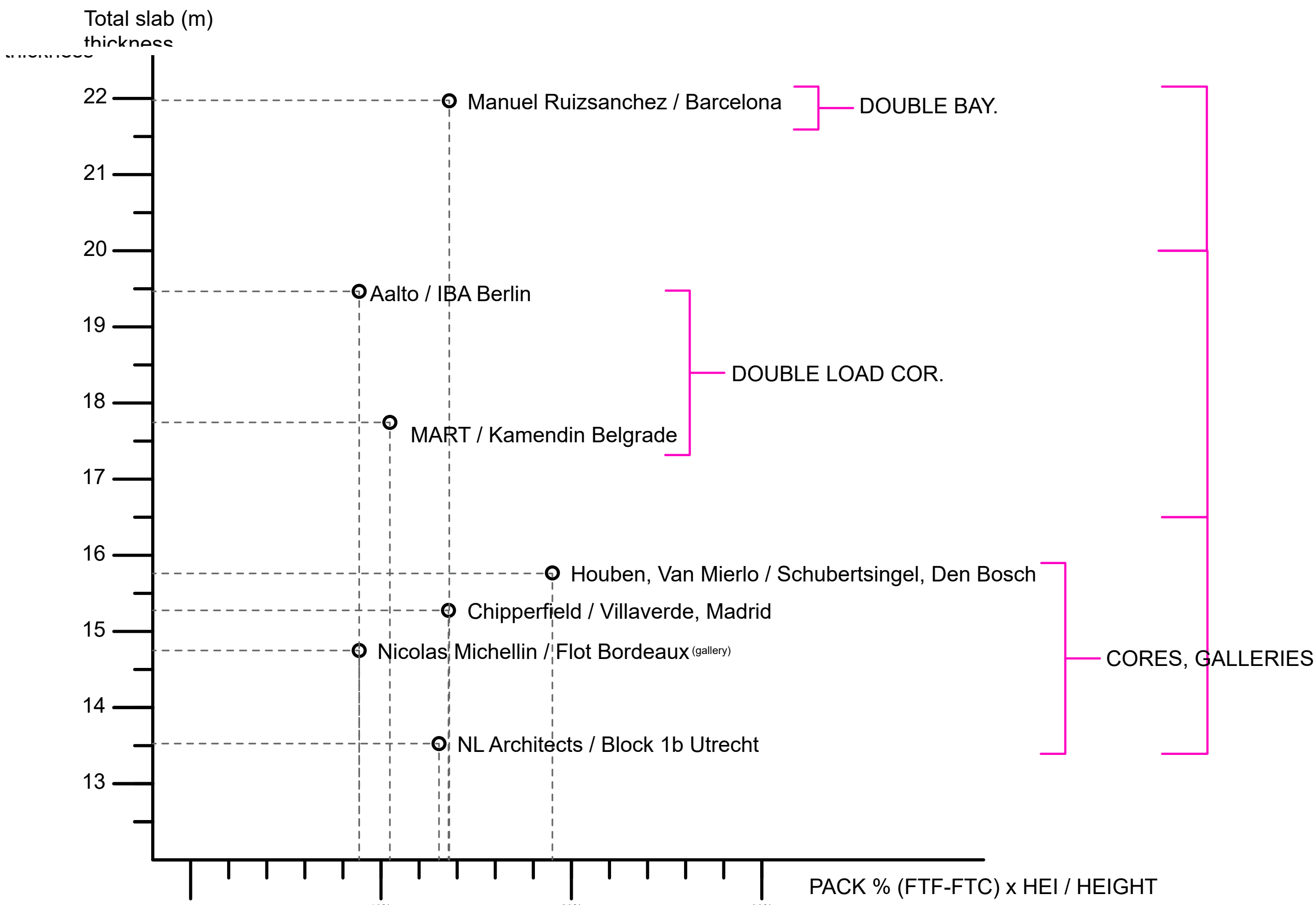


Chart 14. Housing / Slabs- comparative chart – CTF depth vs. Floor package

DEPTH RATIO VS. OPENINGS % / Shows the interrelation between the total thickness of the slab building related to depth and the FTC (floor to ceiling height) with the indications about the % of openings on the facade and the applied thermal / light related devices.

CONCLUSIONS:

The scalar relation of the overall building depth and the depth ratio (CTF/FTC) is almost linear because of the ascending scale of chosen buildings, average for housing slabs is between 2.5 -3.1. The deeper floorplans are usually solved with higher % of facade openings even if located in the colder climate (Den Bosch example), while the shallower can receive sufficient light even with less openings in the warmer climates (Chipperfield, Madrid).

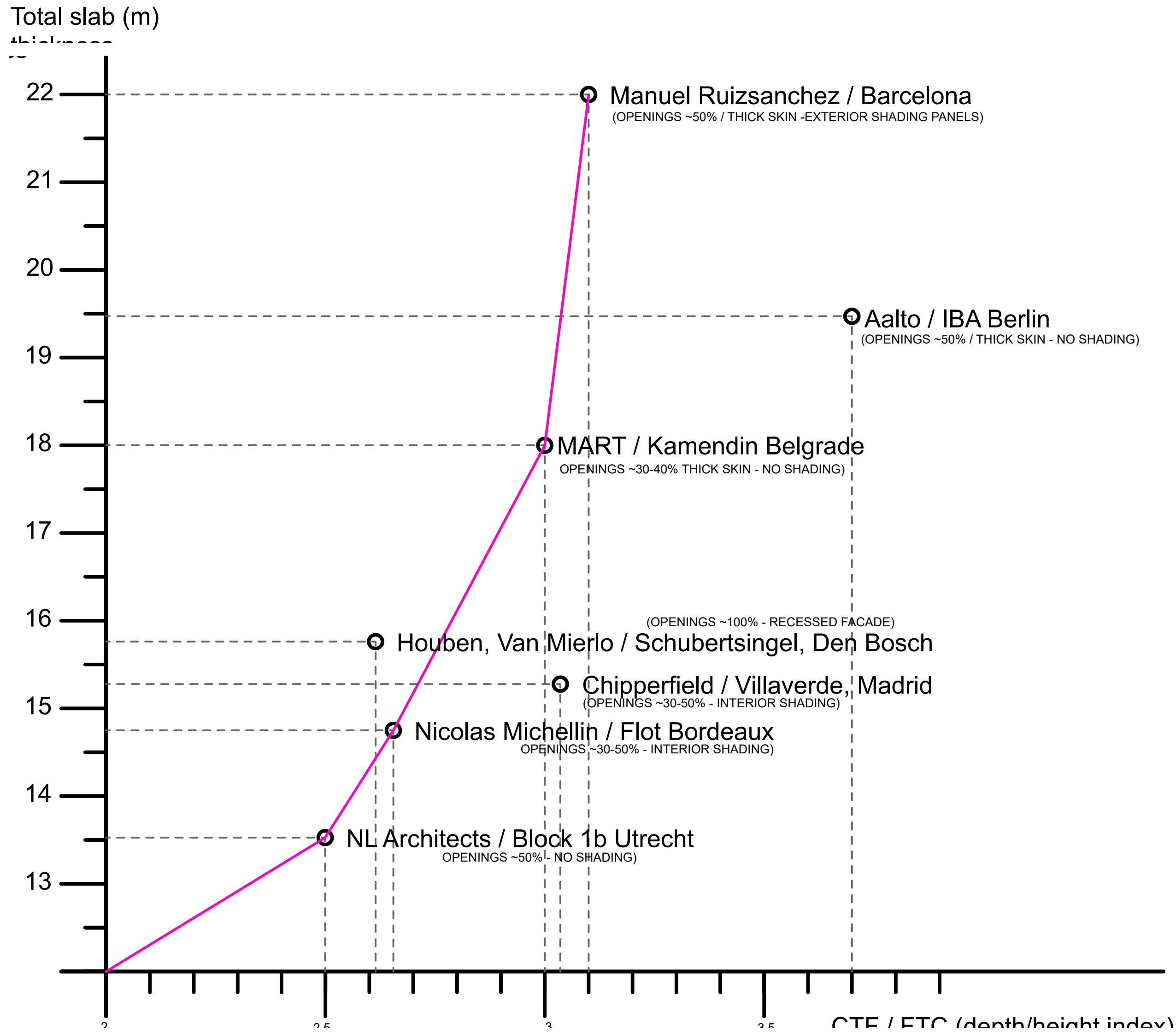


Chart 15. Housing / cubes comparative chart - Depth vs. Openings %

URBAN PARAMETERS, DENSITY AND LAND VALUE

The first chart establishes the relation between the urban density and FAR, height index HEI (number of levels), site occupancy %, and a land cost estimation in order to determine the characteristics of the urban contexts where project are developed. Average housing projects of a slab offices are developed on a medium density city ares FAR 2.7- 4.8, with average 50% site coverage, HEI 6-10 usually not built as highrises. The projects with higher site occupancy are developed closer to the city centers on a more expensive land, all the project except the Siemens HQ are built within mixed use city centers..

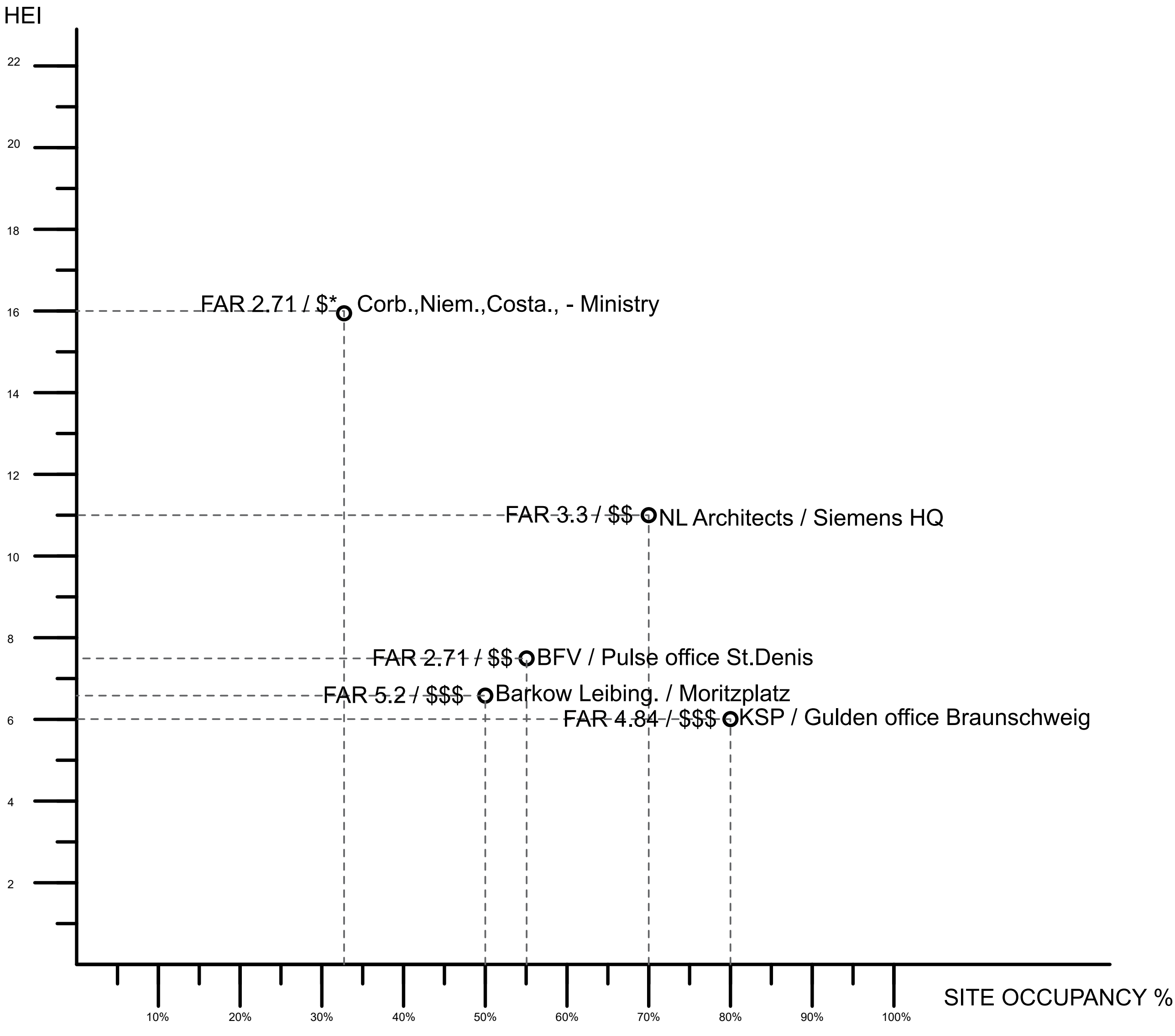


Chart 16. Office / slabs – comparative chart showing urban parameters, density and land value

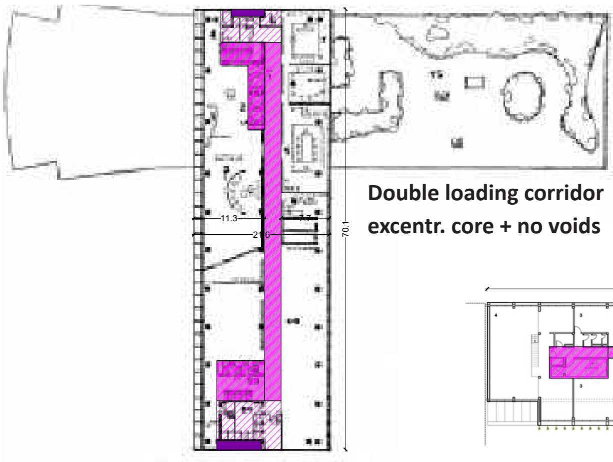
IMPLICATIONS OF TYPOLOGY AND SCALE

The chosen slab office buildings are relatively similar in scale in terms of the slab thickness, and typologically are organized as central double loading corridor typology, or double bay typology with services and cores in between two bays .

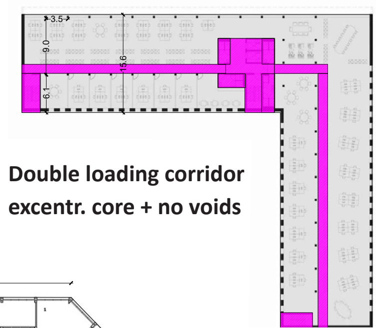
Double bay offices facilitate more services and can grow deep, so they are more convenient for HQs, wile double loading corridor offices achieve depth by being more flexible and transparent as they don't have visual obstacles between facades.

In terms of fitting their context slab offices can be freestanding or if built in more dense areas can easily be a part of the compact city block, or can grow up to a scale of a full block.

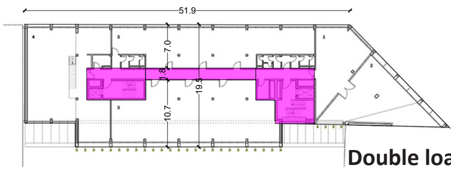
Table 23. Office / slabs – implications of typology and scale



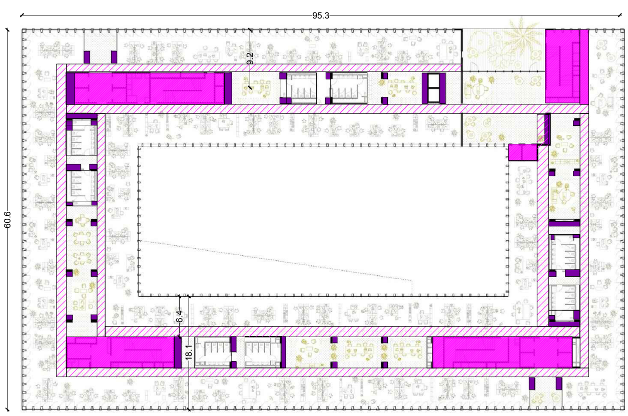
Double loading corridor excentr. core + no voids



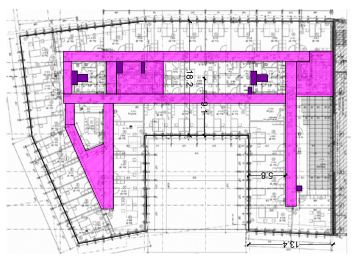
Double loading corridor excentr. core + no voids



Double loading corridor centr. core + no voids



Doublebay office, centr. cores and services + entrance void



Doublebay office, centr. cores and services + no voids

PLANAR EFFICIENCY / The planar efficiency for the slab buildings relates the total slab thickness to the GLA%/GFA determining the efficiency of the plan.

CONCLUSIONS:

The spatial efficiency of typical plans of the chosen project can be divided into two groups : double loading corridor projects and double bay projects(The modernist example is less efficient in plan due to the fact that it is an old public project). Double loading corridor project are more efficient in plan, because of the increased depth (Barkow & Leibinger) or increased length (Siemens HQ). Double bay offices offer higher standards and more services therefore their GLA% is 5-10% smaller.

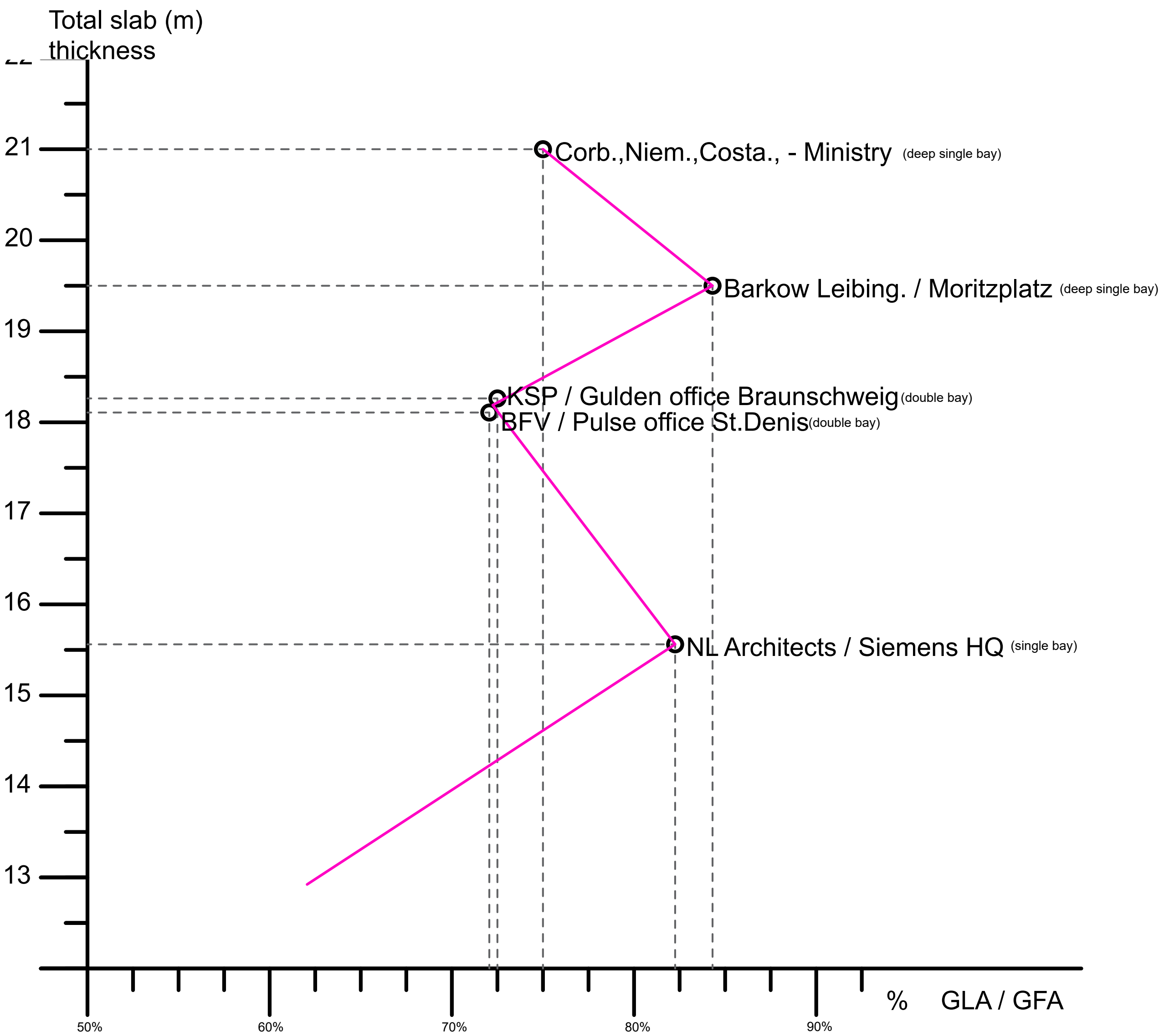


Chart 17. Office / slabs – Planar efficiency comparative chart: Slab thickness vs. GLA%/ GFA

PLANAR AND SECTIONAL EFFICIENCY / This chart relates the planar efficiency with the share of all floor packages in the overall height determining the structural and sectional efficiency indexed with floor package %.

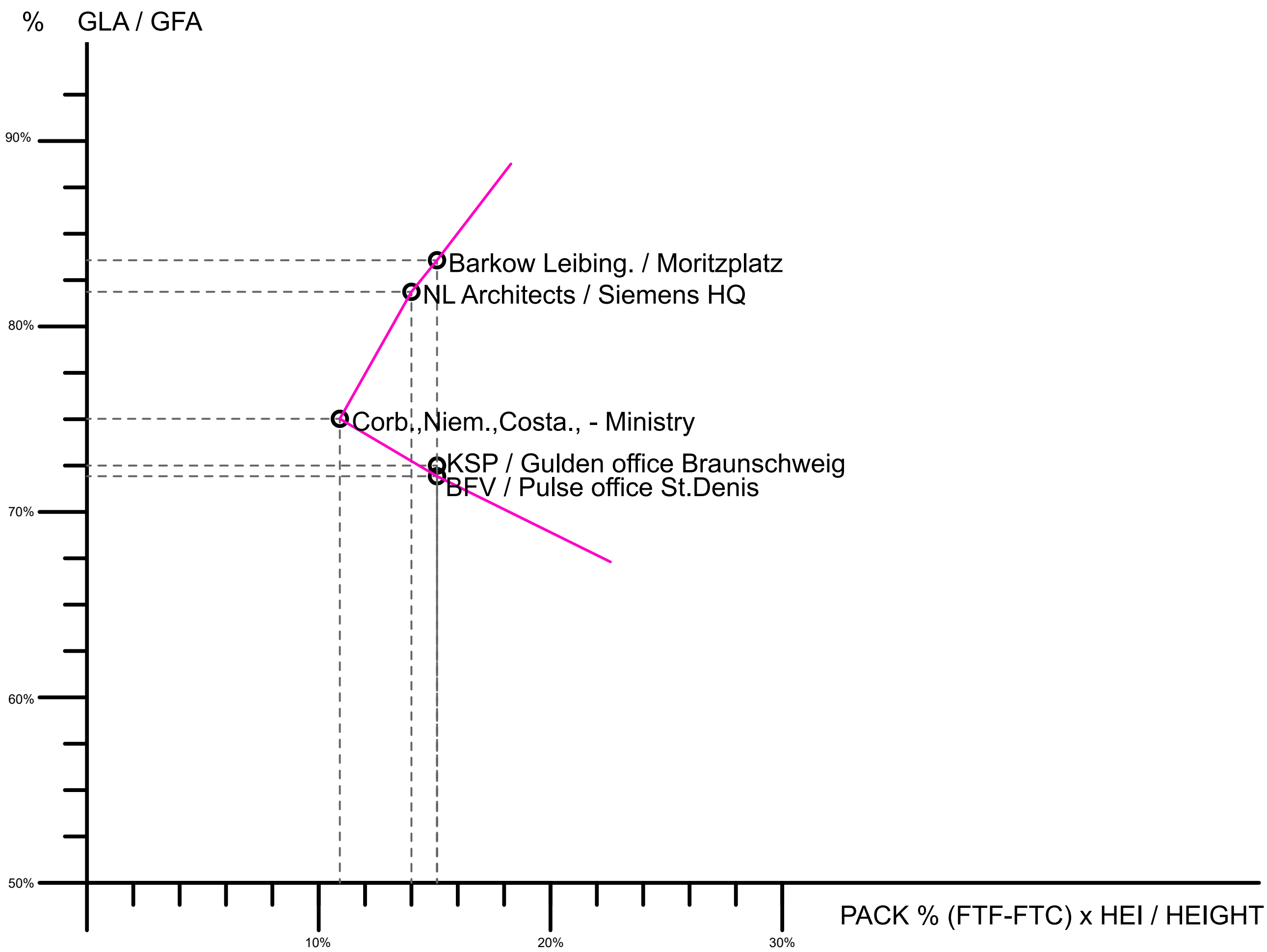


Chart 18. Office / slabs comparative chart - Planar and sectional efficiency

DEPTH VS. PACK / Shows the interrelation between the depth of slab buildings (total slab thickness) and the thickness of the floor package.

CONCLUSIONS:

Almost all the office plans have similar thickness of the floor package ~15% of the overall height. This tendency does not change a lot even thought the total slab thickness varies from 15.5-19.5m since the structural spans are kept short and the HVAC standards are relatively similar for all the buildings.

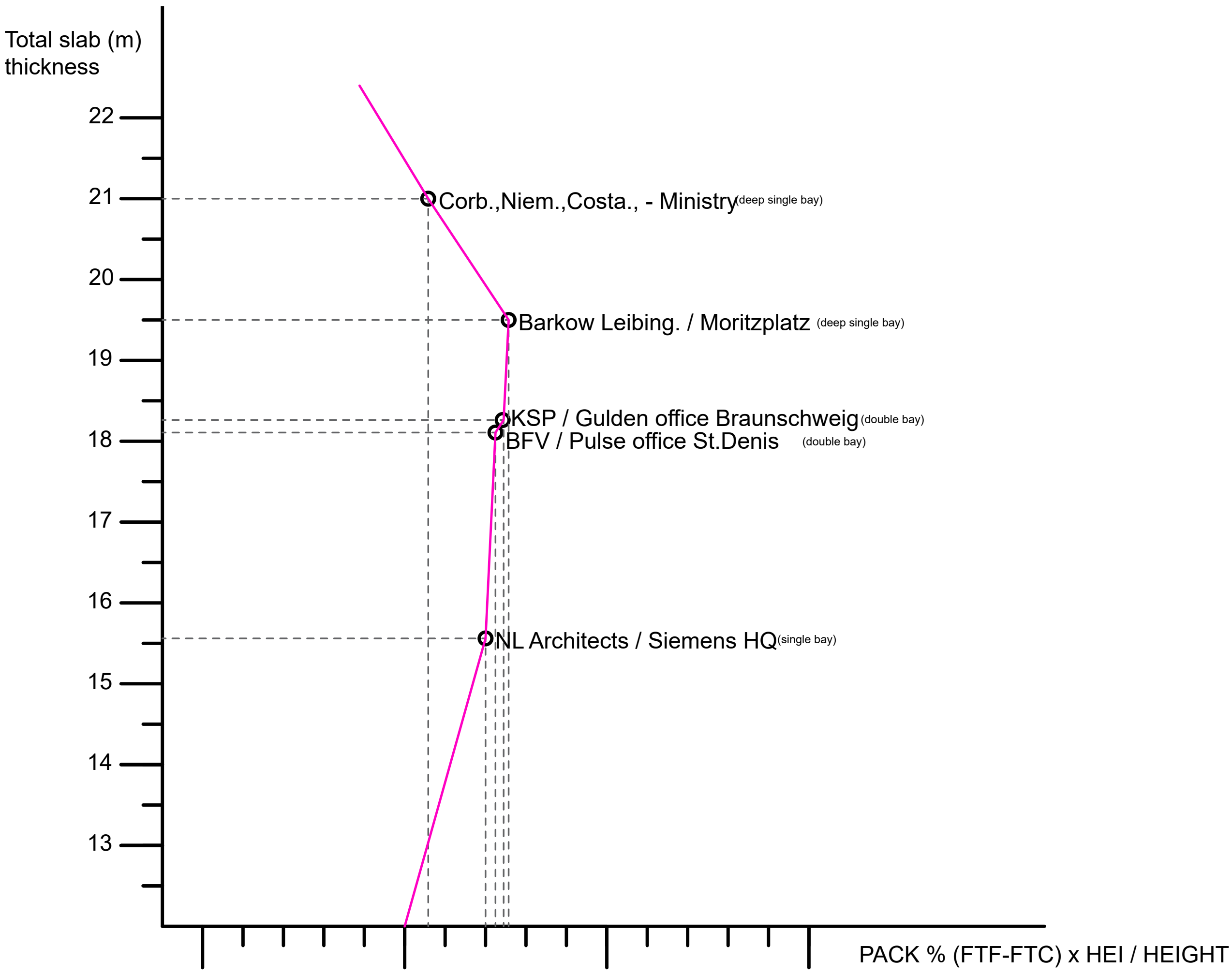


Chart 19. Office / Slabs- comparative chart – CTF depth vs. Floor package

DEPTH RATIO VS. OPENINGS % / Shows the interrelation between the core to facade CTF of slab buildings (in this case this is the depth of the bay) related to depth and the FTC (floor to ceiling height) with the indications about the % of openings on the facade and the applied thermal / light related devices.

CONCLUSIONS:
Central corridor buildings tend to provide more transparency even with the small depth ratio due to the need that the central corridor areas also receive natural light. Because of the large % of openings they integrate facade gestures to prevent heat gains. Double bay buildings are less transparent as their bays even with the higher depth receive sufficient light while central services are artificially lighted. By being less transparent they are more insulated and therefore more efficient in terms of energy consumption.

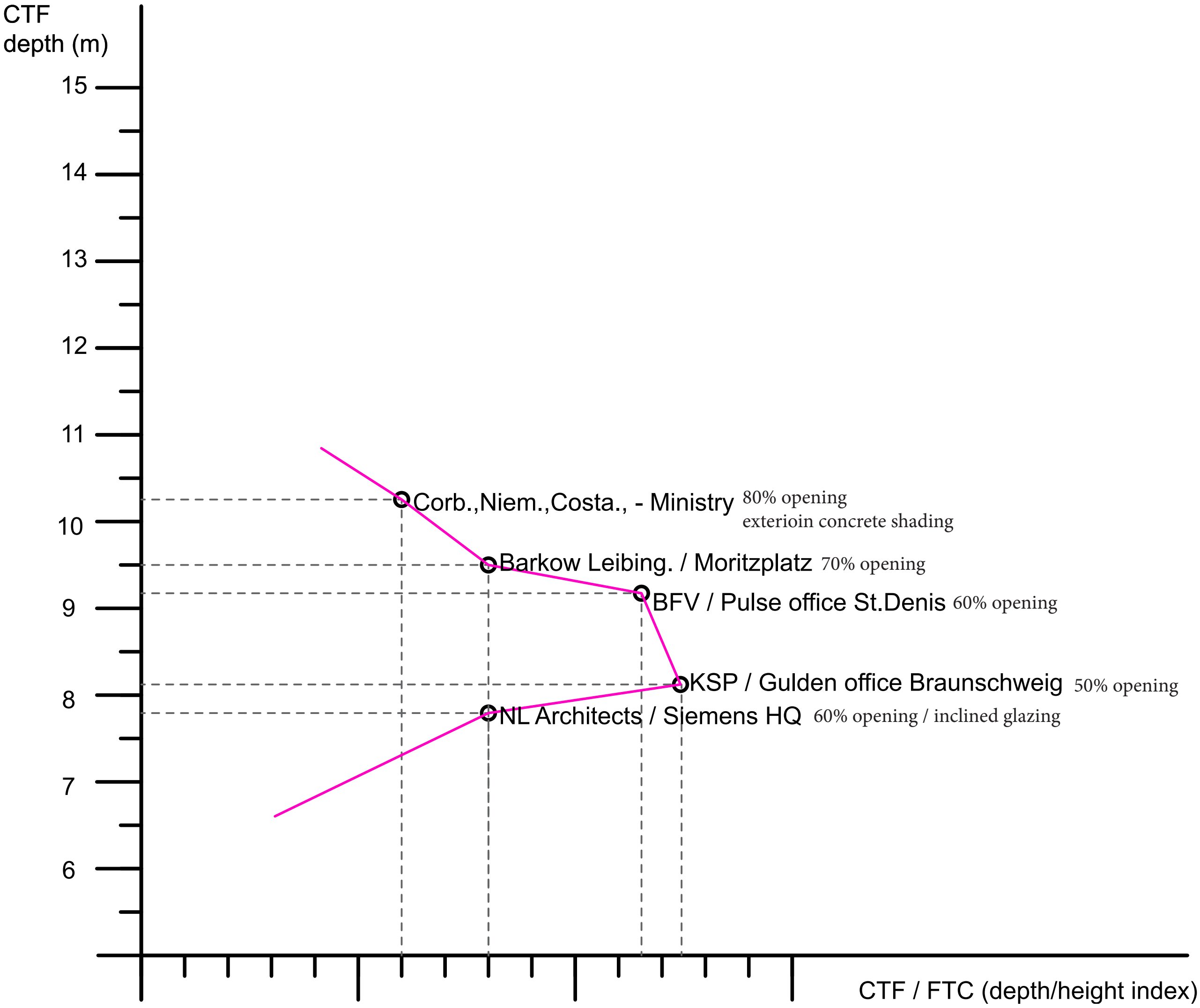


Chart 20. Office / cubes comparative chart - Depth vs. Openings %

PLANAR EFFICIENCY / The planar efficiency chart relates core to facade depth to the GLA%/GFA determining the efficiency of the plan.

CONCLUSIONS:

It can be observed that housing projects have a 5-10% more efficient floor-plan than office projects, besides housing project have a less deep floor-plate 7-9m CTF. Overlapping values which satisfy both programs can be drawn.

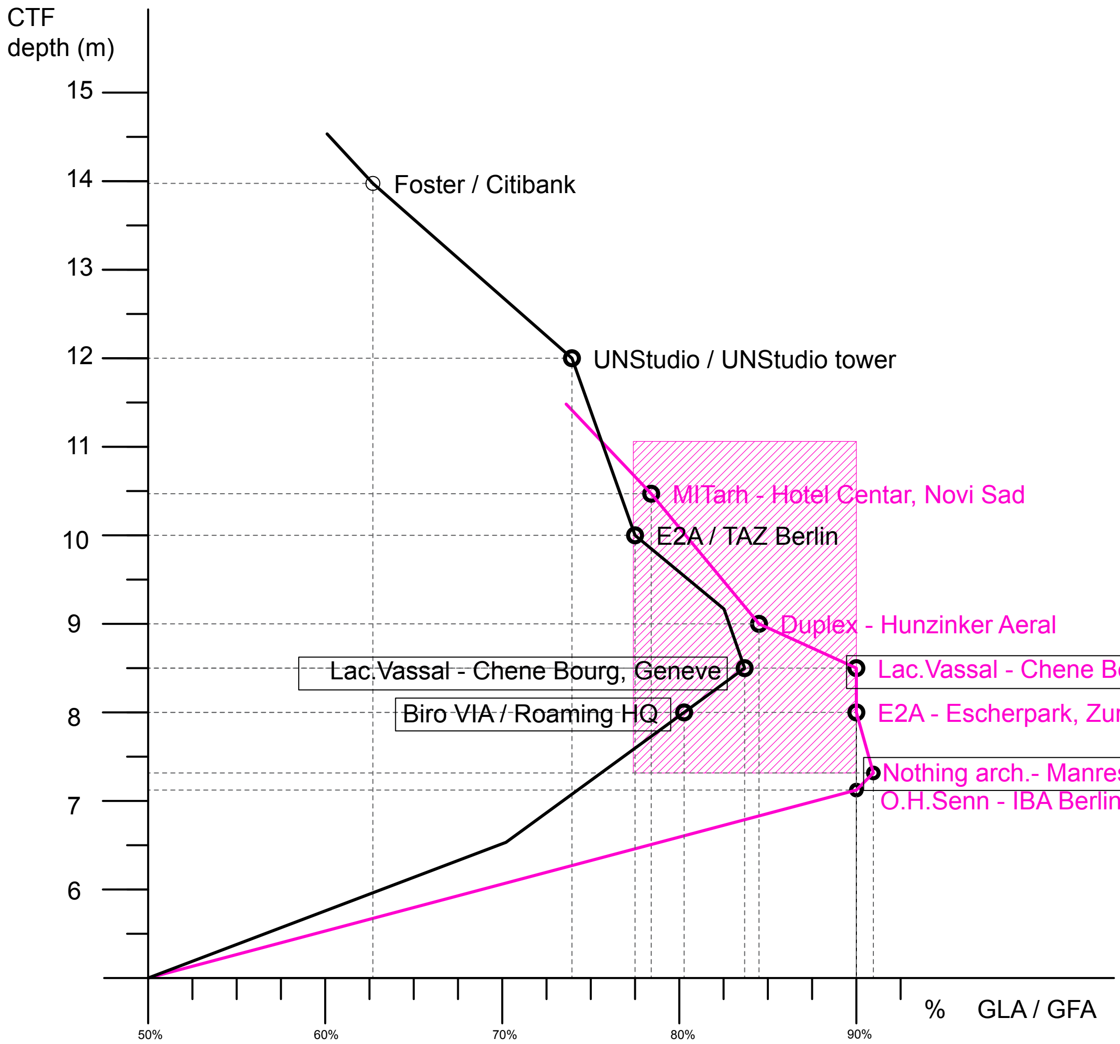


Chart 21. Office vs. Housing / cubes comparative chart - Planar efficiency

PLANAR EFFICIENCY / The planar efficiency for the slab buildings relates the total slab thickness to the GLA%/GFA determining the efficiency of the plan.

CONCLUSIONS:

It can be observed that housing projects have a 5-10% more efficient floor-plan than office projects. But it can be observed that office slabs are not so much deeper than housing which was not the case with cubes. Overlapping values which satisfy both programs can be drawn: slab thickness 17-21m, 80-85% GLA.

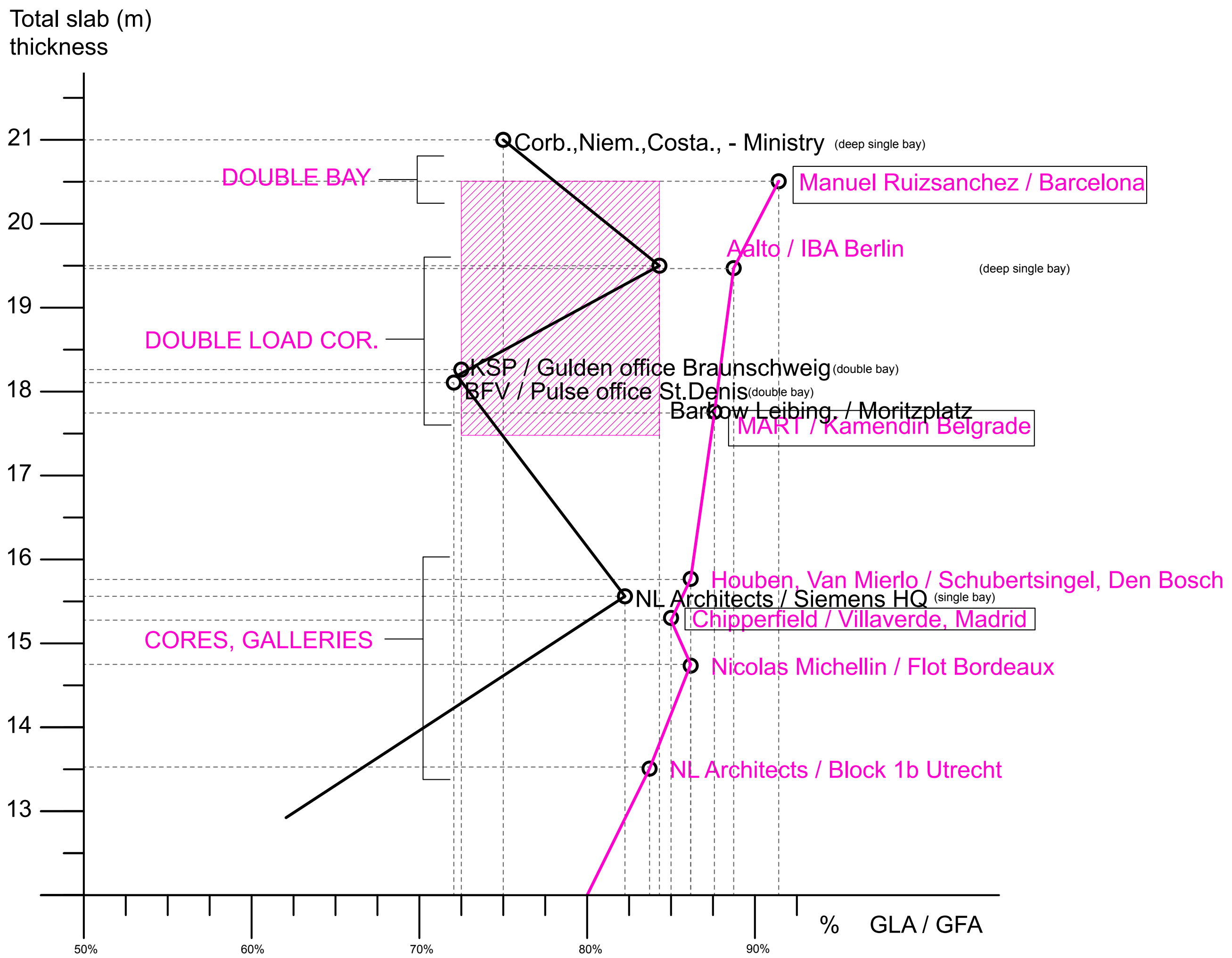


Chart 22. Office vs. Housing / Slabs - comparative chart - Planar efficiency

PLANAR AND SECTIONAL EFFICIENCY / This chart relates the planar efficiency with the share of all floor packages in the overall height determining the structural and sectional efficiency indexed with floor package %.

CONCLUSIONS:

Office project have a slightly higher floor-package with respect to the over 16-20%, than housing 10-15%. A common ground can be found between the two or a strategy with exposed installations can be used for offices to increase the FTC height.

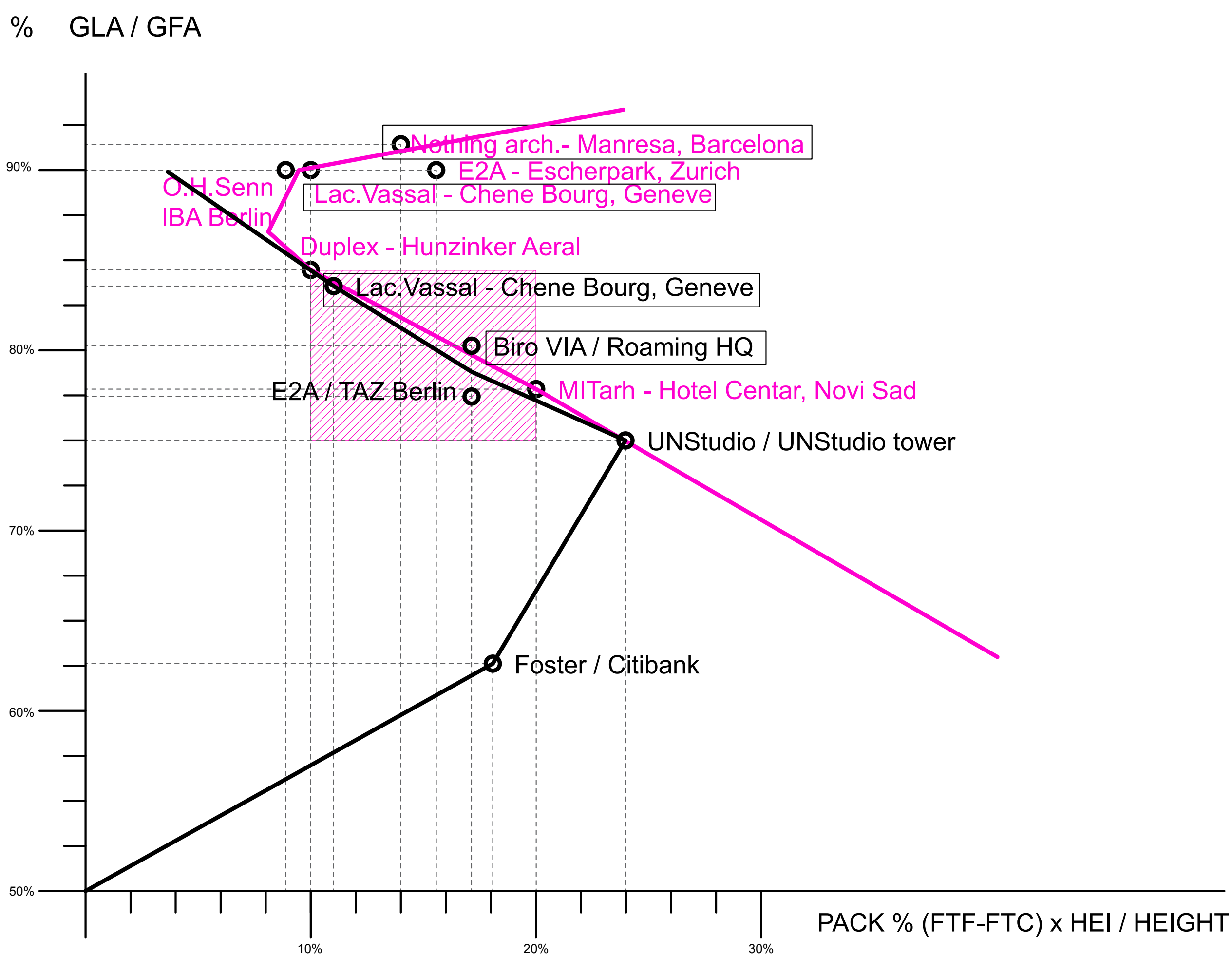


Chart 23. Office vs. Housing / cubes - comparative chart - Planar and sectional efficiency

PLANAR AND SECTIONAL EFFICIENCY / This chart relates the planar efficiency with the share of all floor packages in the overall height determining the structural and sectional efficiency indexed with floor package %.

CONCLUSIONS:

In slab volume typologies the difference floors-lab thickness is generally smaller due to the shorter structural spans, so a 12-15% of floor packeges/ height can satisfy both programs.

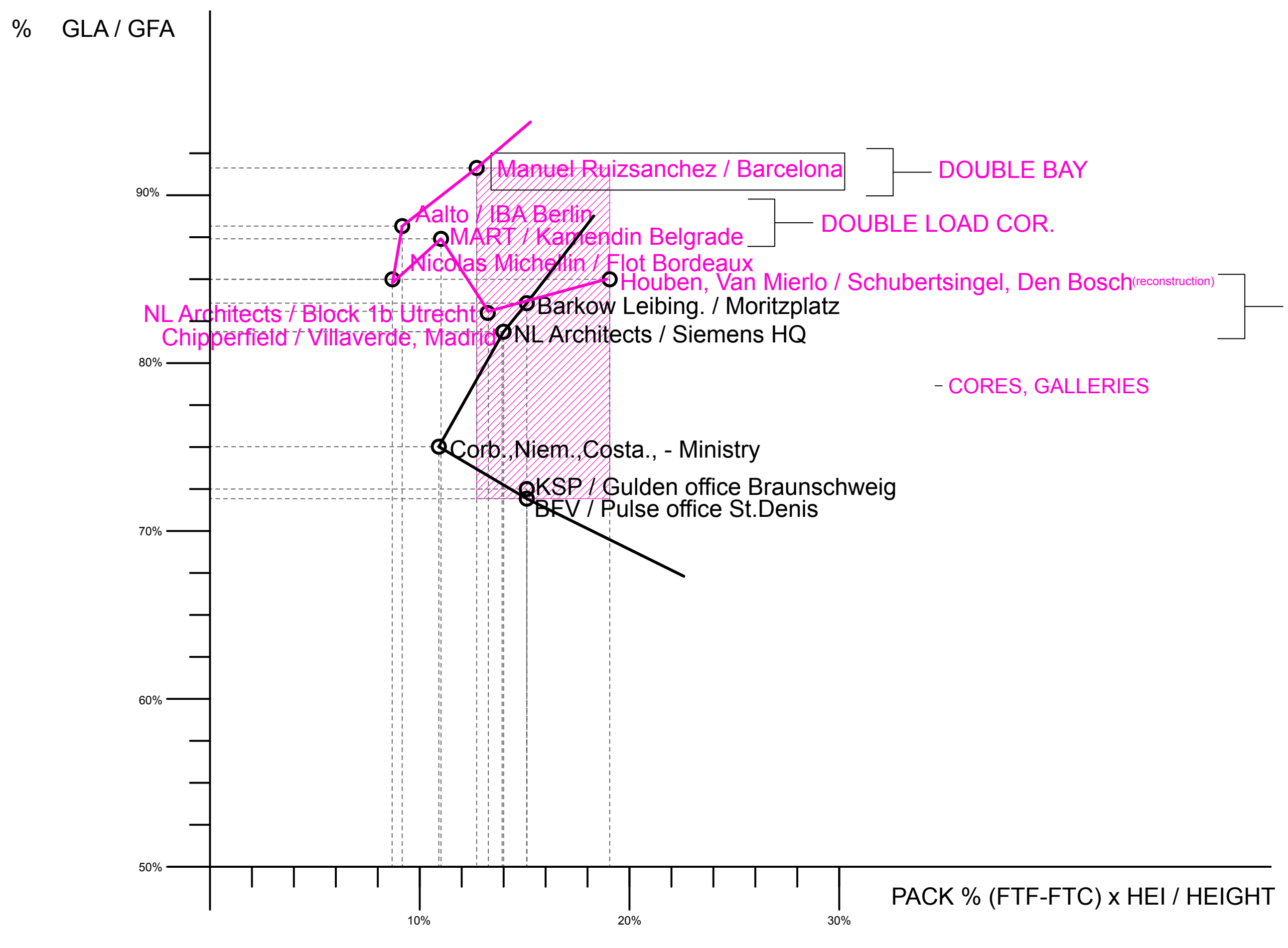


Chart 24. Office vs. Housing / slabs - comparative chart - Planar and sectional efficiency

DEPTH VS. PACK / Shows the interrelation between the CTF depth of cubic volume building and the thickness of the floor package.

CONCLUSIONS:

The floor-package of office buildings increases with depth as the increase of depth is followed with the increase of structural span because of the need for more flexibility so they range from 11-23%. Housing project have a bit smaller CTF depths but they regulate it by shortening the span by adding more columns which results with more efficient floor package.

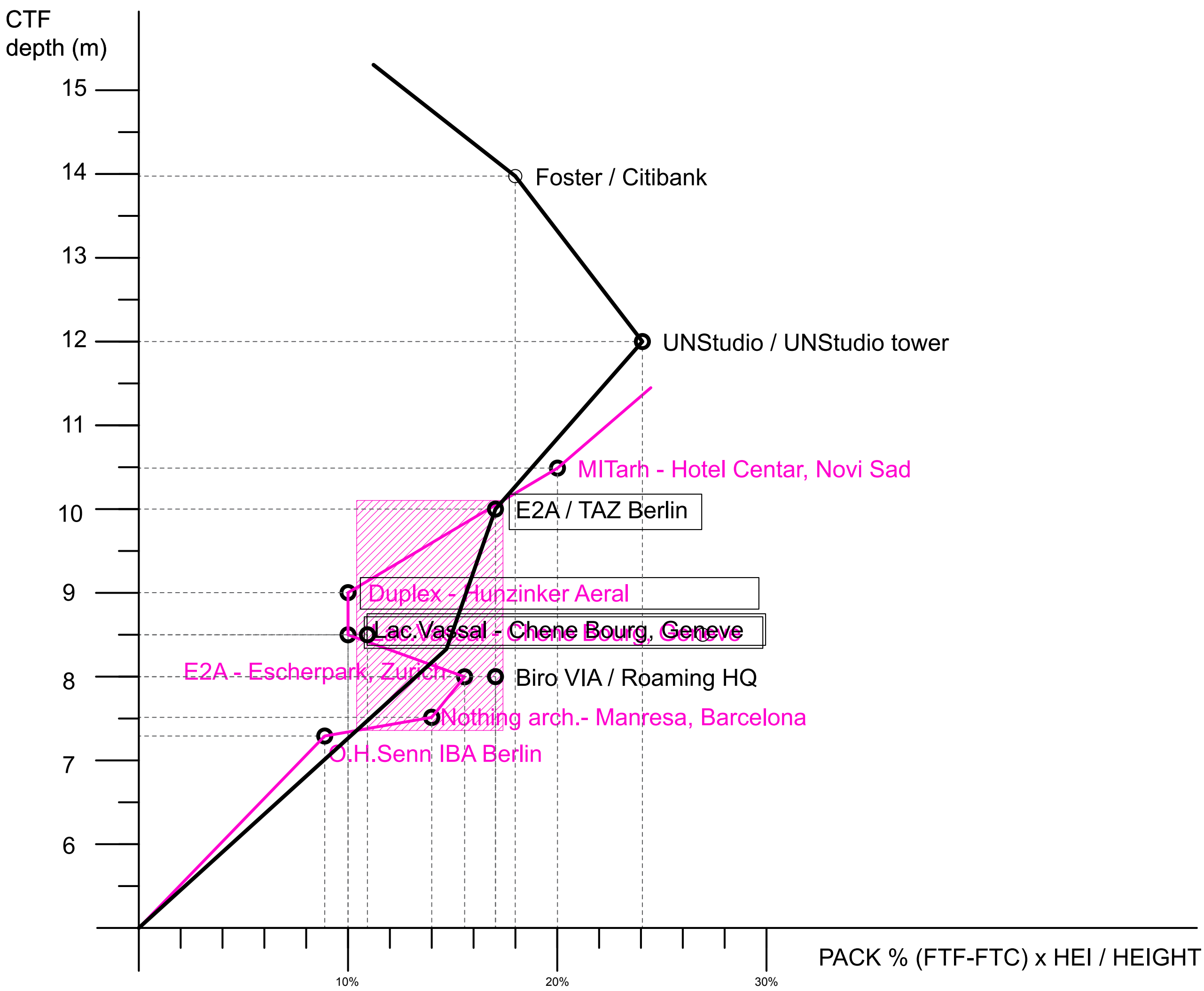


Chart 25. Office vs.Housing / cubes - comparative chart – CTF depth vs. Floor package

DEPTH VS. PACK / Shows the interrelation between the CTF depth of cubic volume building and the thickness of the floor package.

CONCLUSIONS:

In slab volume typologies the difference floor-slab thickness is generally smaller due to the shorter structural spans, so a 12-15% of floor packages/ height can satisfy both programs.

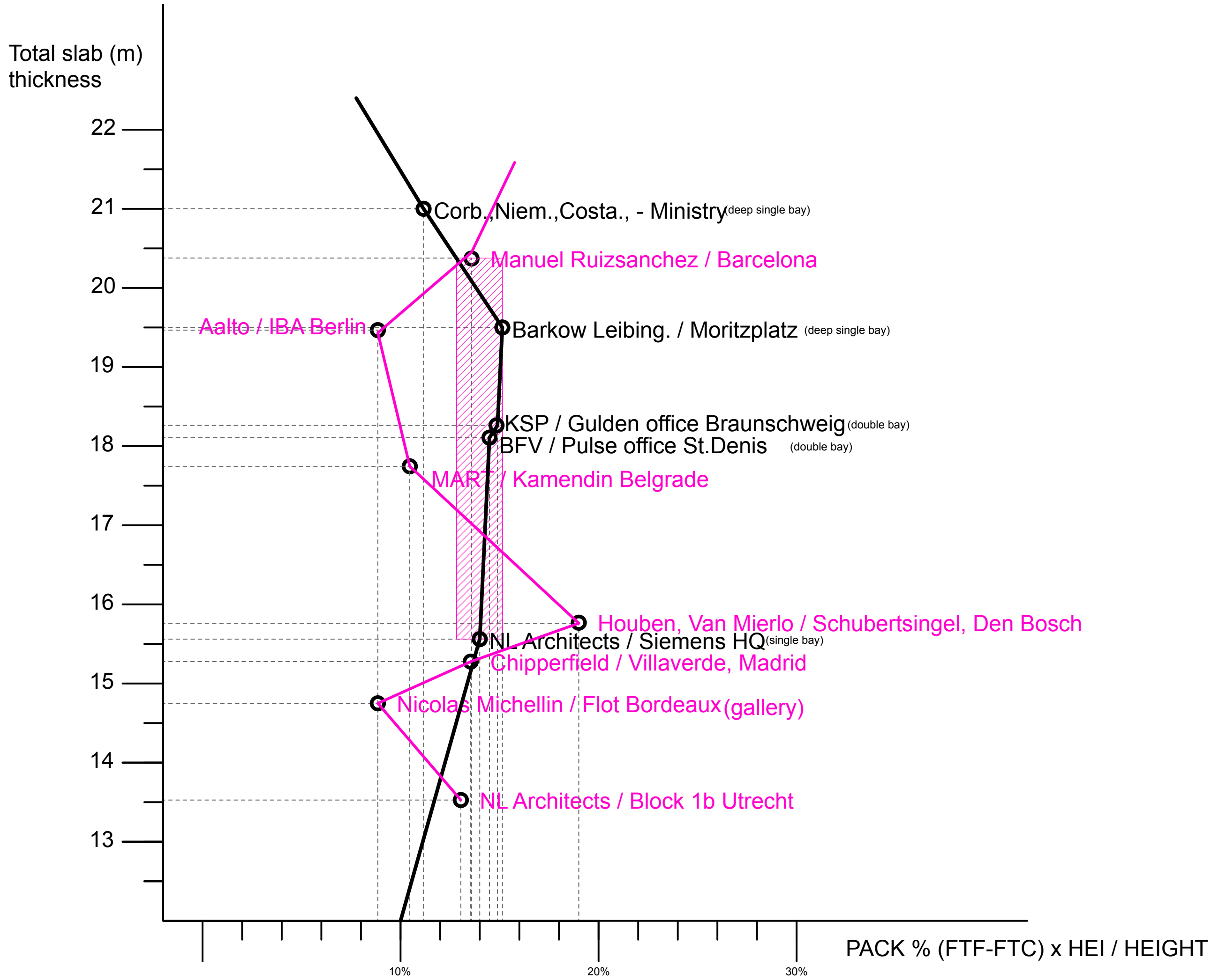


Chart 26. Office vs.Housing / Slabs - comparative chart – CTF depth vs. Floor package

DEPTH RATIO VS. OPENINGS % / Shows the interrelation between the core to facade CTF of cubic buildings with the indications about the % of openings on the facade and the applied thermal / light related devices.

CONCLUSIONS:

Depth is one of the key parameters which differentiates for office and housing, however a common range can be distinguished 7.5- 10m, while the depth ratio ranges between 2.9 and 3.5.

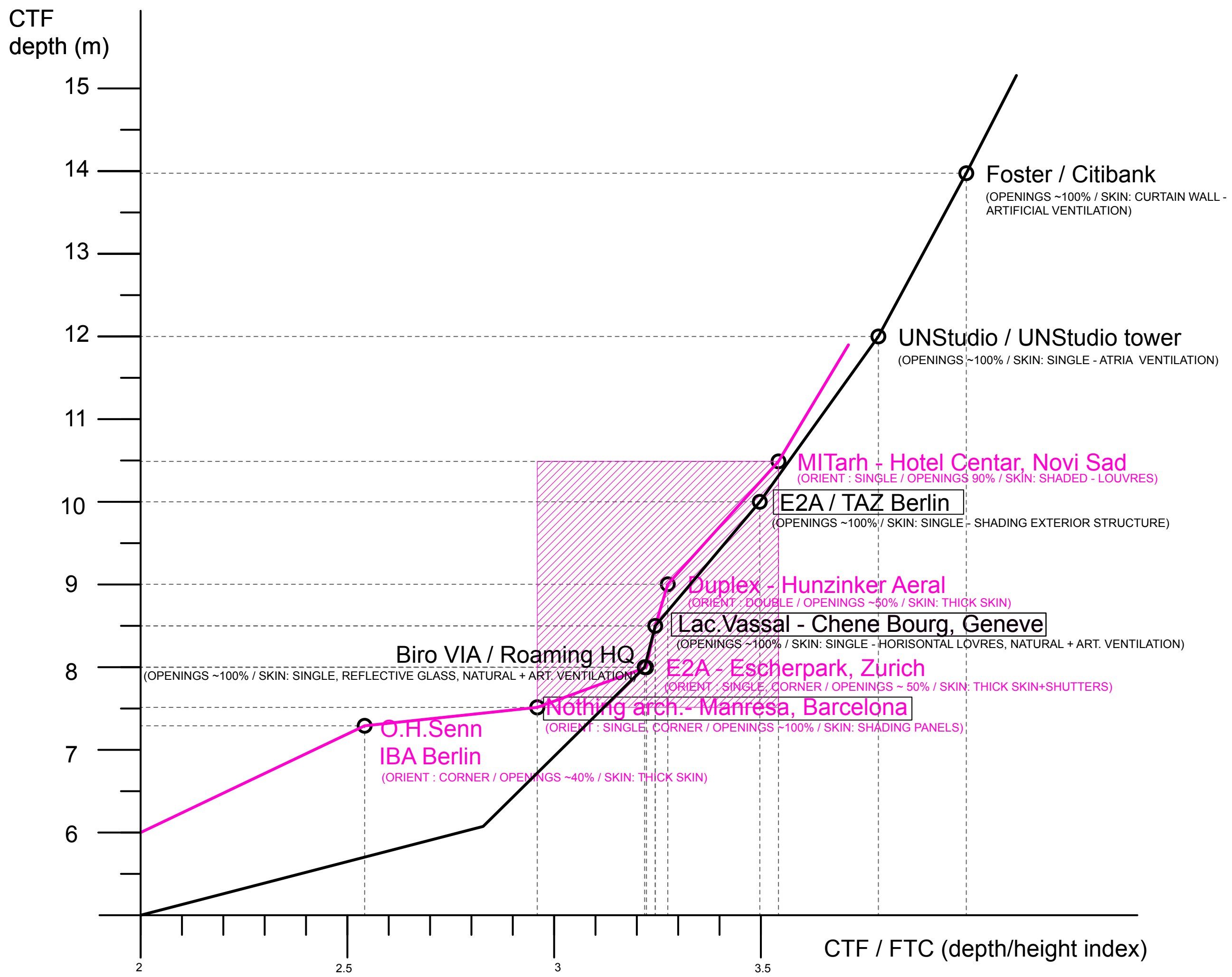


Chart 27. Office vs. Housing / cubes comparative chart - Depth vs. Openings %

DEPTH RATIO VS. OPENINGS % / Shows the interrelation between the total slab depth of slab buildings with the indications about the % of openings on the facade and the applied thermal / light related devices.

CONCLUSIONS:

A slab depth that satisfies office and housing can be found in a common range from 15.5- 19.5m, while the depth ratio ranges between 2.8 and 3.2.

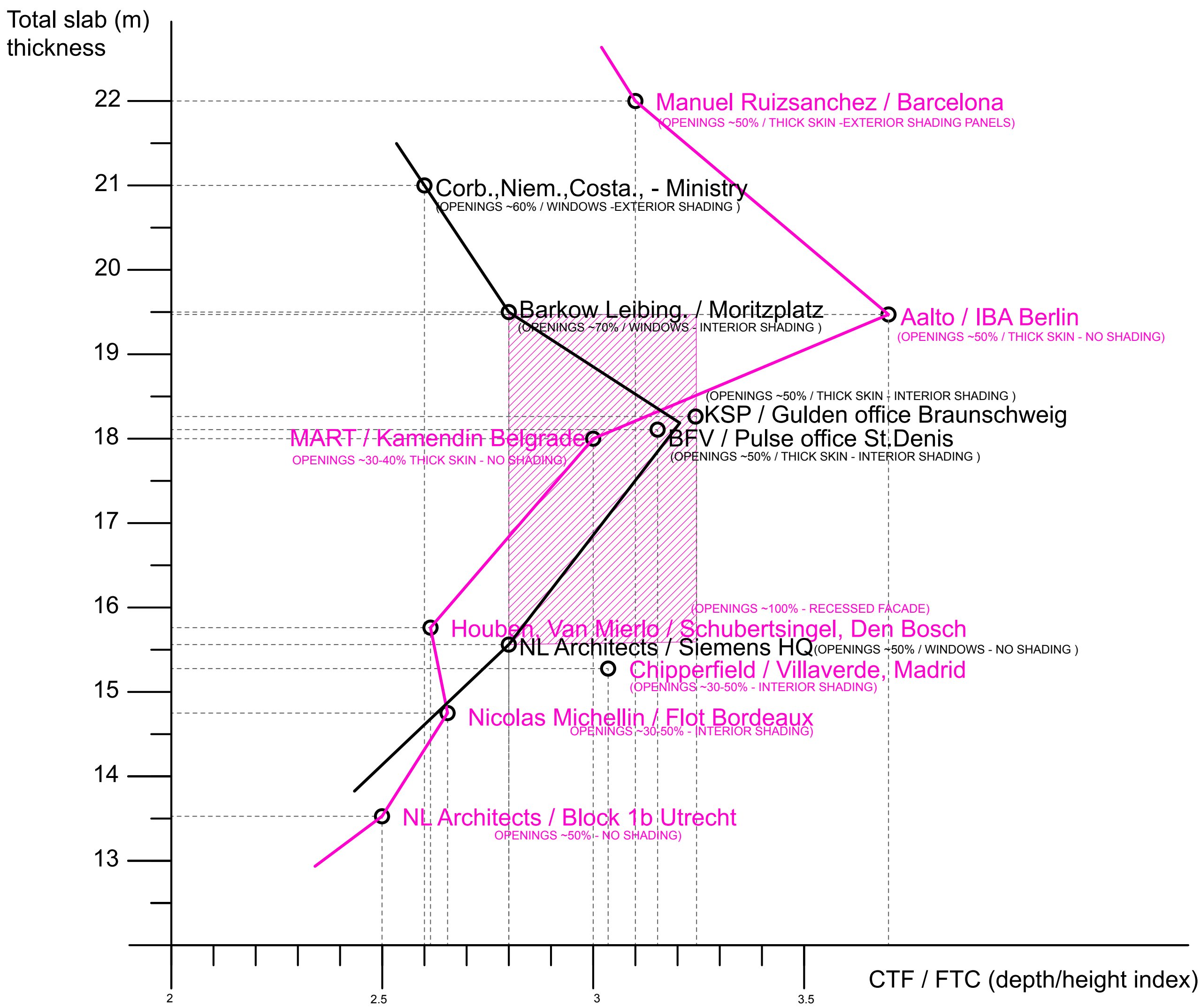


Chart 28. Office vs. Housing / slabs comparative chart - Depth vs. Openings %

URBAN PARAMETERS, DENSITY AND LAND VALUE

This chart establishes the relation between the urban density and FAR, height index HEI (number of levels), site occupancy %, and a land cost estimation in order to determine the characteristics of the urban contexts where project are developed. The common range of urban parameters that satisfy both programs is FAR 2-6, HEI 6-22, while the site occupancy ranges from 35-60%.

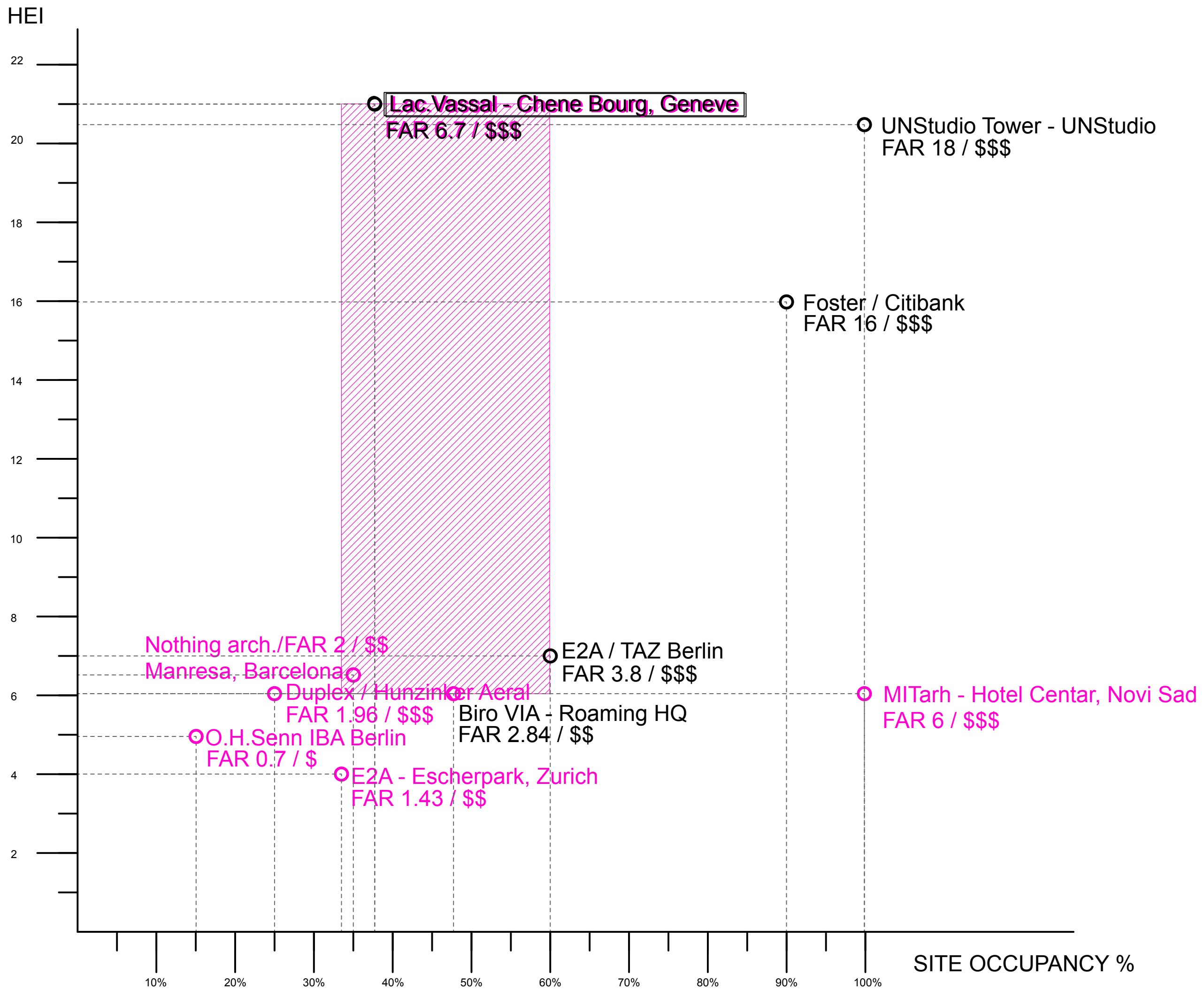


Chart 29. Office vs. Housing / cubes – comparative chart showing urban parameters, density and land value

URBAN PARAMETERS, DENSITY AND LAND VALUE

This chart establishes the relation between the urban density and FAR, height index HEI (number of levels), site occupancy %, and a land cost estimation in order to determine the characteristics of the urban contexts where project are developed. The common range of urban parameters that satisfy both programs is FAR 2-4.8 , HEI 6-9, while the site occupancy ranges from 50-80%.

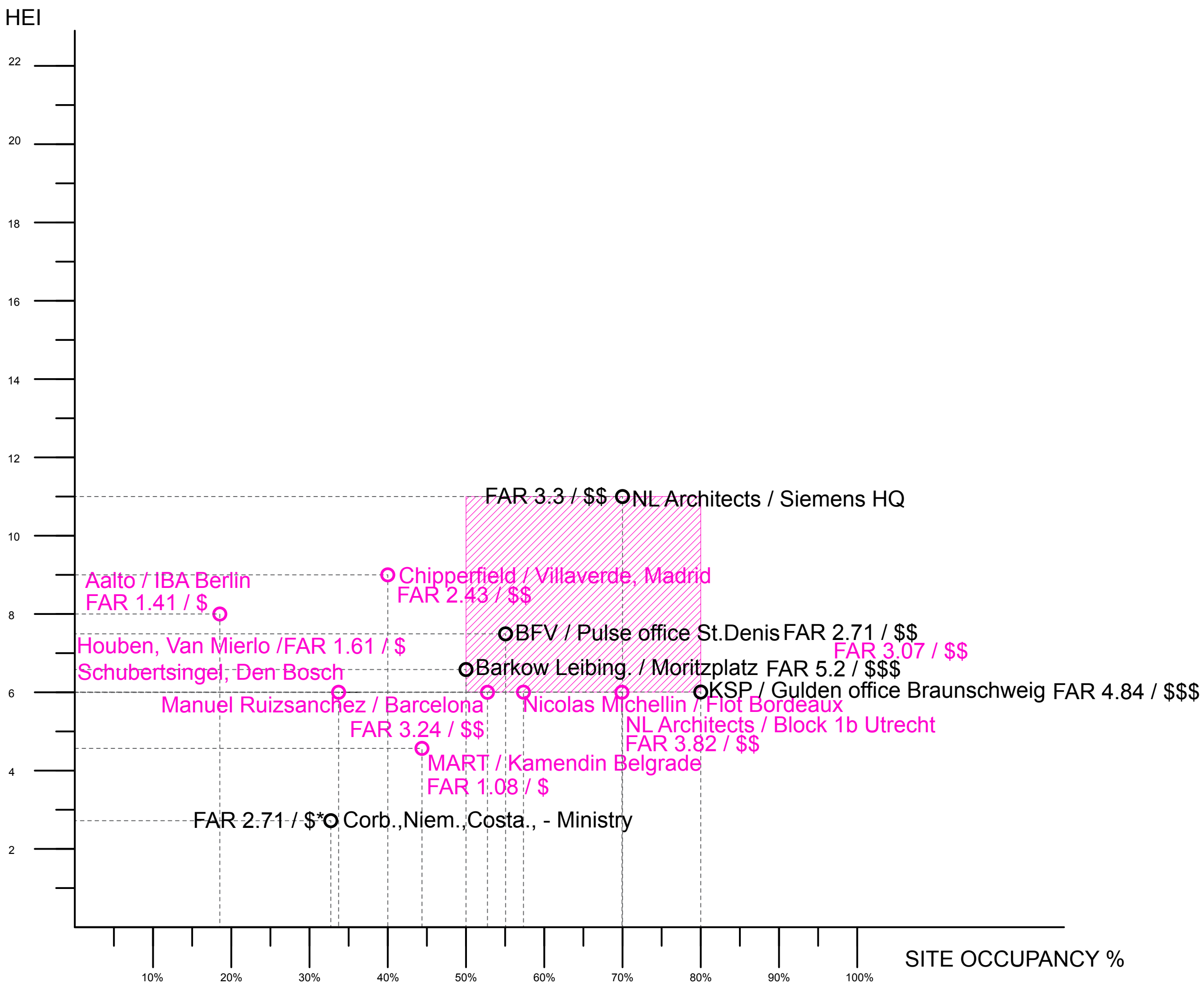
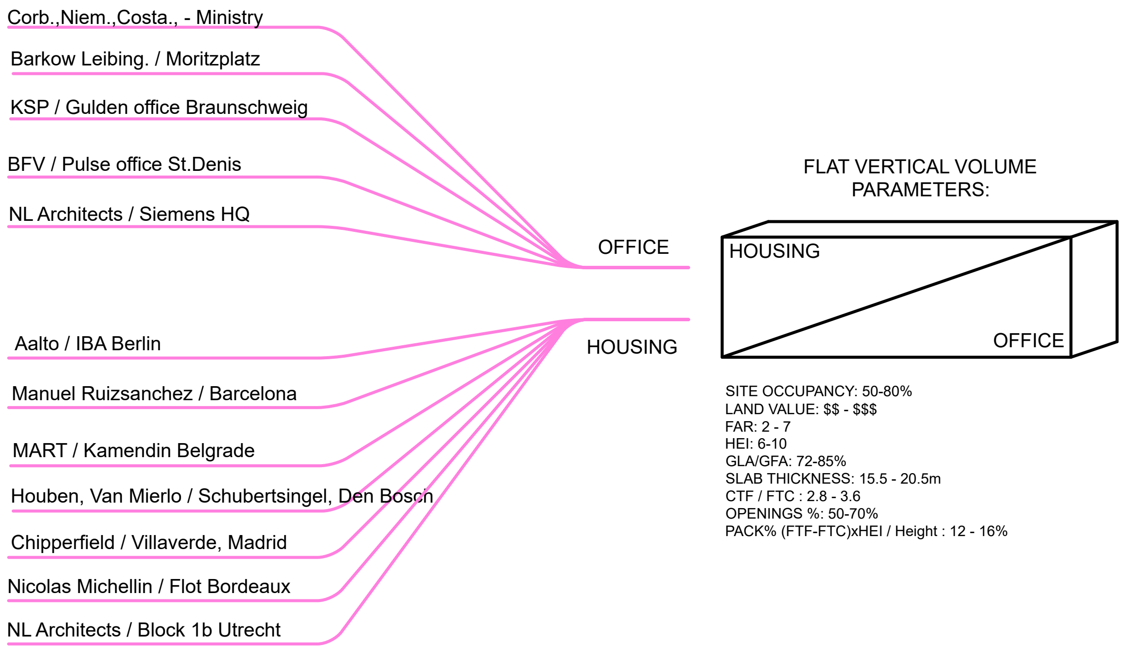


Chart 30. Office vs. Housing / slabs – comparative chart showing urban parameters, density and land value



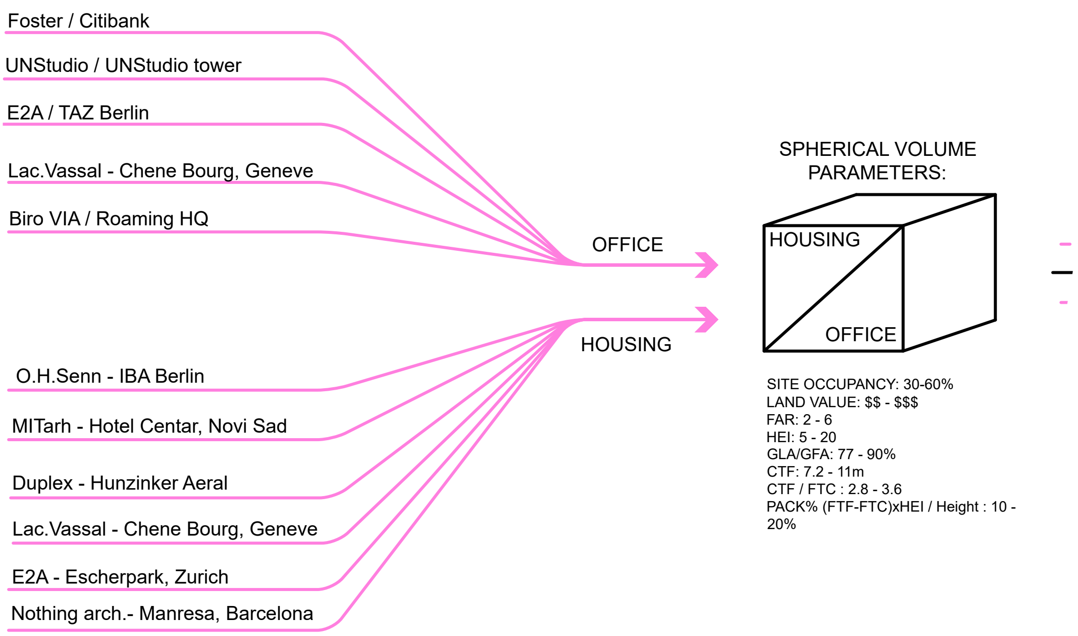


Diagram 45. A step-by-step workflow for the from the case study analysis towards the demonstration of its results and possible application (STEP1)

6.2 CASE STUDIES 2: DETERMINING THE POSSIBILITIES FOR PROGRAMMATIC CHANGES AND MIXED USE ABILITY WITHIN THE ARCHITECTURAL COMPOSITIONS OF FOUR CHOSEN PROJECTS

Cubic and Slabs volume typology, office and housing - qualitative analysis

1. MIXED USE / CUBES /NEWBUILT:

Tour Opale - Lacaton & Vassal, Geneve, 2019.

2. HOUSING / SLABS /TRANSFORMATION:

Schubertsingel - Houben & Van Meirlo, Den Bosch, 2018.

3. OFFICE /CUBE /RECONSTRUCTION:

Roaming HQ - Biro Via, Belgrade, 2018.

4. OFFICE / SLABS /NEWBUILT:

Aufbauhaus 84 - Barkow & Leibinger, Berlin, 2015.

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

GENERAL INFORMATION

PROGRAM: Mixed use: housing + office, (other program: retail)
VOLUMETRIC TYPOLOGY: Cube / vertical
DEVELOPER: SBB (Swiss railway company)

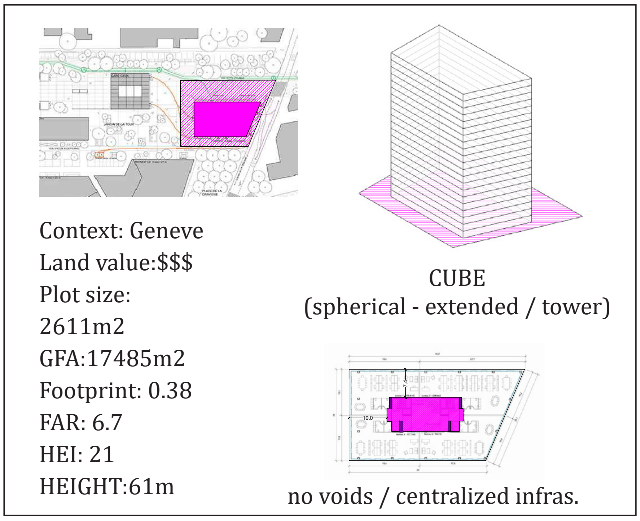


Diagram 46. Tour Opale - Urban Parameters and Typology

Figure 56. Tour Opale - Completed

Figure 57. Tour Opale - visualization in Chene Bourg context

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

URBAN CONTEXT / OBSERVATIONS (Table 24)

- property owner is a state railway company the site have been developed as a larger urban plan
-the train tracks of the nearby train station have been moved underground so a part of the site has been liberated and a mixed use tower has been proposed together with the urban promenade and an underground parking
-the large distances to neighbouring buildings and high price of the land resulted with a high FAR parameter 6.7, suitable for a mixed use development within a single building typology
-relatively low site occupancy together with the high FAR resulted with the deep tower typology (or an extended spherical volume building)

Table 24. Tour Opale - Urban parameters

URBAN	Lacaton Vassal CheneBourg, Geneve, Switzerland 2019.
1. PLOT SIZE	2611m2
2. PLOT SIZE & OCUPANCY	Footprint = 1000 m2 / Site occupancy 38%
3. FAR	FAR 6.7 $$$
4. DENCITY	6,800pax/km2
5. HEI & h	21 / 62.5m
6. LAND PRICE RANK	$$$
7. PARKING	ON ADJACENT PLOT

Figure 58. Tour Opale - situation drawing

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

SPATIAL EFFICIENCY / OBSERVATIONS

- the building hosts office and housing programs hosted on the same floor-plate size ~1000m2 both programs have highly efficient GLA% per typical floor although they have separate acces and vertical transportation. In section both programs are set on the same FTF height, office with visible installations, so the FTC remains acceptable 2.6m.
- For housing the floorplan is very deep but this is solved with gradual setbacks with open balconies which don't count in the GFA and winter-gardens which partially count, so the official floor-plate is "smaller", and the balconies can be considered as external void spaces. Housing floors are services with 2 cores with elevators and fire escape stairs- office floors has a larger depth ratio since the curtain wall facade has been moved outside till the slab edge, even with the fact the office GLA floor plate is smaller because of the two residential cores (which they share in case of fire) a large floor-plate ensures that the GLA% remains high. (Table 25)

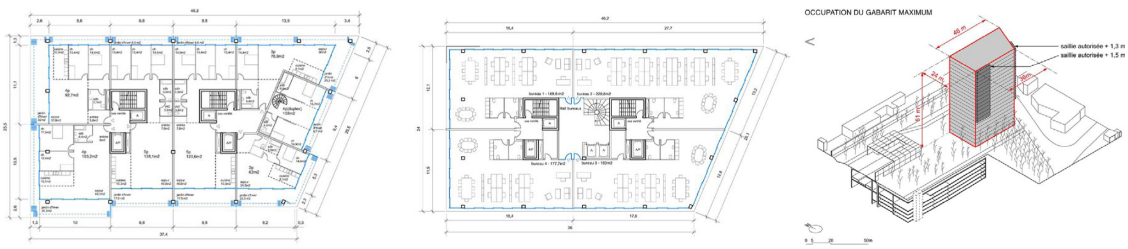


Figure 59. Tour Opale - Typical plans and volume size

Table 25. Tour Opale - spatial efficiency

SPATIAL EFFICIENCY	Lacaton Vassal CheneBourg, Geneve, Switzerland 2019.	
1. TOTAL GFA	17485m2	
2. GLA / GFA % HOUSING	GFA / typ. floor = 780, /GLA / typ.floor = 704 GLA / typ.floor. = 90%	
3. GLA / GFA % OFFICE	GFA / typ. floor = 1000 / GLA / typ.floor = 838 GLA / typ.floor. = 83%	
4. FTF - FTC	FTF 2.9 / FTC 2.60 , FTF-FTC 0.3m %ftf-ftc / HEI = 6.3 /61 = 10.5%	
5. CTF (core to facade)	H COR x FACADE = 7.5 m ROOM depth = 5m	O COR x FACADE = 8.5 -10 m ROOM depth = 7.5m
5. DEPTH RATIO CTF / FTC	H depth/ FTC = 7.5 /2.6 = 2.88	O depth/ FTC = 8.5 /2.6 = 3.26
6. VOID x VOLUME %	INTERAL VOID 120M2 / COMMERCAL	EXTERNAL VOIDS / WINTERGARDENS 23.2%

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

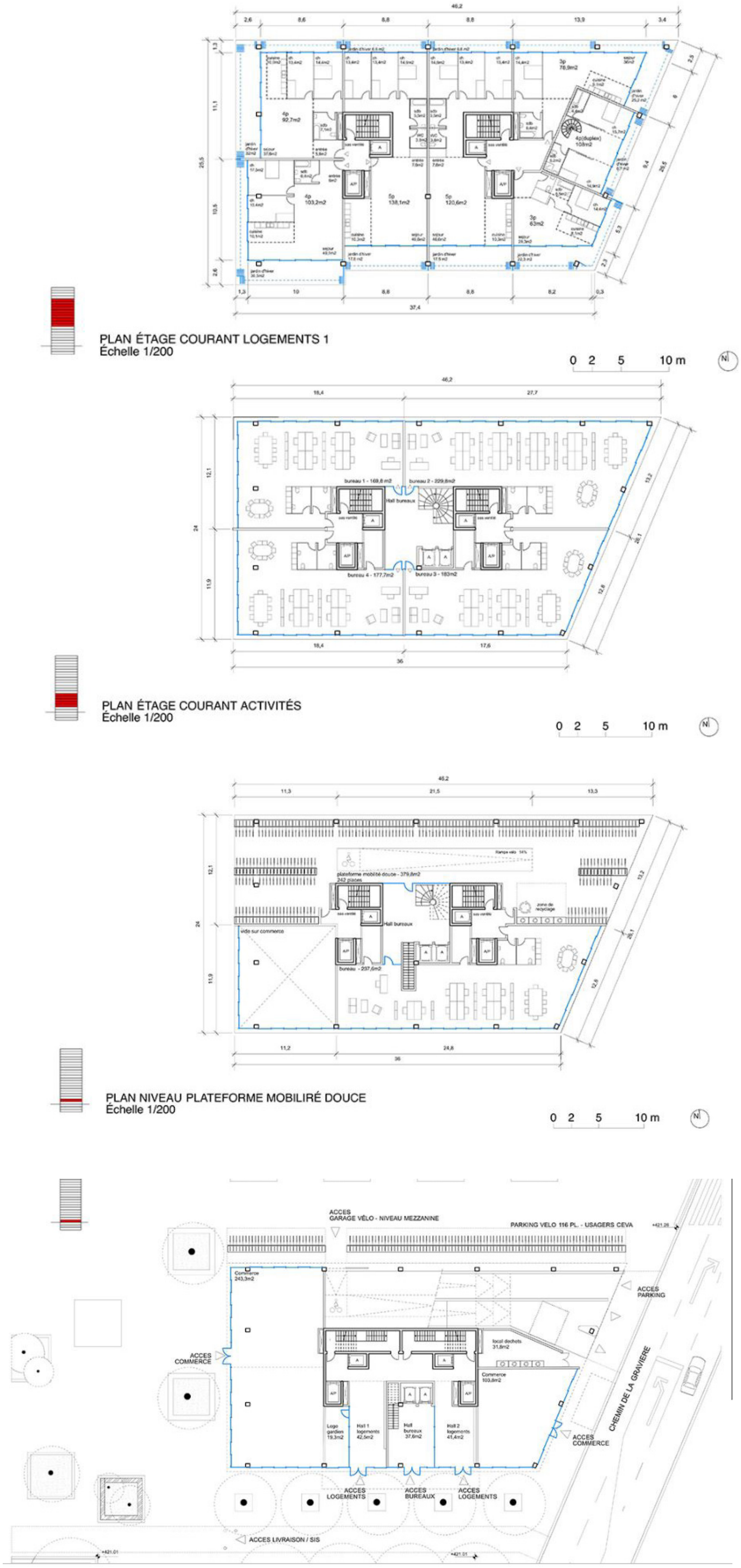


Figure 60. Tour Opale - Plan drawings

HOU SING OFF ICE

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

ECONOMY / OBSERVATIONS (Table 26)

- the developer of the Opale Chenebourg is working with both rental and sales concept, housing can be bought (upper floors) or rented, while office floors can be only rented.

- the overall investment of almost 50 milion EUR results, results with a breakdown of 2828 EUR /m2

- the average sales value of the approx. 10560 m2 GLA of housing (based on Geneve avg. price per m2 11402eur/m2) in total is 120.4 MiO eur.

- In the completely rental concept / the average rental value of housing 30eur/m2, and average office rent price of 52eur/m2 give the full return of investment in about 10 years

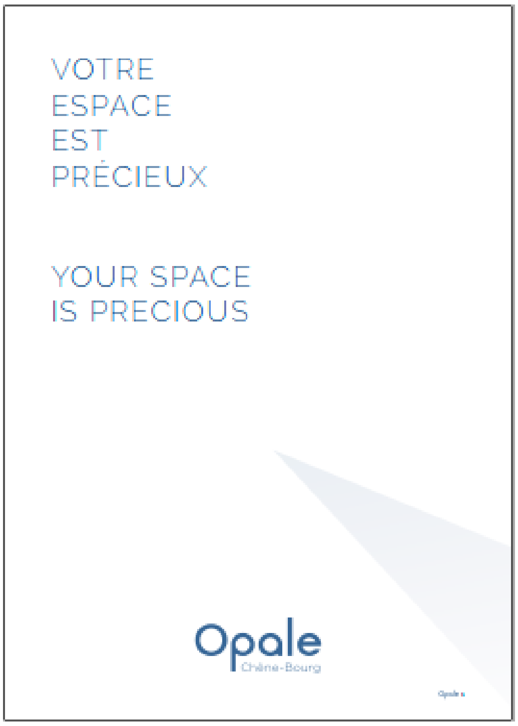


Figure 61. *Your space is precious*

Table 26. Tour Opale - Economy

ECONOMY	Lacaton Vassal CheneBourg, Geneve, Switzerland 2019.
1. CLIENT	SBB (CFF Immobilier) / Railway company
2. INVESTMENT VALUE	49.45 MIO EUR / 2.828 EUR / m2 GFA
3. HOUSING PRICES	€11,402 per sq. m /AVG HOUSING PRICE https://www.globalpropertyguide.com/Europe/Switzerland/Price-History €26.66 - 45 per sq. m /AVG HOUSING RENT https://www.globalpropertyguide.com/Europe/Switzerland/Price-History 30e / m2 rent / in 10 years make profit https://opale-chene-bourg.ch/logements/
4. OFFICE PRICES	€52.16per sq. m /AVG OFFICE RENT https://www.statista.com/statistics/431672/commercial-property-prime-rents-europe/
5. LAND VALUE	$$$ / HIGH
6. PARKING	OPERATED BY THIRD PARTY

HOU SING OFF ICE

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

PROGRAM / OBSERVATIONS (Table 27)

- The building is vertically mixed and it is developed with three stacked programmatic segments: retail, office and housing

- The retail units are located on the ground and first levels enhanced with the use of double height spaces

- The office section is spread on five level and it is designed as a multi-tenant office with a floor-plate of 760m2 which can be subdivided to smaller units untill 170m2

- The housing section is the largest and it accommodates rental or sales units, a typical floor can be subdivided to 4-6-8 units per floor providing apartments mostly double or corner orientation.

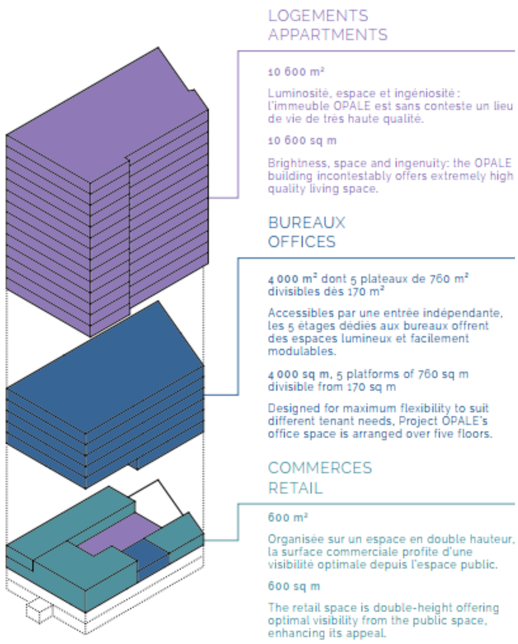


Figure 62. Tour Opale - Program axo

Table 27. Tour Opale - Program

PROGRAM	Lacaton Vassal CheneBourg, Geneve, Switzerland 2019.
1. HOUSING	10920 m2 61%
2. OFFICE	4800 m2 26%
3. ADDITIONAL PROGRAM	RETAIL 600 m2 - 3%
4. UNITS	6-7 FLATS / FL. 1-4 OFFICES / FL.
5. TENANTS	HOUSING: Rent and Sales? MAGELLAN MEDIC GROUP: 700m2 LEMANIS TEAM 150m2, COWORKING
6. FACILITIES	RETAIL, PARKING, BIKE PARKING, STORAGE ROOMS

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

STRUCTURE / OBSERVATIONS (Table 28)

- Since the floor-plate of the tower is big and wide, the structure has been developed with two vertical cores separated from each other which enabled to have usable space in between on housing floor and a lobby access areas for the office floor.

- This also enabled having a single ring of columns offset around the cores in a grid 7x8.8m, which gives lots of flexibility in plan, and the grid span for the beams and concrete slams remains efficient in section

- Floor-plates have 30cm thickness, which is significantly thick but beams are avoided and slabs are made of hollowed concrete and integrate MEP installations and floor layers so at the end this is a highly efficient solution in section

Figure 63. Tour Opale - Section

Table 28. Tour Opale - Structure

STRUCTURE	Lacaton Vassal CheneBourg, Geneve, Switzerland 2019.
CORES	SKELETAL / CONCRETE CORES + SINGLE ROW OF COLUMNS
CORES	2 x
COLUMN GRID	7 x 8.8m
FLOORSLAB	30cm hollowed concrete, 300kg/m2
FACADE	CURTAIN WALL , DOUBLE SKIN WINTER GARDEN

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

SUSTAINABILITY / OBSERVATIONS (Table 29)

- The building has both active and passive energy strategies. In terms of water treatment it is the active strategy which works both for the housing and office programs such as heating with solar panels, gray water hear recuperation system, the active strategy for the office program is used for the heat recuperation of air.

- The passive strategy for housing done with the winter-gardens creating a thermal buffer zone in the winter and balcony setbacks which protect from the high summer sun reducing heat gains, the passive strategy for the offices uses the mobile Venetian type outside shaders

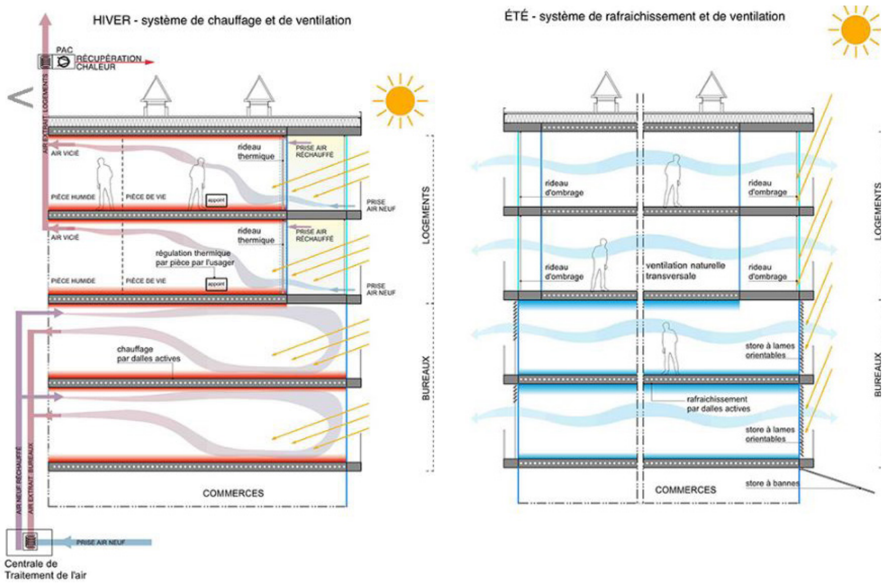


Figure 64. Tour Opale - Sectional heating and ventilation diagram

Table 29. Tour Opale - HVAC, MEP, Energy

HVAC, MEP, ENERGY		Lacaton Vassal CheneBourg, Geneve, Switzerland 2019.
PASSIVE SYSTEMS	H - WINTERGARDENS	O - SHADING
HVAC	FLOOR & CEILING HEATING	FLOOR & CEILING HEATING AIR TRETMENT AND RECUPER.
ACTIVE SYSTEMS	SOLAR PANELS FOR POWERING WATER TREATMENT, RAIN WATER COL, GRAY WATER HEAT RECUPER.	
DUCTS	GARBAGE 31M2, TECH 130M2 x 2 =260m2, TOTAL TECHNICAL SPACES = 1.6%	VERTICAL DUCTS (VENT&SEW) = 0.5%

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

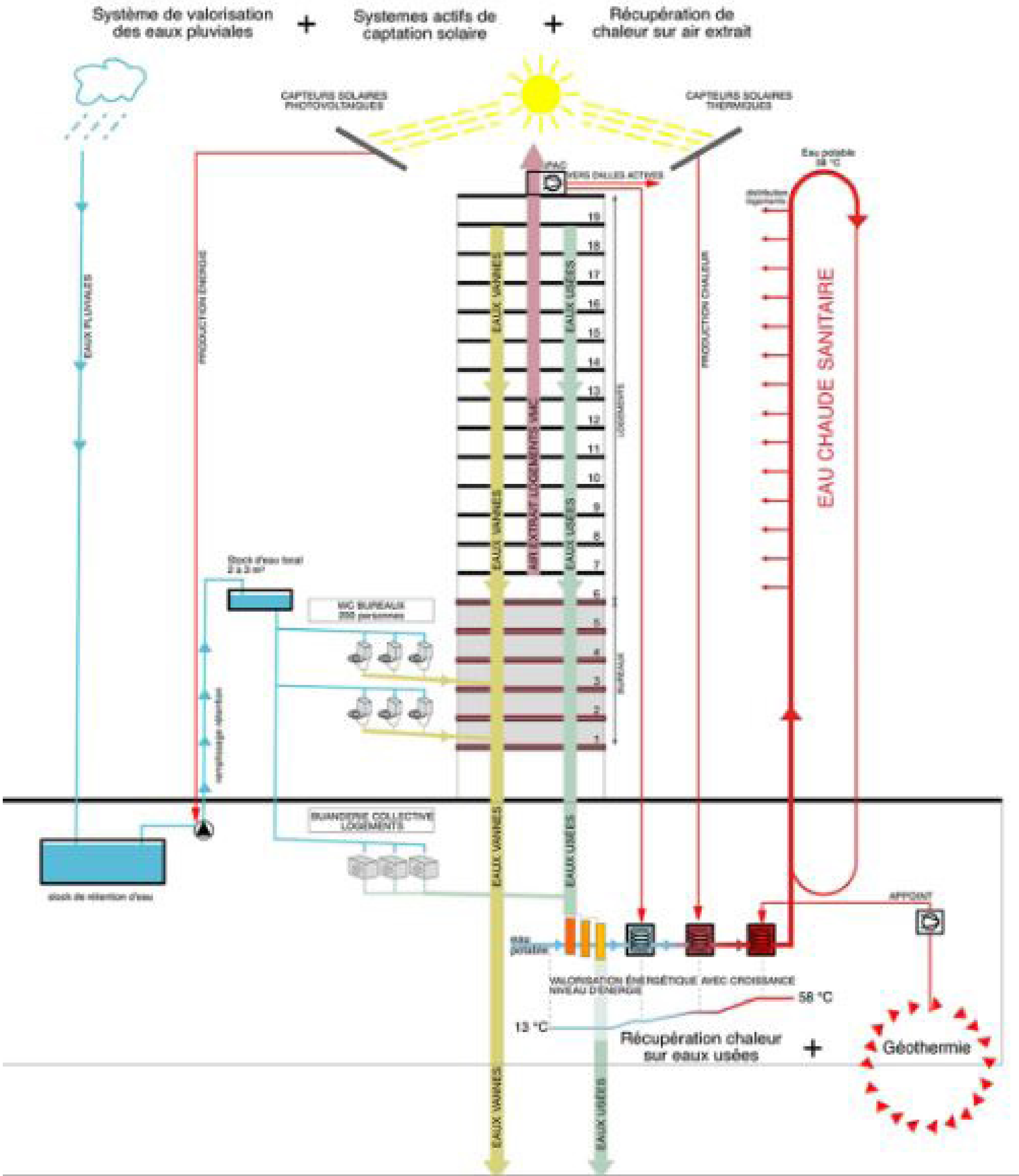


Figure 65. Tour Opale - Sustainability diagram

CASE STUDY 1: TOUR OPALE , GENEVE
Lacaton & Vassal Architectes, 2019.

CIRCULATION / OBSERVATIONS (Table 30)

- most of the ground level is reserved for circulation: two housing lobbies one office lobby, with accesses to the vertical cores/communication, then the car access ram to the garage and the bicycle ramp to the bike park in the mezzanine level

- fire escapes are shared between programs and are located in the office floors, for the projected number of users 2 stairs were necessary

- in total the buildings have 6 elevators, 4 residential and 2 office, in general the ratio of elevators/ GFA is 1elevator / 2500m2 GFA

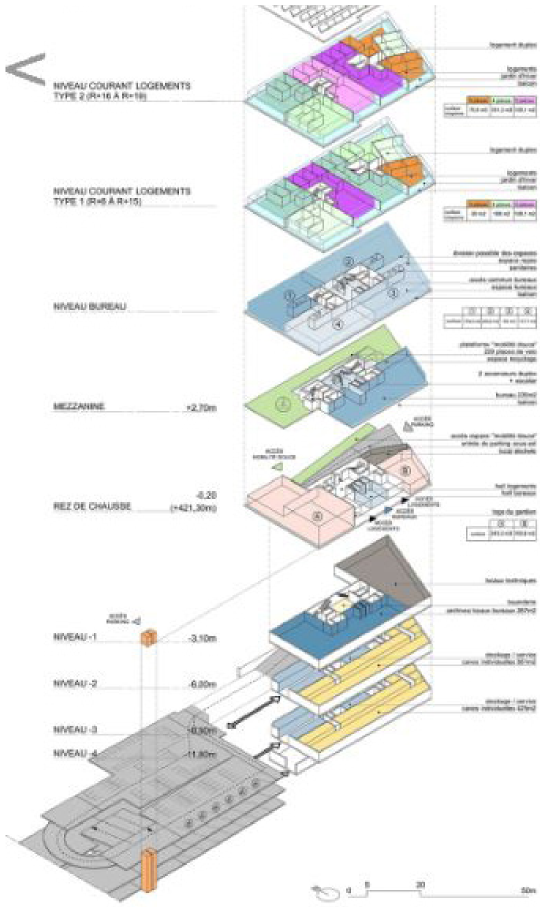


Figure 66. Tour Opale - Program / movement

Table 26. Tour Opale - Circulation

CIRCULATION			Lacaton Vassal CheneBourg, Geneve, Switzerland 2019.
ACCESS	pedestrian 85m2	bycicle 425m2	car 317m2
LOBBIES	2 X HOUSING		1 X OFFICE + LOBBY / FLOOR
STAIRS	2 X FIRE ESCAPE		1 X OFFICE STAIRS
ELEVATORS	30m2 x office floor 4x res.elevator + 2 office elevat.		30m2 x office floor 4x res.elevator + 2 office elevat.

CIRCULATION

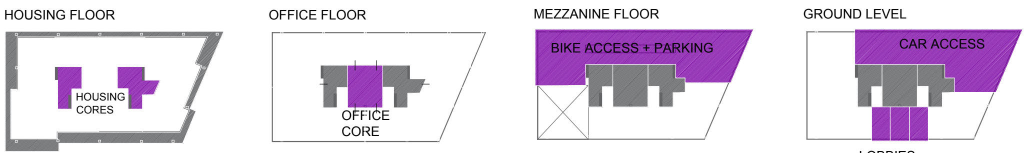


Figure 67. Tour Opale - Access schemes

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

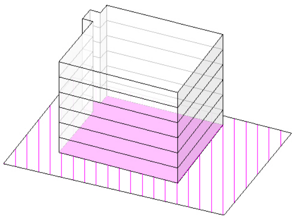
GENERAL INFORMATION

PROGRAM: Office / Co-working
VOLUMETRIC TYPOLOGY: Cube
DEVELOPER: Roaming Group

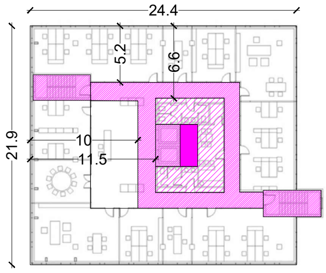
Site info:

Plot size: 2010m2
Footprint 680m2
Site coverage 33%
GFA 4080m2
FAR 2.2
HEI 6

Context: Belgrade city area
Land value:$$



Spherical / point building



central + excentr. cores

Diagram 47. Roaming HQ - Urban parameters and typology

Figure 68. Roaming HQ - street view

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

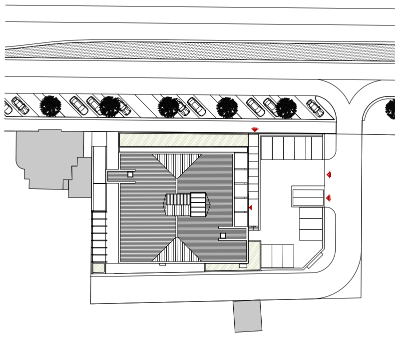


Figure 69. Roaming HQ - Situation

URBAN DESINGN / OBSERVATIONS

- Property owner is a private telecommunication holding company ROAMING Group, the project is developed as a their HQ building with the possibility to sublet the space as a multi-tenant office in case the company overgrows the building capacity in the future. The investor bought a plot with an existing unfinished building design as an office building for a Belgrade Water and Sewers department. The existing building didn't use the maximum allowed GFA and site occupancy so the investor asked the city authorities for an extension of 420m2, so the final building was developed following the: FAR 2.2, HEI 6 levels, and the existing height limit of 24.1m. Initially the building didn't have a parking garage so the site was completely excavated during reconstruction and the garage was added underneath the whole site.

Table 31. Roaming HQ - Urban parameters

URBAN	Biro VIA, Belgrade, Serbia, 2018.
1. PLOT SIZE	2010 m2
2. PLOT SIZE & OCUPANCY	Footprint = 680 m2 / Site occupancy 33%
3. FAR	FAR 2.2
4. DENCITY	18000pax/km2
5. HEI & h	6 / 24.1m
6. LAND PRICE RANK	$$$ 2 000 000 Eur / 10000e /m2
7. PARKING	PLOT + GARAGE

Figure 70. Roaming HQ - before reconstruction

Figure 71. Roaming HQ - Situation

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

SPATIAL EFFICIENCY / OBSERVATIONS

- Typical floors are envisioned with the possibility to host multiple tenants but the current layout was adapted as a single tenant HQ so the floors have been designed slightly less “dense” than expected for a multi-tenant office. Typical office floor has an optimal 79.5 GLA%, if a new-built was built this would probably be higher as for a building of this size only one fire escape would be sufficient.
- In section both the building has a quite high and inefficient FTF height compared to the achieved FTC height, because of the existing steel structure with thick beams the MEP systems and floor layers thickened the ceiling package to 0.7m
- Average CTF depth of 8.5m is optimal for an office buildings with the rooms 6.5m m deep to the areas that lack sunlight are only the lobbies around the centrally positioned elevator core
-The building volume has two external void spaces (porch and a roof terrace (possibly to reduce GFA)

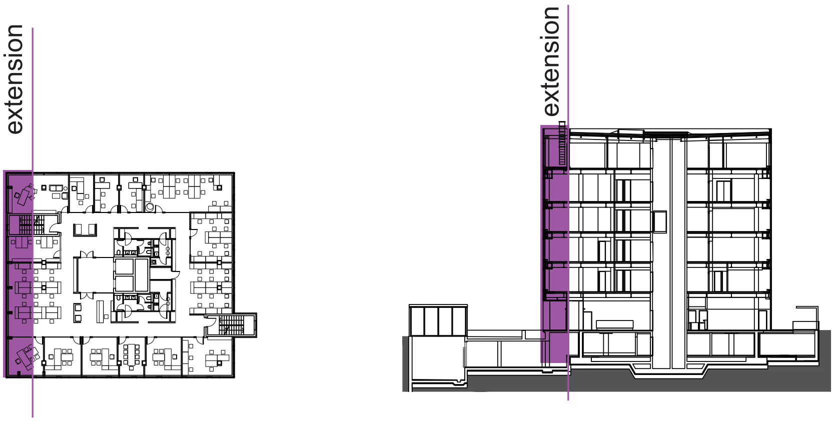


Diagram 48. Roaming HQ - Zones of extension

Table 32. Roaming HQ - Spatial efficiency

SPATIAL EFFICIENCY	Biro VIA, Belgrade, Serbia, 2018.
1. TOTAL GFA	4080m2
2. GLA / GFA % OFFICE	GFA / typ. floor = 680, /GLA / typ.floor = 540 GLA / typ.floor. = 79.5%
3. FTF - FTC	FTF 3.6 / FTC 2.9 , FTF-FTC 0.7m %ftf-ftc / HEI = 6.3 /61 = 17%
4. CTF (core to facade)	COR x FACADE = 8.5m ROOM depth = 6.5m
5. DEPTH RATIO CTF / FTC	depth/ FTC = 8.5 /2.9 = 2.93
6. VOID x VOLUME %	EXTERNAL (porch & terraces) 200m2 / 14% t.f

OFF ICE

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

Figure 72. Roaming HQ - Plans

Figure 73. Roaming HQ - Street perspective

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

ECONOMY / OBSERVATIONS

- The developer ROAMING GROUP is have built an office buildings as a rental space, however they are currently using it as a HQ for their company instead of renting out spaces in other office building.
- The overall investment of almost 7.2 million EUR results with a breakdown of 1764EUR /m2. In the completely rental concept / the average rental value of office class A is 16.66eur/m2, so if the building would rented out the full return of investment would be expected in 11 years.

Table 33. Roaming HQ - Economy

ECONOMY	Biro VIA, Belgrade, Serbia, 2018.
1. CLIENT	ROAMING (telecommunication trader)
2. INVESTMENT VALUE	5.2 MIO EUR CONSTR. + 2 MIO EUR PLOT / 1764 EUR / m2 GFA
3. HOUSING PRICES	€16.66/sq. m /AVG OFFICE RENT https://www.statista.com/statistics/530157/office-real-estate-prime-rent-belgrade-serbia-europe/ €16.66 / m2 rent / in 8.9 years make profit
4. LAND VALUE	2 MIO € (plot + unfinished building)
5. PARKING	PRIVATE

PROGRAM / OBSERVATIONS

The building is designed as a single use with floors 1-6 being reserved purely for offices and desks. There are lobbies, receptions and informal meeting spaces on each floor. The ground level is organized as a communal space with a porch, large lobby, a bar, and assembly rooms for meetings, presentations and conferences.
Recreational areas are placed outside the building volume fitness space for the employees is placed underground and a terrace on the level 6.

Table 34. Roaming HQ - Program

PROGRAM	Biro VIA, Belgrade, Serbia, 2018.
1. OFFICE	4080 m2 100%
2. UNITS	POSSIBLE 2 OFFICES / FL.
3. TENANTS	SINGLE - ROAMING HQ.
4. FACILITIES	PARKING, FITNESS 100M2

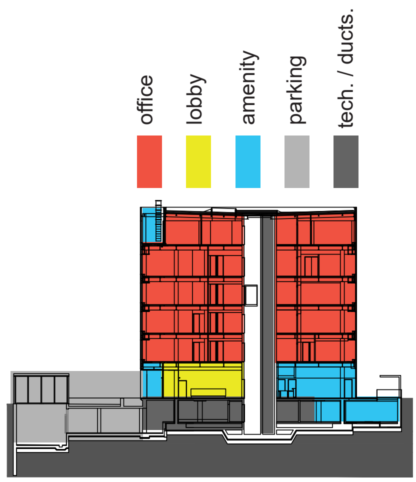


Diagram 49. Roaming HQ - Program

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

CIRCULATION / OBSERVATIONS

- Vertical circulations works with two ex-centric stairs and a centrally positioned elevator set with a circular corridor ring including a small informal lobby on each floor. Theoretically the building could be vertically split to host two different tenants each of them could have an independent vertical access to all floors

- Fire escape stairs are not placed centrally in the plan, so the 2 routes are needed, if the stair was placed centrally one fire escape route would probably be sufficient for a building of this class. In total the buildings have 2 elevators, centrally positioned forming a structural core.

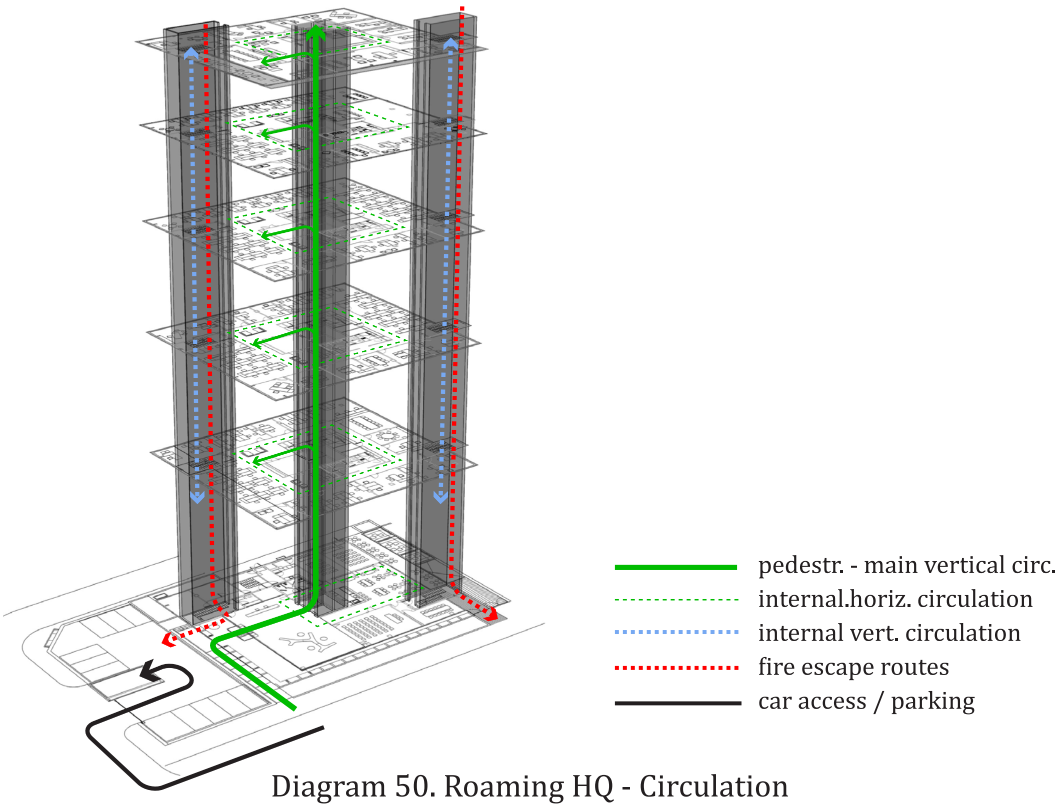


Diagram 50. Roaming HQ - Circulation

Table 35. Roaming HQ - Circulation

CIRCULATION	Biro VIA, Belgrade, Serbia, 2018.
LOBBIES	132m2 / ground level, 50m2 / typical floor
STAIRS	2 X FIRE ESCAPE / 34m2 / typ.floor
ELEVATORS	2 x ELEVATOR / 12m2 /typ.floor

OFF ICE

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

STRUCTURE / OBSERVATIONS

- Structural system combines concrete and steel skeletal system in a 9x9m and 3x9m grid, as a 9 m span is quite large for a relatively small building like this it resulted with relatively thick steel beams (50cm). Floor-plates are kept original as prefabricated hollowed concrete, and they do not integrate any installations within so all the floor layers and installation increased the overall thickness of the ceiling package.

-The initial prefabricated concrete parapets have been removed in favour of the curtain wall facade, which encloses the new building, the glass finish is continuous in the vertical planes covering both the FTC zone and the floor package opaque zones

Table 36. Roaming HQ - Structure

STRUCTURE	Biro VIA, Belgrade, Serbia, 2018.
CORES	SKELETAL / STEEL : CORES + COLUMN GRID
CORES	3 (2 x fire stairs + 1 elevator set)
COLUMN GRID	9x9m, 3x9m
FLOORSLAB	prefab hollowed concrete
FACADE	CURTAIN WALL

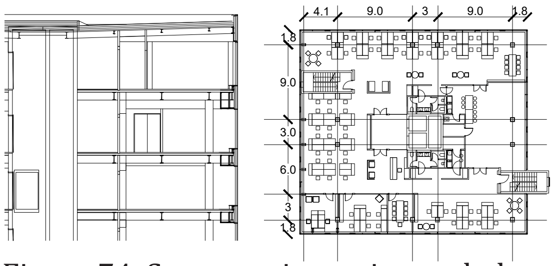


Figure 74. Structure in section and plan

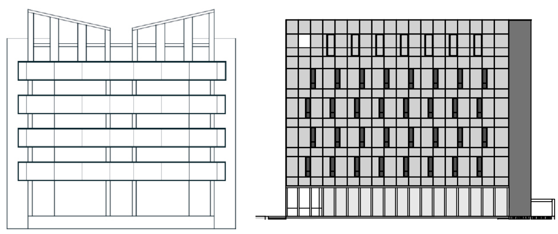


Figure 75. Facade before and after

Figure 76. Steel structure and cores - before reconstruction

OFF ICE

CASE STUDY 2: ROAMING HQ , BELGRADE
Biro VIA, 2018. (reconstruction)

SUSTAINABILITY / OBSERVATIONS

- Energy efficiency was not the priority in this project as it is not in most of the projects in Serbia due to the low cost of electric energy so the architects went for the inexpensive solutions for this type of building so there are no active energy efficient systems
- In terms of HVAC systems VRV heat pumps are used paired with the ceiling fan coils and the the branching systems for air treatment and recuperation
- An option of operable windows is left for the users, as a source of fresh air for the individual offices
- As the building is sitting on a slope and the primary orientation in north east, no shading system is used since a highly reflective glass is chosen for the curtain wall to prevent the heat gains

Table 37. Roaming HQ - HVAC, MEP, ENERGY

HVAC, MEP, ENERGY		Biro VIA, Belgrade, Serbia, 2018.
ENERGY EF. LEVEL	C	
PASSIVE SYSTEMS	OPTIONAL NATURAL VENTILATION	
HVAC	VRV HEAT PUMPS	CEILING FAN COILS AIR TRETMENT AND RECUPER.
ACTIVE SYSTEMS	SOLAR PANELS FOR POWERING WATER TREATMENT, RAIN WATER COL, GRAY WATER HEAT RECUPER.	
DUCTS	VERTICAL DUCTS (VENT&SEW) = 1% (6m2 / typ. floor)	

Figure 77. Roaming HQ - Interior view - exposed HVAC installations

OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

GENERAL INFORMATION

PROGRAM: Office (additionally retail, housing)
VOLUMETRIC TYPOLOGY: Slab
DEVELOPER: Aufbau Verlag

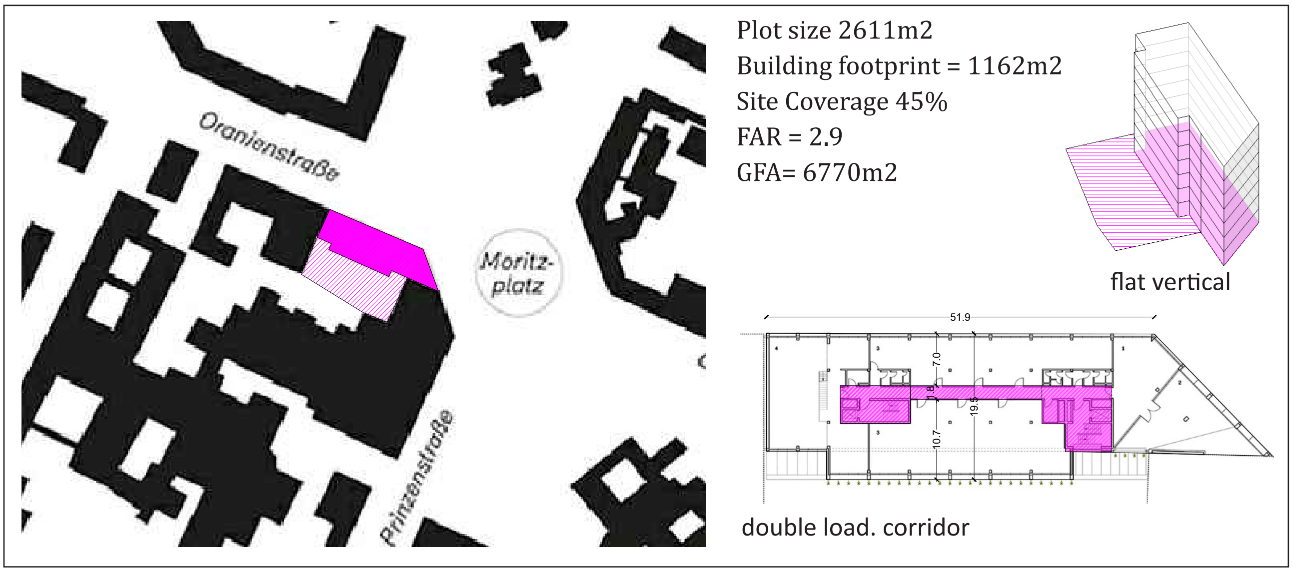


Diagram 51. Aufbauhaus - Urban parameters and typology

Figure 78. Aufbauhaus - street view

OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

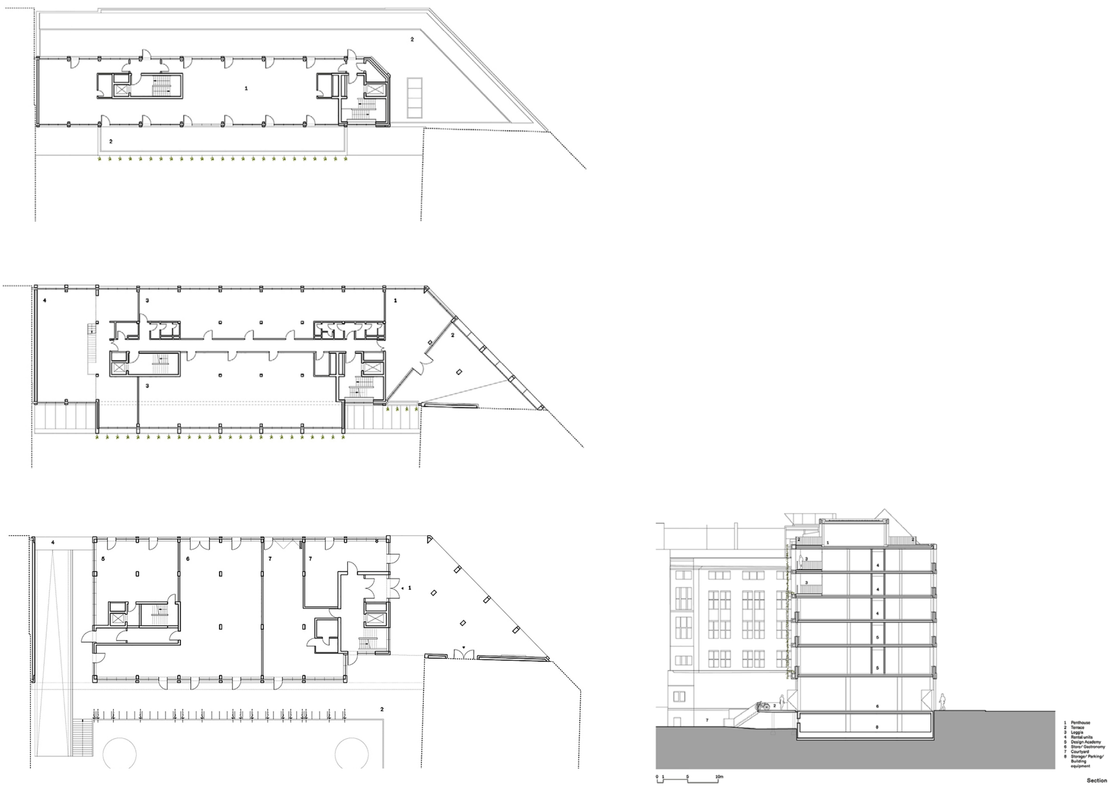


Figure 79. Aufbauhaus - Plans and section

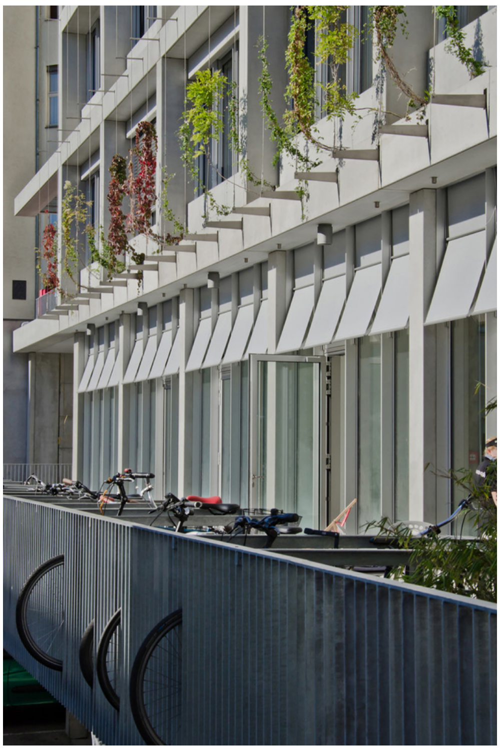


Figure 80. Aufbauhaus - backyard view

Figure 81. Aufbauhaus - Facade detail

OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

URBAN CONTEXT / OBSERVATIONS

- Aufbauhaus 84 is a specific building that closed the gap in a compact block in Moritzplatz, erected after a competition in 2012, designed as a flexible office building typology accommodating various activities such as office, education, retail and residential program

-The building mediates between an existing Aufbauhaus 85 mixed use office/education/retail building and the adjacent historical Elsnerhaus building from 1914, the building is characterised bu using the split level strategy, by being functionally connected to Aufbauhaus 85, with large gaps and generous ceiling height achieving 5 levels in total and therefore reducing the Max. GFA, the section in the Oranienstrasse have used the more rational floor heights achieving 6 levels

- The building took the maximum volume but due to the specific functional mix didn't achieve the maximal GFA

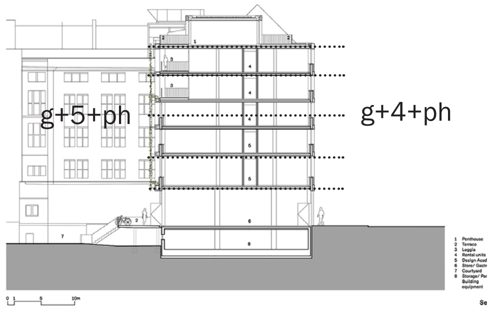


Figure 82. Aufbauhaus - Facade perspective and section

Table 38. Aufbauhaus - Urban parameters

URBAN	Barkow&Leibinger - Aufbauhaus 84,Berlin, Germany 2015.
1. PLOT SIZE	2611m2
2. PLOT SIZE & OCUPANCY	Footprint = 1162 m2 / Site occupancy 45%
3. FAR	FAR 2.9 $$$
4. DENCITY	3809 pax/km2
5. HEI & h	6.5 / 31.5m
6. LAND PRICE RANK	$$$
7. PARKING	UNDERGROUND /ON THE PLOT

OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

SPATIAL EFFICIENCY / OBSERVATIONS

- Typical office floors are designed to host multiple tenants, as mostly single oriented offices accessible through a central corridor. Typical office floor has an optimal 83 GLA%,
- In section both segments of the building has unusually high FTF heights, in general for this type of building 6 levels would be optimal as achieved in Oranienstrasse, If the building was envisioned as housing with a retail at the ground level 7.5 levels could be achieved, but it would result with a social housing category inappropriate for this location. Depth ratios are quite generous because of tall FTF heights (2.85-3.85) and well distributed as the cores and central corridor have been placed asymmetrically within the volume (10m deep space has southern orientation, 6.5m deep offices are north facing). The building have about 8% of voids within the overall volume, the voids are places as complementary spaces to the retail program on the ground level 4% achieving the functional connection and more intensive use of the courtyard, and the other two are adjacent to the Design academy forming a covered terrace as a gathering place and a functional connection to Aufbauhaus 85, and a double height gallery space connecting the 1st and 2nd floor occupied by the design academy.

Table 39. Aufbauhaus - Spatial efficiency

SPATIAL EFFICIENCY	Barkow&Leibinger - Aufbauhaus 84,Berlin, Germany 2015.
1. TOTAL GFA (overground)	6770m2
2. GLA / GFA % HOUSING	GFA / typ. floor = 420, /GLA / typ.floor = 345 GLA / typ.floor. = 82% (penthouse only)
3. GLA / GFA % OFFICE	GFA / typ. floor = 1020 / GLA / typ.floor = 840 GLA / typ.floor. = 83%
4. FTF - FTC (design academie)	FTF 4.9 / FTC 4.4 , FTF-FTC 0.5m
4.1 FTF - FTC (office floors)	FTF 4.0 / FTC 3.5 , FTF-FTC 0.5m
4.2 FTF - FTC (exhibition / assembly floors)	FTF 6.0 / FTC 5.5 , FTF-FTC 0.5m
5. TOTAL SLAB THICKNESS	19m / room depths 6.5-10m
5. DEPTH RATIO CTF / FTC	6.5 / 3.5 = 1.85 (MIN) 10 / 3.5 = 2.85 (MAX) (max depth / south orientation)
6. VOID x VOLUME %	8% / void spaces (4% retail / 4% design academy)

OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

ECONOMY / OBSERVATIONS

-The client is a publishing company Aufbau Haus GmbH, whose headquarters are already on site in the neighbouring building. The building is fully rental with an expected 36e/m2 rent for the office spaces. It is designed as a very flexible space, for various tenants with the Berlin design academy as a largest tenant already occupying about 40% of GLA.

Table 40. Aufbauhaus - Economy

ECONOMY	Barkow&Leibinger - Aufbauhaus 84,Berlin, Germany 2015.
1. CLIENT	Aufbau Varlag (publishing) & Berlin design academie
2. INVESTMENT VALUE	no info.
4. OFFICE PRICES	https://www.statista.com/statistics/431672/commercial-property-prime-rents-europe/ €36per sq. m /AVG OFFICE RENT 5000M2 OFFICE GFA / 851M2 RETAIL GFA / 345M2 HOUSING GLA
5. LAND VALUE	$$$ / HIGH
6. PARKING	LEASIBLE FOR THE TENANTS

PROGRAM / OBSERVATIONS

81% of the total GLA is designed as office space half of which have been used for educational purposes additionally to that there is 13% of retail space located on the ground level and 6% of residential penthouse space placed on the last recessed floor. It is interesting that the interior of the building is not designed at all, but intentionally left as the second phase to be customized for the tenants once they move in.

Table 41. Aufbauhaus - Program

PROGRAM	Barkow&Leibinger - Aufbauhaus 84,Berlin, Germany 2015.
1. HOUSING	420 m2 6%
2. OFFICE	5500 m2 81%
3. ADDITIONAL PROGRAM	RETAIL 850 m2 - 13%
4. UNITS	1-4 OFFICES / FL.
5. TENANTS	HOUSING: Sales OFFICE /EDUCATION: Berlin Design akademie OFFICE: multitenant
6. FACILITIES	RETAIL, PARKING, BIKE PARKING, STORAGE ROOMS

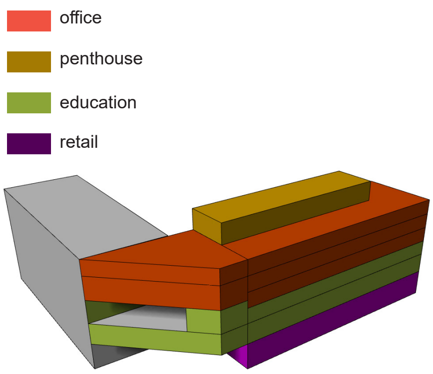


Diagram 52. Aufbauhaus - Program

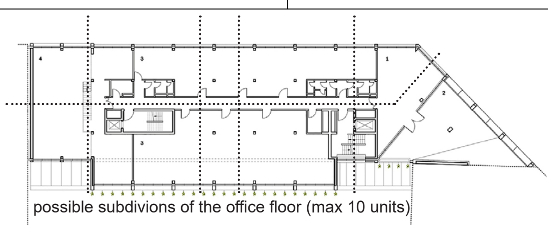


Diagram 53. Aufbauhaus - Subdivisions of the office floor

OFFICE

CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

STRUCTURE / OBSERVATIONS

-Main structure is designed as a simple skeletal system supported by two vertical concrete cores (spans vary from 7x8.2 to 5.4 x 5.4). Penthouse level done as a laminated wood structure between concrete cores.

- Floors-labs are made of solid concrete with integrated floor heating and exposed ceiling installations.
- Facade parapets that vary in height are solid, cladded with natural stone to the outside fitted with operable large windows.

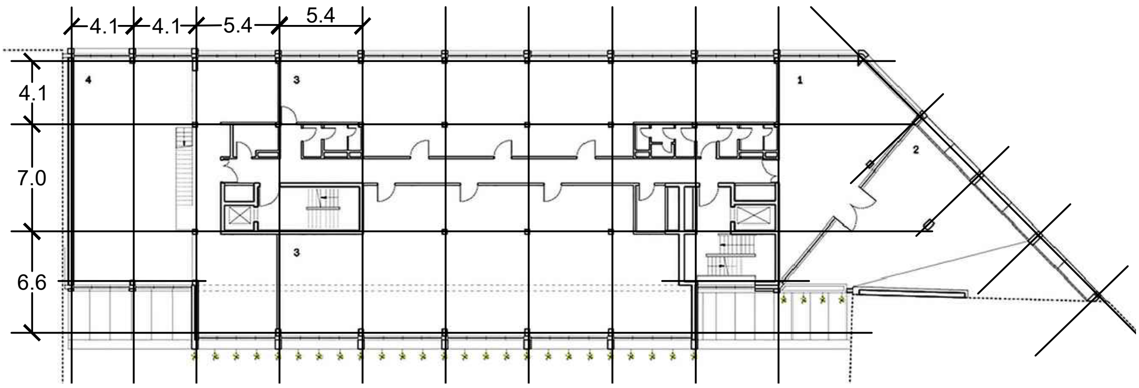


Diagram 54. Aufbauhaus - Structural grid sizing

Table 42. Aufbauhaus - Structure

STRUCTURE	Barkow&Leibinger - Aufbauhaus 84,Berlin, Germany 2015.
CORES	SKELETAL / CONCRETE CORES BETWEEN THREE ROWS OF COLUMNS
CORES	2 x
COLUMN GRID	7x8.2 , 5.4 x 5.4, 5.4 x 6.6
FLOORSLAB	30cm SOLID CONCRETE
FACADE	SOLID THERMIC, CONRETE & STONE FINISH + OPERABLE WINDOWS

Figure 83. Aufbauhaus - penthouse interior

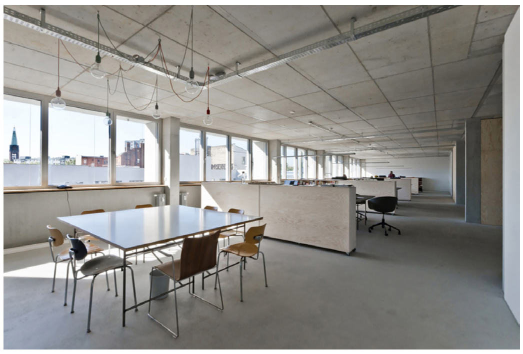


Figure 84. Aufbauhaus - Office interior

OFFICE

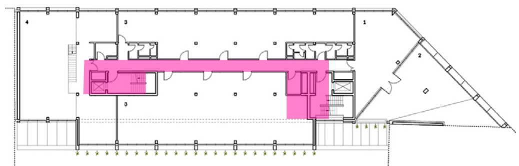
CASE STUDY 3: AUFBAUHAUS , BERLIN
Barkow & Leibinger, 2015.

CIRCULATION / OBSERVATIONS

Vertical circulation is achieved through two cores with a stretched central corridor in between can be noticed that for an office building there are not so many elevators one per core, it is possible that this is a consequence of having a design academy as a tenant on levels 1 and 2 who actually access the building from neighbouring Aufbauhaus85 on level 2.

Table 43. Aufbauhaus - Circulation

CIRCULATION	Barkow&Leibinger - Aufbauhaus 84,Berlin, Germany 2015.		
ACCESS	pedestrian 85m2	bycicle 425m2	car 317m2
LOBBIES	2 X OFFICE LOBBY		
STAIRS	2 X FIRE ESCAPE	1 X INTERNAL STAIRS (BDA)	
ELEVATORS	8m2 x typical floor (1 elevator / core)		



positioning of horizontal and vertical circulation

Diagram 55. Aufbauhaus - Circulation in plan

SUSTAINABILITY / OBSERVATIONS

Energy efficiency was achieved in a passive way by using a highly insulated solid facade and efficient window and glass surfaces. A southern orientation is used to achieve deeper offices and this facade is shaded with small cantilevered balconies with greenery, additional textile outdoor shades are used as well. The building don't need cooling and special air treatment due to the climate zone so operable windows are used for natural ventilation. The building uses floor heating and radiators presumably using central gas powered heating typical for German cities.

Table 44. Aufbauhaus - HVAC, MEP, ENERGY

HVAC, MEP, ENERGY	Barkow&Leibinger - Aufbauhaus 84,Berlin, Germany 2015.
PASSIVE SYSTEMS	GREEN SHADING / SOUTH FACADE
HVAC	FLOOR HEATING AND PARAPET RADIATORS / NATURAL VENTILATION
ACTIVE SYSTEMS	
DUCTS	VERTICAL DUCTS (VENT&SEW) = 1% (11m2 / typ.floor)

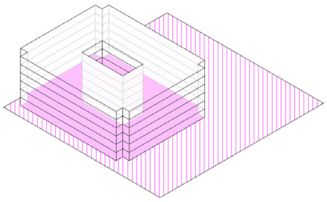
HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH
Houben & Van Meirlo, 2018. (transformation)

GENERAL INFORMATION

PROGRAM: Housing (additionally retail)
VOLUMETRIC TYPOLOGY: Slab atrium(flat vertical)
DEVELOPER: Wijkerzand / MWPO

PLOT SIZE 6204m2
Footprint = 2010 m2
Site Coverage 33%
FAR = 1.61
GFA= 10000m2
HEI = 6
HEIGHT=21m



flat vertical / courtyard - gallery

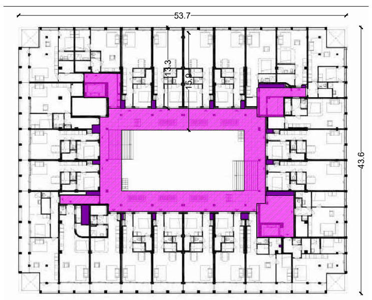


Diagram 56. Schubertsingel - Urban parameters and typology

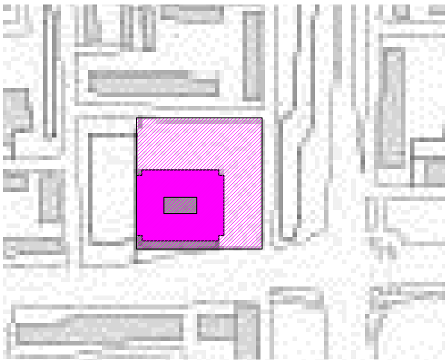


Figure 85. Schubertsingel - Situation

Figure 86. Schubertsingel - before reconstruction

Figure 87. Schubertsingel - after reconstruction

HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH Houben & Van Meirlo, 2018. (transformation)

URBAN CONTEXT / OBSERVATIONS

- The property is located in close to the urban centre of Hertogenbosch (Den Bosch) in the Netherlands. The site is a larger plot with the existing building dating from the 70s which used to house a municipal court.

- The original buildings had 4 levels + the attic (approximately 7500m2 overground GFA), as the developer decided to refurbish the existing building he was allowed to engage the building vertically and to develop a two level crown instead of an existing attic totalling with 6 levels

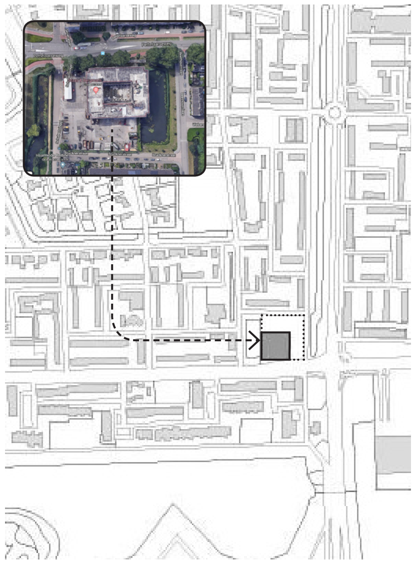


Figure 88. Schubertsingel - Context

- The final building was developed following the parameters: FAR 1.6, HEI 6 levels, and the total height limit of 21m. Exhisting building didn't have underground parking garage so the existing large plot is used to develop parking overground as it was used before, underground levels have been used for bike parking.

Table 45. Schubertsingel - Urban parameters

URBAN	Houben & Van Meirlo / Schubertsingel, Den Bosch, 2015
1. PLOT SIZE	6204m2
2. PLOT SIZE & OCUPANCY	Footprint = 2100 m2 / Site occupancy 34%
3. FAR	FAR 1.61
4. DENCITY	1,811pax / km2
5. HEI & h	6 / 21m
6. LAND PRICE RANK	$$$
7. PARKING	ON THE PLOT + UNDERGROUND

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH Houben & Van Meirlo, 2018. (transformation)

SPATIAL EFFICIENCY / OBSERVATIONS

- Existing typical floors are used in a very efficient manner by reducing the number of cores from 4 to 2 ad adding an outside atrium galleries for circulation reaching 83% GLA, the two new-built levels on the crown of the building are even more efficient 87%.

-In section, the building has a relatively high and no so efficient FTF (3.25m) height compared to the achieved FTC (2.75m) height, because of the existing thick concrete structure which resulted with thick ceiling package of 0.5m, above ground level in order to hold the large cantilever the package reached 1.5m because of the thick concrete beams characteristic for the brutalist architecture of the initial construction period.

-Since the apartments are double oriented CTF depth can be calculated as a half of the overall slab thickness which gives good depth ratio 2.43 with enough light, so which enabled more opaque energy efficient thermal facade.

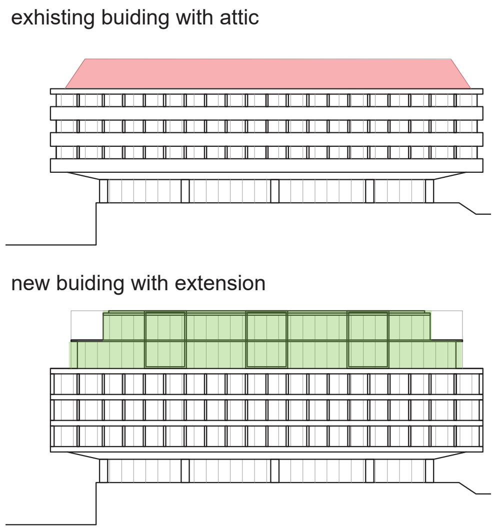


Figure 89. Schubertsingel - original vs. extension

Table 46. Schubertsingel - Spatial efficiency

SPATIAL EFFICIENCY	Houben & Van Meirlo / Schubertsingel, Den Bosch, 2015
1. TOTAL GFA	10 000m2
2. GLA / GFA % HOUSING	GFA / typ. floor = 2100, /GLA / typ.floor =1750 GLA / typ.floor. = 83% (87% on the newbuilt)
3. FTF - FTC	FTF 3.25 / FTC 2.75 , FTF-FTC 0.5m %ftf-ftc / HEI = 5x0.5m +1.5gf =4m /21m=19%
5. CTF (core to facade)	Slab thick. = 13.4 m room. depth max = 7.5m
5. DEPTH RATIO CTF / FTC	$\frac{1}{2}$ of Slab thick./ FTC = 6.7 /2.75 = 2.43
6. VOID x VOLUME %	EXTERNAL / LOGGIAS

HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH
Houben & Van Meirlo, 2018. (transformation)

Figure 90. Schubertsingel - plans

Figure 91. Schubertsingel - courtyard view

HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH
Houben & Van Meirlo, 2018. (transformation)

ECONOMY / OBSERVATIONS

- The building is developed by a local MWPO Dutch developer company,after the acquisition of the existing building with the plot for 2,5 million eur, initially they wanted to develop offices but later they decided for a conversion to housing as the old building is situated in a growing residential neighbourhood. Total investment value is unknown.

- The existing three floors (1-3) are purely rental housing units while the larger apartments on the upper floors are owner occupied, expected sales price is 3-4000 eur/m2, while the expected rent is cca. 17e/m2.

MWPO

Figure 92. Schubertsingel - MWPO brochure interior view

Table 47. Schubertsingel - Economy

ECONOMY	Houben & Van Meirlo / Schubertsingel, Den Bosch, 2015
1. CLIENT	MWPO Real Estate developer
2. INVESTMENT VALUE	
3. HOUSING PRICES	€ 3978 per sq. m /AVG HOUSING PRICE https://www.numbeo.com/property-investment/country_result.jsp?country=Netherlands € 17 per sq. m /AVG HOUSING RENT https://www.statista.com/statistics/612261/average-housing-rent-in-the-netherlands/
4. LAND VALUE	2.500 000 eur / plot+ exhisting building
5. PARKING	FOR THE TENANTS

HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH
Houben & Van Meirlo, 2018. (transformation)

PROGRAM / OBSERVATIONS

- Most of the building GLA is a housing program 92% with retail stores on the ground level as an additional program.

- Most of the apartments are rental apartment on the existing floors (75 units) and 22 owner occupied on the upper floors

- The central part if the ground level is lowered and used to create a patio yard while the underground is kept for storages, technical spaces and bike parking.

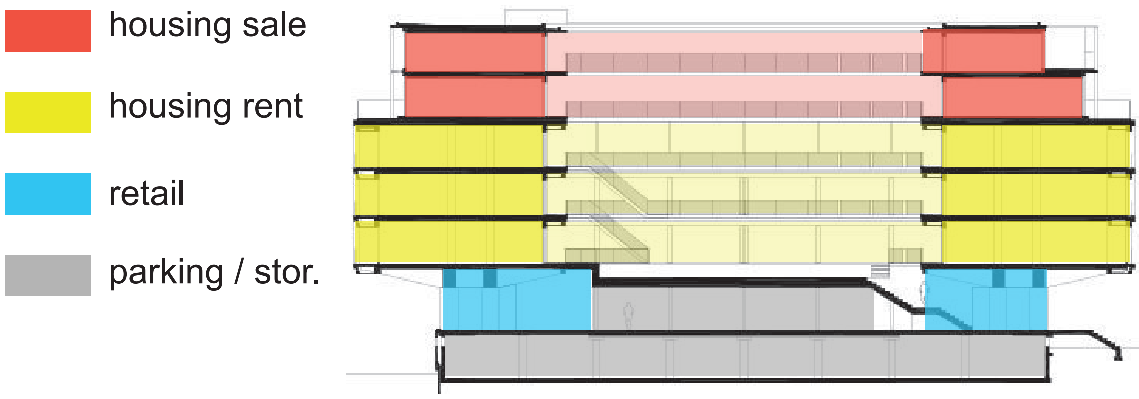


Diagram 57. Schubertsingel - Section / Program layout

Table 48. Schubertsingel - Program

PROGRAM	
1. HOUSING	8300 m2 GLA 92%
3. ADDITIONAL PROGRAM	RETAIL 620 m2 - GLA 8%
4. UNITS	97 apartments 11-26 per floor
5. TENANTS	75 rental apartments, 22 owner occupied
6. FACILITIES	RETAIL, PARKING, BIKE PARKING, STORAGE ROOMS, PATIO YARD

HOUSING CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH
Houben & Van Meirlo, 2018. (transformation)

CIRCULATION / OBSERVATIONS

- Vertical circulations have been reduced from the initial project from 4 cores to two to increase the efficiency of the floor-plate because of the added gallery circulation around the patio, still the two cores are used for fire escapes

- The ground level circulation is interesting because of lowering the central ground level with two protrusions enabled a transversal communication through the patio and an additional access to the galleries.

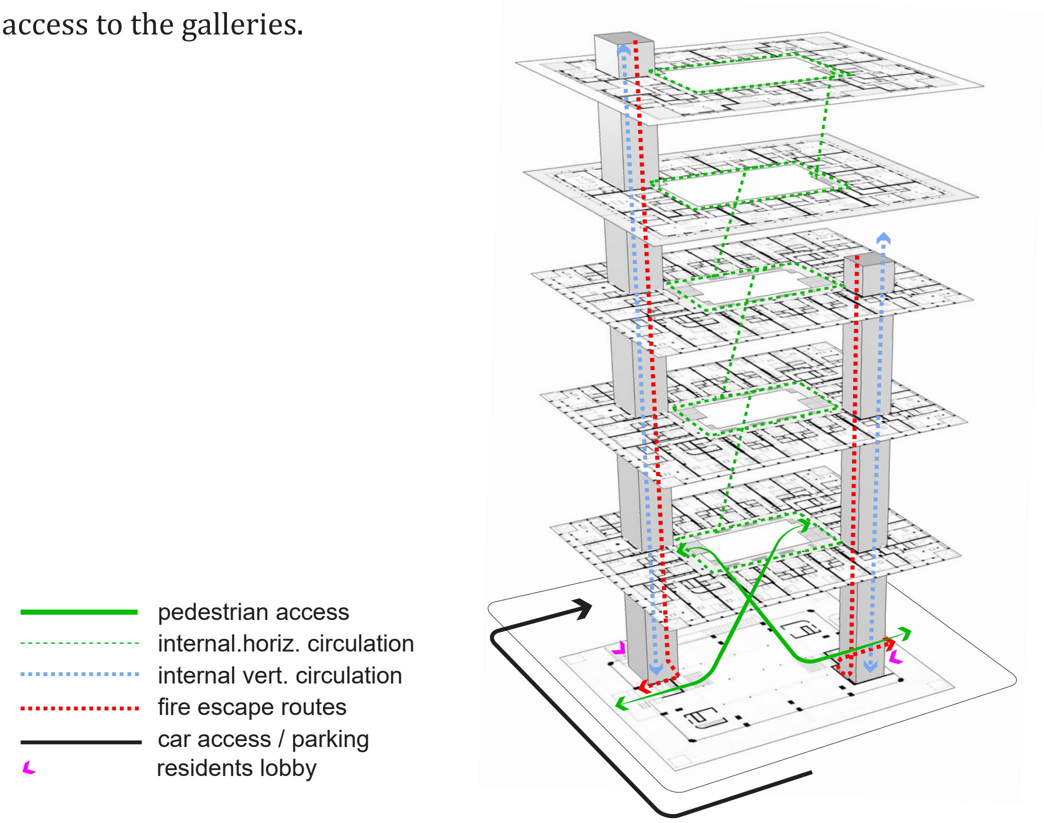


Diagram 58. Schubertsingel - Circulation diagram

Table 49. Schubertsingel - Circulation

CIRCULATION	Houben & Van Meirlo / Schubertsingel, Den Bosch, 2015
ACCESS / LOBBIES	2 X HOUSING = 55m2 2 X PATIO ACCES = 80m2
GALLERIES	130m2 / typical floor
STAIRS	2 X FIRE ESCAPE = 36m2 / typ. floor
ELEVATORS	2 x 8.5m2 = 17m2 / typ. floor

HOUSING

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH
Houben & Van Meirlo, 2018. (transformation)

STRUCTURE / OBSERVATIONS

- Structural system is a concrete skeletal system set on a repeating grid 5.2x5.2 and 5.2x2.4m, which is quite dense, probably because of a large cantilever above the ground level. There are 4 structural cores, two of which have been inhabited with housing spaces, and the other two are still in operation.

-The initial prefabricated concrete parapets have been removed in favour of the new modular facade with widow walls.

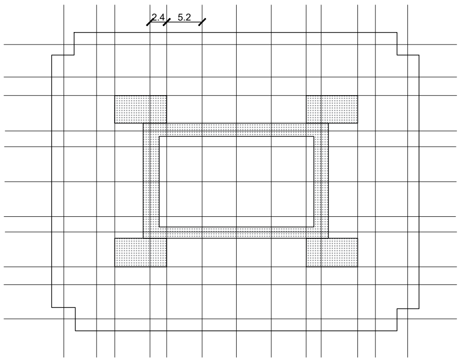


Diagram 59. Schubertsingel - Structural grid

Table 50. Schubertsingel - Structure

STRUCTURE	Houben & Van Meirlo / Schubertsingel, Den Bosch, 2015
CORES	SKELETAL / CONCRETE CORES THREE ROWS OF COLUMNS
CORES	4 x
COLUMN GRID	5.4 /2.6/ 6.8 x 5.4m
FLOORSLAB	
FACADE	Exhist. fl. / 75% transp. / modular windows Added fl. / 50% transp. / modular windows

Figure 93. Structure - street level

Figure 94. Structure - lobby

CASE STUDY 4: SCHUBERTSINGEL , DEN BOSCH
Houben & Van Meirlo, 2018. (transformation)

SUSTAINABILITY / OBSERVATIONS

-Since a building a reconstruction a large degree of sustainability have already been achieved however there are certain passive and active systems applied. The deep recessed balconies on south and west side as well as the summer sun protections on the upper floors

- As the apartments have double orientation natural ventilation strategy have been boosted with opening the ground level on two sides. In terms of HVAC systems, there is only heating which is a city heating (gas heated hot water, usual in the Netherlands). Additionally the air source heat pumps are installed using the heat from the solar panels on the roof and the geo-thermal heat to produce an additional quantity of energy.

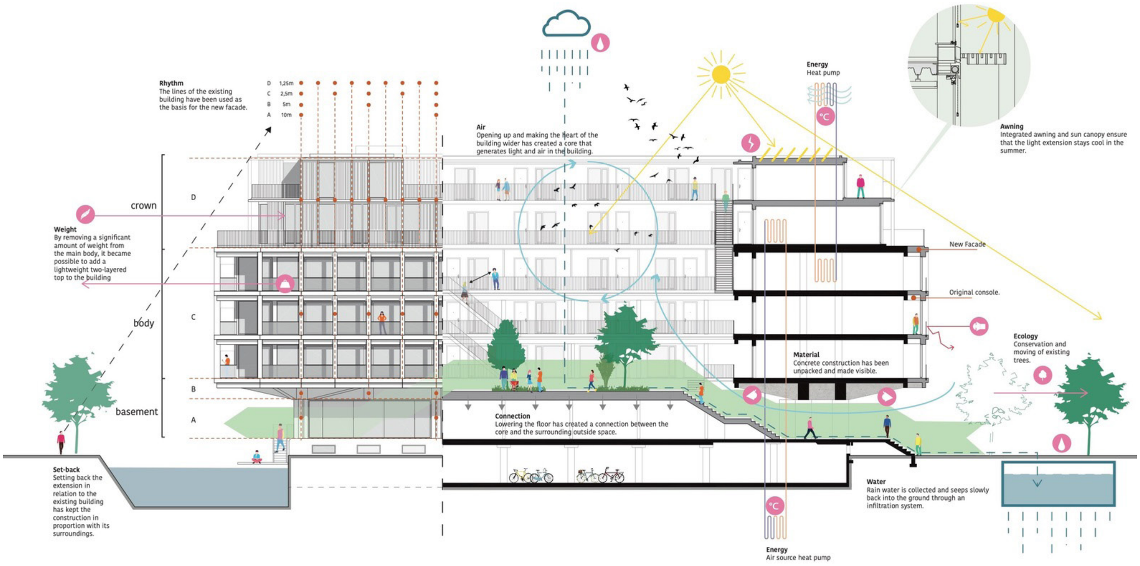


Figure 95. Schubertsingel - sustainability diagram

Table 51. Schubertsingel - HVAC, MEP, ENERGY

HVAC, MEP, ENERGY	Houben & Van Meirlo / Schubertsingel, Den Bosch, 2015
PASSIVE SYSTEMS	FACADE SETBACK ON SW PROTECTION GRILLS FROM SUMMER SUN
HVAC	FLOOR HEATING, HOT WATER + AIRSOURCE HEAT PUMPS
ACTIVE SYSTEMS	SOLAR PANELS, RAIN WATER COLLECTION
DUCTS	VERTICAL DUCTS (VENT&SEW) 20m2/typ floor = 1.5%

7. SOURCES (LITERATURE, FIGURES, DIAGRAMS, TABLES, PROJECT DOCUMENTATIONS, CHARTS)

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7.2 FIGURES

Figure 1. Migron settlement
Reuters. "Migron settlement." 2012. https://sevenmonthsintelaviv.com/tag/migron/.

Figure 2. Ma'ale Adumim
"Israeli settlement of Ma'ale Adumim (Jerusalem Governorate): 35,673 inhabitants, established in 1975, 1,759 acres." 2015. http://www.uncubemagazine.com/blog/15801995jpg.

Figure 3. A global yes to capitalism
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Cailleboute, Gustave. "Le Pont de l'Europe." n.d. Musée du Petit Palais [fr], Geneva. https://en.wikipedia.org/wiki/Le_Pont_de_l%27Europe.

Figure 5. Girl with mandolin
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Figure 9. Museo Aero Solar
Saraceno, Tomas. "Museo Aero Solar." https://studiotomassaraceno.org/. 2007. https://aerocene.org/buildit/.

Figure 10. Fundamentals exhibition - fireplace
OMA. "Elements exhibition." 2014. Venice Biennale 2014. http://www.continuum.com.au/raia/courses.php?o=list&c=19.

Figure 11. Fundamentals exhibition - ceiling
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Figure 12. Archigram, Monaco Entertainment center, catalogue of element
(source: Sadler, Simon. Archigram: Architecture without Architecture. Cambridge, MA: MIT Press, 2005.)

Figure 13. Envelope / volume typologies
Zaera-Polo, Alejandro. "The Politics of The Envelope." Log, no. 13/14 (2008): 193-207. Accessed January 2, 2021. http://www.jstor.org/stable/41765249.

Figure 14. Infrastructure and fit outs
"Plexal Here East innovation center." Sam Shead. n.d. https://sg.finance.yahoo.com/news/plexal-quirky-innovation-centre-high-162400046.html?guccounter=1.

Figure 14a. Transformational strategies - illustration

Figure 15. Infrastructural ground
A collage created by the author compiling section and elevation drawings of following projects: Falling water House (Wright,1939), Farnsworth House (Van Der Rohe, 1951), Villa Savoye(Le Corbusier, 1931) and Dee and Charles Wyly Theatre (OMA/REX, 2009)

Figure 16
A slide from a lecture by: Reiner De Graaf, "Where from here" (lecture, New Zealand Institute of Architects, Auckland, New Zealand, February 13, 2019)

Figure 17- An Anti - Vitruvian architectural composition
De Graaf, Reiner. "Where from here." Lecture, New Zealand Institute of Architects, Auckland, New Zealand, February 13, 2019.

Figure 18. (Tables 1,2,4) Cost based conclusions on the building transformations
Tables are from the paper: Hilde Remoy and Theo Van Der Voord, "SUSTAINABILITY BY ADAPTABLE AND FUNCTIONALLY NEUTRAL BUILDINGS" (Paper presented at SASBE 2009, 3rd CIB International Conference on Smart and Sustainable Built Environments, Delft, May 15, 2014), 3-6.

Figure 19. Strategy of the Void II
Rem Koolhaas, "Junkspace," in Content (Koln: Taschen, 2003), 77.

Figure 20. Yokohama Masterplan (OMA)
OMA. "Yokohama Masterplan." 1991. https://oma.eu/projects/yokohama-masterplan.

Figure 21. IFCCA 24h cycle (UNStudio)
UNStudio. "IFCCA competition diagram." 1999. https://www.unstudio.com/en/page/12062/ifcca.

Figure 22. Herman Hetzberger - Diagoon houses layouts
Hertzberger, Herman. "Diagoon houses plans." 1970. https://archinect.com/news/article/30540087/editor-s-picks-241#&gid=1&pid=1

Figure 23. FAR game exhibition
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Figure 24. Hugh Ferris' vision of Manhattan
Ferriss, Hugh. "Manhattan zoning laws." 1920. http://words.provolot.com/parallel-dates/38.

Figure 41. REAL+ app demo screenshot
MLA+, “REAL + app demo screenshot,” , 2019, https://www.realplus.biz/.

Figure 42. Online filter for plot search (illustration)

Figure 43. Search matching, mixed used city center zoning areas in Belgrade (illustration)

Figure 44. Block 18 in Belgrade GIS app - Beoinfo

Figure 45. Preview plan of detailed regualtion (PDR), 2017.
Graovac, Ana and Lazovic, Ana, Plan detaljnje regulacije bloka 18 - Elaborat za rani javni uvid, (Belgrade: Direkcija za gradjevinsko zemljiste i izgradnju beograda, 2017), http://www.beograd.rs/lat/gradski-oglasi-konkursi-i-tenderi/1732006-rani-javni-uvid-u-plan-detaljne-regulacije-bloka-18/.

Figure 46. Broader context of Block 18

Figure 47.Current state of Block 18 (Google Maps, Google street view)

Figure 48. Block 18 in famous Politika newspaper (screenshot)

Figure 49. Block 18 in Danas newspaper (screenshot)

Figure 50. Winning competition scheme - exploded diagram of program distribution
compete project documentation of the winning competition proposal is acquired from the author (Vanja Panić) for the purpose of this research, on 24.09.2019.

Figure 51. An aerial perspective of the winning proposal
compete project documentation of the winning competition proposal is acquired from the author (Vanja Panić) for the purpose of this research, on 24.09.2019.

Figure 52. Situation, program layout and transversal section of the urban proposal

Figure 53.An aerial perspective of the winning proposal 2

Figure 54. Plot in block 18 for sale
“Plot in Block 18,” HaloOglasi, 2019, https://www.halooglasi.com/nekretnine/prodaja-zemljista/beograd-novi-beograd-blok-18-staro-sajmiste.

Figure 55. A screenshot from a developed segment for the Urban Automation Tool - a Grasshopper script definition v1.0, that generates a volumetric boundary cage based on zoning laws generates the desired number of buildings, which can be moved withing boundaries defined by local zoning, it is possible to balance the program mix in each of the segments, and automatically “call” and map a typical functionally neutral plan according to the building proportion, program, and mix. Quantitative outputs can be multiple: 1) GFA, GLA 2) Surface of facade 3) Volume.... The m2 data can be used for rough cost estimations projections.

Figure 55a. A screen-shot from a developed segment for the Urban Automation Tool - zoomed segments

7.3 DIAGRAMS

of 19 blocks is proposed (blocks in white remain reserved for public functions) based on the average size from the overview of competition entry (Diagram 18).
Diagram 28. Hierarchy of the urban plans

Diagram 29. Typical block - comparative analysis 1/3

Diagram 30. Typical block - comparative analysis 2/3

Diagram 31. Typical block - comparative analysis 3/3

Diagram 32. Typical block – comparative analysis: overview of feasible massing options

Diagram 33. Grasshopper script branch - incorporating the zoning laws to generate a volumetric boundary fot a chosen block

Diagram 34. Selection of desirable massing options for further analysis

Diagram 35. Programming the chosen massing option according to the urban context

Diagram 36. Choosing the type and degree of mixed program within massing options

Diagram 37. Applying the library of functionally neutral plans to the massing options

Diagram 38. Tuning the program mix

Diagram 39. Informing the chosen generic massing options with the context sensitive data

Diagram 39a. A self corrected and updated BIM model - with Rhino inside Revit

Diagram 40. BIM model as final output

Diagram 41. Positioning a generated urban block as a BIM model back into GIS

Diagram 42. A possibility to explore the generated 3d model in VR

Diagram 43. Urban Automation tool - a platform for stakeholder dialogue

Diagram 44. Implementing automated BIM urban design models as a new GIS data layer.
The diagram uses two web images:
Advanced solutions Inc., "BIM Project phases," , 2017, https://www.letsbuild.com/blog/recognising-bim-roles-project-cycle.
Ontario County, NY, "GIS Data layers," , 2016, https://www.usgs.gov/media/images/gis-data-layers-visualization.

Diagram 45. A step-by-step work flow for the from the case study analysis towards the demonstration of its results and possible application (STEP1)

Diagram 46. Tour Opale - Urban Parameters and Typology

Diagram 47. Roaming HQ - Urban parameters and typology

7.4 TABLES

Tables appendix

Table 51. Schubertsingel - HVAC, MEP, ENERGY

7.5 PROJECT DOCUMENTATIONS

Sources for the project images, figures, drawings and data used in Table 4, Table 5, Table 6, table 7, Table 18, Table 19, Table 20, Table 21, Table 22, Table 23, Diagram 10, Diagram 18, Diagram 19:

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7.6 CHARTS

* All charts are developed by the author. All data originates from project documentations or is measured and extracted by the author.

SUPPLEMENTS

- Biography
- Authorship statement
- Authors confirmation that the printed and electronic version of PHD are identical
- Statement about the use of PHD

BIOGRAPHY

Nemanja Kordić, dipl.eng.arch./ MA.AD, PhD candidate

Teaching assistant, University of Belgrade - Faculty of Architecture / Department of Architecture / Tel. + 381 64 1427 133/ E-mail: nemanjakordic@gmail.com

Nemanja Kordić (1984), is a Ph.D. candidate (2018), graduated at the Faculty of Architecture University of Belgrade with a Master's degree in Architectural Technologies (2009), and obtained a postgraduate Master of Arts in Advanced Architectural Design (2012) at Staedelschule Architecture Class (SAC) in Frankfurt, Germany.

Throughout his professional career, he worked as an architect in several international offices (Feichtinger Architectes /Paris (2008), Studio Tomas Saraceno / Berlin (2010-2012) and UNStudio / Amsterdam (2013-2014)) on a variety of building typologies ranging from office buildings, museums, department stores, metro stations and exhibition pavilions (Projects: VoestAlpine office - Linz, BWC Department store - Baku, Qatar Railways metro stations - Doha, IBG pavilion - Groningen…). Currently he is a partner in his Belgrade based design studio MART Architecture. Since 2016, he has been employed as a Teaching Assistant at the Faculty of Architecture, working on Bachelor and Master design courses focused on: housing, office, educational and public building typologies.

He is engaged in scientific work through a his PhD research titled: Role of infrastructure in determining the architectural composition in the XXI century. His current research focuses on infrastructural tenets of the functionally neutral architectural typologies, and their possible application through urban automation software platforms.

Author of 2 family housing projects, 1 multifamily housing, 4 residential and 3 retail interiors, and 17 architectural and urban design competitions. Received 7 awards and recognitions for his professional work at national and international architectural competitions. His works were published and exhibited in national and international publications and exhibitions.

Образац 5.

Изјава о ауторству

Име и презиме аутора **Немања С. Кордић**

Број индекса **Д 03 -2014**

Изјављујем

да је докторска дисертација под насловом

УЛОГА ИНФРАСТРУКТУРЕ У ДЕТЕРМИНИСАЊУ АРХИТЕКТОНСКОГ СКЛОПА У XXI ВЕКУ

ROLE OF INFRASTRUCTURE IN DETERMINING THE ARCHITECTURAL COMPOSITION IN XXI CENTURY

- резултат сопственог истраживачког рада;
- да дисертација у целини ни у деловима није била предложена за стицање друге дипломе према студијским програмима других високошколских установа;
- да су резултати коректно наведени и
- да нисам кршио/ла ауторска права и користио/ла интелектуалну својину других лица.

Потпис аутора

У Београду, ________________

Образац 6.

Изјава о истоветности штампане и електронске верзије докторског рада

Име и презиме аутора **Немања С. Кордић**

Број индекса **Д 03 -2014**

Студијски програм **Докторске Академске Студије**

Наслов рада **УЛОГА ИНФРАСТРУКТУРЕ У ДЕТЕРМИНИСАЊУ АРХИТЕКТОНСКОГ СКЛОПА У XXI ВЕКУ**

Ментор **др Ана Никезић, ванредни професор**

Изјављујем да је штампана верзија мог докторског рада истоветна електронској верзији коју сам предао/ла ради похрањена у **Дигиталном репозиторијуму Универзитета у Београду.**

Дозвољавам да се објаве моји лични подаци везани за добијање академског назива доктора наука, као што су име и презиме, година и место рођења и датум одбране рада.

Ови лични подаци могу се објавити на мрежним страницама дигиталне библиотеке, у електронском каталогу и у публикацијама Универзитета у Београду.

Потпис аутора

У Београду, ________________________

Образац 7.

Изјава о коришћењу

Овлашћујем Универзитетску библиотеку „Светозар Марковић“ да у Дигитални репозиторијум Универзитета у Београду унесе моју докторску дисертацију под насловом:

УЛОГА ИНФРАСТРУКТУРЕ У ДЕТЕРМИНИСАЊУ АРХИТЕКТОНСКОГ СКЛОПА У XXI ВЕКУ

ROLE OF INFRASTRUCTURE IN DETERMINING THE ARCHITECTURAL COMPOSITION IN XXI CENTURY

која је моје ауторско дело.

Дисертацију са свим прилозима предао/ла сам у електронском формату погодном за трајно архивирање.

Моју докторску дисертацију похрањену у Дигиталном репозиторијуму Универзитета у Београду и доступну у отвореном приступу могу да користе сви који поштују одредбе садржане у одабраном типу лиценце Креативне заједнице (Creative Commons) за коју сам се одлучио/ла.

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Кратак опис лиценци је саставни део ове изјаве).

Потпис аутора

У Београду, ______________________

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