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A Systemic Modeling Methodology for Evaluating Built Environment Performance: Measuring Urban Proxinity

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Abstract

In today's world, built environment plays the key role in socio-economic relations and the environment is being affected most dominantly by urban life. Cities are growing fast, and faster are growing the numbers of urban inhabitants. At present, more than half of the world's population lives in cities and it is estimated that this ratio will increase to 70 percent by 2050. It means that if they are not managed now, the urban-related issues we are facing today will be taken to much more intensity tomorrow and even more severe environmental risks and socio-economic conflicts are yet to arise.

Currently, about 80 percent of the global primary energy is being consumed in urban areas, cities are being guilty of emitting more than 60 percent of the total world's greenhouse gases, and the list of social issues in urban arrangements are endless. On the other hand, cities are the economic engine of the world, and by being on average responsible for more than 75 percent of a country's Gross Domestic Product (GDP) their further expansion is an inevitable perspective.

In this situation, and as sustainability becomes the main development framework for all parts of economic communities, adopting innovative approaches towards development in the built environment is becoming urgent.

In the recent decades, there have been many attempts to define all-inclusive strategies and act globally for sustainable development. Currently, the main universal framework for approaching sustainability is the UN Agenda 2030 which defines the Sustainable Development Goals for the year 2030 and offers a comprehensive set of indicators for measuring the improvement.

Since the socio-economic and environmental relations form a highly complex integrated matrix, all the Sustainable Development Goals are fundamentally linked together. Thus, the only possible approach to the UN Program would be through a profound systemic interpretation that highlights the linkage between the goals. This demands an elevated level of interdisciplinarity in all the attempts directed to meet the Sustainable Development Goals. However, it is conventional for the first methodological steps to be taken in monodisciplinary research laboratories working only one goal or even few targets within the SDGs. Therefore, it is crucial for institutional and research bodies to consider the entire perspective when they develop methodological platforms to approach sustainability in their field. Such consideration requires a deep holistic understanding of the field of study and the overall obstacles of sustainability involving systemic synthesis with the usual scientific methods. In other words, any methodology defined to approach each one of the UN SDGs should be defined in a robust structure able to scientifically communicate to other fields involved. For this, the methods cannot be limited to analytical thinking but must adopt a clear system-thinking approach in their theoretical formation.

The built environment is composed of various morphological, typological, and technological subsystems from which the performing manner of the entire system is originated. Claiming sustainability in urban establishments demands a comprehensive understanding of cities as complex systems and clear identification of the role player subsystems within them. The majority of current trends and design methods adopt simplified analytical approaches and practically deal with the subsystems as independent entities; hence neglect the importance of phenomena resulting from their interconnections in different scales.

With the aim of developing a better understanding of the built environment's systemic structure, the intention of this Ph.D. research is to offer a holistic methodology for studying the behavior of the built environment and investigate the methods for measuring the effect of urban structure to the performance. This goal will be pursued through an inquiry into the morphological components of the urban systems and the complex relationships between them. Particularly, this research focuses on the morphological patterns that might influence the non-motorized traffic. The measurable morphological values will be investigated and an automatizing calculating methodology will be developed. Then, a theoretical platform for studying the pattern of relationship between the mentioned values and performance indicators will be argued.

All the findings and applied methods in this thesis will be applied on the following case study: As it is predicted by UN that by

2050 around 70 percent of the urban population would live in informal settlements, it seems appropriate that the men-tioned methodology will be tested in such a context. Therefore, PolomiParaRo-cinha which is a 2016 Polisocial award-winning project is selected as the case study. PolimiparaRocinha is a project with a theme of environmental performance and social inclusion for Rocinha, the biggest Favela of Rio de Janeiro, Brazil of which the author of this thesis is the coordinator of the operative team. For the case study adaptation, the non-motorized traffic patterns and parameters induced within the local morphological is being studied and their effects in terms envi-ronmental performance is being investigated both in the local and city scales.
The core value of this research is demonstrating that the direct relationship between action and behavior can be scientifically measured. This highlights the necessity of similar approaches for studying the built environment leading to developing decision support tools able to predict the behavior of the urban arrangement after certain modification scenarios from a sustainable point of view.
Keywords
Built Environment, Sustainability, Ecology, Systems, Complex Adaptive Systems, Sustainable Indicators, Urban Morphology, Key Categories, Morphological Attributes, Structural Tools, Evaluation Tools, Operational Facet, Modelling Methodology

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CHAPTER 1

Introduction

1.1 Sustainable Development and Practical Challenges

1.1.1 Sustainability: The Historical Account and A Realistic Perspective

It has taken two centuries for man to doubt the promises of his boundless economic growths brought to him by the Industrial Revolution. The reactions of the environmental systems to the continuous extractions of the seemingly unlimited resources were so alarming that in the mid-1970s, experts agreed that the ongoing development models could not continue for long. Almost half-century later, we are still in a difficult struggle for replacing those traditional ways with tangible models with which the scientific communities, policymakers, and economic bodies may comply.

Parallel with the organized environmental concern in the last 50 years, as the human population of the world doubled, the carbon emission related to the industries raised by more than twice the planet earth surface had warmed by around 0.5° Celsius in the average, and its wildlife decreased by 60 percent in numbers (Allan et al. 2017; World Wildlife Fund 2018; Geck 2017; O'Neill et al. 2012). Climate change surprises us year after year, and beside severe damages to our infrastructures and resources brings serious and unprecedented economic and socio-politic challenges. All this is happening at the golden age of humanity when the man's knowledge is flowering on its peaks, and the global collaboration seems to be higher than ever before.

What has happened in this small period of history that causes such horrifying results? Moreover, what it is that makes us so shockingly impotent in controlling the circumstances that we have created? Is the problem the product of the ways we think and act in, or is it rooted in the mechanisms of the environmental systems?

For answering these questions, there is no choice for the man to meekly accept his powerlessness to comprehend the nature and the fundamental relationships of things and phenomena which shape our world. We need to look back at the critical junctures in our development history that took us to this perilous historic gorge.

Although there is evidence of some trivial prehistoric environmental concerns (Anderson 2008), the first relatable clues might take us precisely to the Neolithic Revolution in 15,000 to 10,000 B.C when the lifestyle of humankind entirely reshaped by the agricultural transition (Weisdorf 2005). This era is the exact turning point in history, where the relationship between man and nature became one of the masters and the slaves. Despite man's great benefit from his one-of-a-kind godly genius to survive in the wild, before the Neolithic Revolution, he was merely a creature just like any other earthly being. He hunted some and was hunted by others. He lived mostly in temporary territories was alien to the concept of development in its today's sense. Back in the nomadic day, the monopolistic hierarchy was not defined in the relationship of humans and nature and people modified the environment through their instinct, size, physical abilities, and their collective behavior in the same way that any other organic being might do.

The agriculture, however, changed the game forever. Man no longer had to wait for the earth's gifts, for he became able to mobilize whatever it takes to extract his food out from the heart of the planet. Many creatures who were equal with him tuned to be his laborers. The temporal territory that he shared with other beings changed into possessed lasting lands. The concept of ownership that was limited to a set of tools and clothes suddenly peaked to the most critical parameter and shaped almost all the human relations ever after. This revolutionary shift is maybe the birthplace of the idea of development as we regard nowadays.

Concerning the man's previous lifestyle, agriculture could not provide healthier foods but certainly created much higher food security, which helped a lot in increasing the population of humankind (Harari 2014). The survival of humans was now tied up to the pieces of land they lived upon, and as the sedentariness became the most popular lifestyle, fewer dangers could threaten their life. People were spreading all around the earth and adjust the environment in much larger scales than before. Now there was a hierarchical pyramid on which the man was on top, and all the creatures below him gradually became the subjects of his readjustments.

The mentioned sedentary lifestyle formed the uterus of the human settlements, which gradually turned into rural and urban organizations the way we recognize them now. Since then, villages and cities have been the bogus filters between humans and nature. While communities have taken a slower changing rhythm, each advancement in human knowledge has been manifested rapidly in cities. Cities, as our eternal homes, were subjected to permanent changes through history, and as soon as our collective lifestyle slightly shifts in any direction, cities adjust themselves.

The human civilization went on with an intimate and mutual relationship with cities. Cities had the role of ensuring the man's need by protecting his agricultural products, his culture, his economy, and his life. Citystates became the flags of the collective identity, wealth, and force, and one crucial role of the rural settlements was to feed them. Although this new lifestyle was a massive shift in relations between man and nature, which led to unprecedented alternations in wildlife ("From Urbanization to Cities: Towards a New Politics of Citizenship" 2010), it seemed altogether harmless for the man himself. However, the Industrial Revolution changed all things again and took the human history to another point of no return.

As science went from the hobby of the intellectual to the sole modern age rule, humans practiced their ability to change the world on a much broader scale. The immense transition in manufacturing process brought by the Industrial Revolution started might have started with textile production at first, but swiftly changed the whole world forever and inspired the creation of everything after that piece of textile.

Once again, every aspect of human life has changed. The economy, politics, and cultures have reacted, adapted to, and evolved with the Industrial Revolution (Rao 2011; Clark 2014). As the production procedures become much faster and cheaper, the expansion of knowledge brought new technologies and medicines year after year. The man became wealthier and healthier. The human population raised again, and cities expanded much faster than before.

The Industrial Revolution completely changed the outward forms of human life in various ways, though, its inward effect on men was much more in-depth. It revolutionized his mindset in many different directions: If the Neolithic Revolution revealed the secrets of Mother Earth's fertility to man, the Industrial Revolution gave him the godly confidence that he can hire his intelligence for changing anything. Moreover, he came to this subversive understanding that the source of the wealth is not limited. Mass production, technology advancement, and science hold the keys of an unbounded treasure.

The perspective drawn by the newly-found wealth sources and the expansion of human knowledge were not all promising. Improvements in daily nutrition, growth of the capital income, and the developments in medical science had their immediate effects on population increase. In 50 years periods, the population of countries became doubled as the total population of Europe increased more than four times during the industrial revolution (Mancuso and Stuth 2015; The New Encyclopedia Britannica 1973).

The first flash of semi-modern environment worriedness is trackable at this point in history. In 1798, the English scholar Thomas Robert Malthus warned the word that "the power of population is so superior to the power of the earth." Therefore, it is inevitable that the food requirement will surpass the capacity of food production (Malthus 2010). He argued that the human population grows exponentially while the food growth remains arithmetical and pictured an apocalyptic future for the humankind due to the starvation which is called the Malthusian Catastrophe after his name (Figure 1.1).

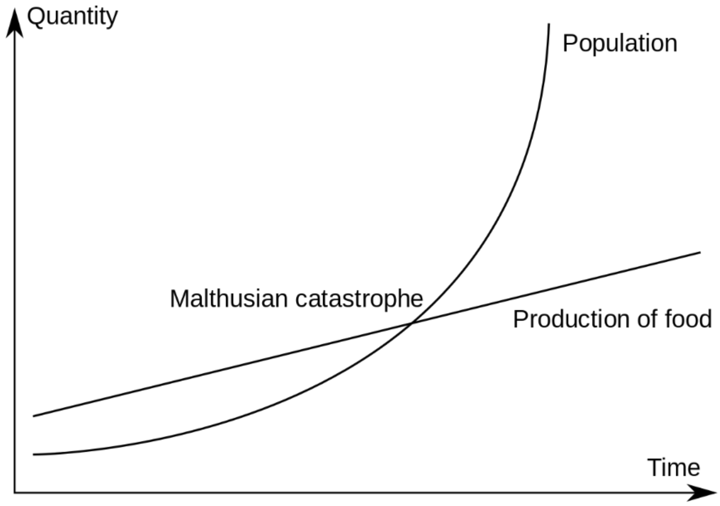

Figure 1.1 Malthusian Catastrophe is the moment in time when the food requirement overpasses the capacity of earth's food production (Source: The Theory of Population, Thomas Robert Malthus)

Malthus called for preventing reproduction in any possible ways and even welcomed disastrous events like wars and epidemic diseases for their gruesome role in controlling the human population. While he succeeded in recognizing an inescapable reaction due to the significant shift in man and nature relationships, he failed to foresee its accurate direction, for he underestimated man's capabilities. His bizarre prescription, which raised scientific and moral criticism, is the evidence of his blind insight into the degree to which humans could engineer nature to their favor.

In the middle of the twentieth century, almost only one century from Malthus' death, the man accomplished to envision another agricultural revolution that appeased the concerns of food production and delayed the Malthusian Catastrophe for beyond any foreseeable future. Newly-discovered chemicals remodeled cultivating systems, and powerful advanced machinery brought unprecedented potentials in production capacities. Despite specific problems and doubts (Pingali 2012; Tilman 1998), this agricultural shift, which was called the Green Revolution, increased the overall food security and managed to meet the needs of the earth population, which significantly increased after the Second World War. However, the Green Revolution could not put an end to environmental worries as nature exhibits its incompleteness for accompanying man's ambitions through many other means.

By the beginning of the 1970s, the mainstream environmentalism's concerns were expressed principally by scientific exercises like "Small is Beautiful" and "The Limits to Growth" (Schayegh 2014; Meadows et al.

2018). These studies warned the global community about serious uncertainties over the economic development trends and their inevitable consequences in the forms of excessive population growth, social injustice, pollution, and dreadful alternations in the ecosystem. In many ways, they allude to the role of Consumer Capitalism as one leading cause of modern problems (Foster 2011; Colombo 2001).

Regardless of puzzling political indoctrinations, it is easy to recognize the distinct capitalistic models of development worldwide, adopted even by the governments which ostensibly defy it (a good case would be the State Capitalism practiced by the Chinese government). By defining new and attractive high ideals, this economic paradigm evolved and produced present-day values and took flexible forms ever since its dawn in the 18th century. Western societies widely practiced capitalism since the maturity of the Industrial Revolution. It became universally accessible in the post-war era. However, it was only in the 1970s that the world tasted the bitterness of possible disintegrations of capitalism into its supporting organizations due to the infamous Oil Crisis (Salameh 2004). Immediately after, it became crystal clear that the side effects will not be limited to the economy, but the social and environmental systems are in much greater danger.

Capitalism is simply the reversed market-oriented economic model. In the classic models, money used as a tool between products to facilitate manufacturing and flow. Capitalism, on the other hand, uses products to bridge between money and more money (Kelly 2013). Therefore, it is safe to say that by founding capitalism, Adam Smith forever transformed the nature of money from the production currency into the supposedly ever-growing capital as the only modern indicator of success. In Smith's time, however, capitalism became holy greed. The profit of production would lead to the expansion of the firm, and consequently, more job opportunities would appear. So the development spiral would continue a circling process that would bring delight to employers and employees and job seekers.

Regardless of vast systematic disinformations, nowadays, it is complicated to identify holiness of any kind in capitalist systems whatsoever. The epidemic obsession for capital growth had led to massive productions, so that for keeping the figures on top, there are urgent needs to discover new markets for the manufactured goods forever. So the model became more products, more consumers, and a more significant capital going on forever. This economic model, which is the most common today, is called Consumer Capitalism and comes at a very high cost.

Despite social inequality due to the tendency to minimizing costs and maintaining minimal wages, consumerism does Irreparable harm to nature and the ecosystem. The reason is for unlimited growth, and there is the need for unlimited resources when, in fact, there is an absolute bar restraining us from too much extraction. The Club of Rome, an international group of experts, passed this resolution in 1972 as the title of their major study, “The Limits to Growth,” is quite evident (Djendoel 1973).

Examining the complexity of the contemporary issues the nations are facing, the Club of Rome agreed on three main characteristics of the *World Problematique*: 1. The problems are universal; 2. They encompass social, economic, and technical elements, and most importantly, 3. They interact. In other words, the problem is too bilateral to be managed by the countries individually. Concealed but fundamental integrities between the world’s different mechanisms, also, make the sectorial approach too outdated to deal with the problem. Hence, to overcome the challenges, not only we need a robust universal will, but we should also upgrade our scientific paradigms for understanding the world’s mechanisms.

Accordingly, from the1970s on, authorities programmed global attempts to involve all the available knowledge and political power worldwide to take action. The word “sustainability,” in the sense we are familiar with today, appeared first in 1972 in the book *Blueprint for Survival.* It rapidly grew as the official term for expressing policies of environmentally friendly development and *No Growth* economic models. By 1978, the United Nations started to use sustainability as the main code of ecodevelopment programs and later in 1987 defined the Sustainable Development and its characteristics through the Brundtland Report, also known as Our Common Future.

Sustainable development consists of three pillars: 1. Economic Growth; 2. Social Development; and 3. Environmental Protection. Accordingly, development is sustainable if and only if it ensures progress in all the three mentioned areas (Figure 1.2). Brundtland Report identifies this inclusion as “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” Therefore, if an economic program excludes society or the environment, it is viable or equitable, respectively. Therefore it is not necessarily sustainable (economy being the main trigger of development as the influence of socio-environmental activities, emerging mostly in the form of NGOs, is negligible).

This standard shift demands revolutionary readjustments into the world’s political and economic systems, which are not necessarily convenient for all countries and stakeholders. In the era of intense industrial and commercial rivalries, sustainability might come at the cost of retreat from the short and long term interests. The reluctance of individual governments to fully comply with global sustainable policies and the existence of intended loopholes paving the way of greenwashing for industries highlights the level of universal ignorance about the horrible consequences of neglecting the environmental challenges. It is crucial to acknowledge that there is no way out of the imminent global failure but unity. There should be a universal will preventing the individual development policies from creating conflicting interests on the world scale.

Therefore it is fundamental to work on political tools demanding practical obligations from the authorities and, at the same time, prioritize researches in sustainability fields and enhance the overall education. There have been many practices in this direction recently: At the beginning of the 21st century, the United nation set eight international development goals, mostly on fighting against poverty, strengthening social structures, and improving health, on a horizon of fifteen years. These goals have been named Millenium Development Goals (MDGs), followed by Sustainable Development Goals (SDGs), which have been set again by the United Nations in 2015.

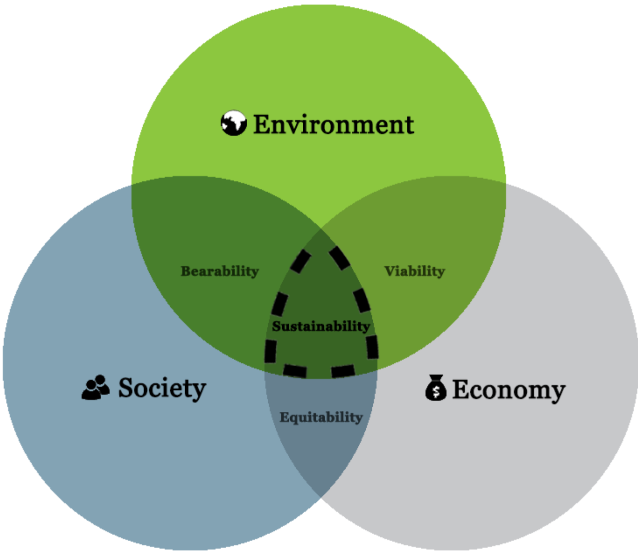

Figure 1.2 Three pillars of sustainability

According to the UN reports, the world has been prosperous in meeting the MDGs on some levels. The child mortality reduced by half, the same as the number of children without proper access to education. The number of patients who receive HIV treatments grew by fifteen percent, and there were some enhancements in the overall income of the poor. There were also significant shortcomings, especially regarding goal number seven, which is on environmental sustainability. Furthermore, the logic of goal setting and the vagueness of indicators for evaluating the MDGs provoked heavy criticism.

Learning from the experiences of the MDGs, in 2015, the UN General Assembly announced a new development agenda approved by its 193 countries named “Transforming Our Future: the 2030 Agenda for Sustainable Development”. This document introduces 17 primary goals for covering substantial domains of the world’s current issues. Moreover, for improving the sufficient resolution of this program, compared with MDGs, the goals involve a system of overall 169 targets and 232 indicators. The UN Agenda 2030 is now the official resolution shared between all countries for transforming the development styles into sustainable practices.

In high political levels too, there have been inclusive attempts to constrain the governments from environmentally harmful development models. After years of difficult negotiations, the 195 members of the United Nations Framework Convention on Climate Change (UNFCCC) signed the Paris Agreement in 2016. This treaty obliges the countries to cut carbon emissions to maintain the global temperature increase below 2° Celsius. Meeting this goal requires radical shifts in industrial foundations and processes supported by robust policies and strict control mechanisms on an international scale. However, the United States, the world's second-biggest carbon emitter, announced its withdrawal from the agreement only one year after signing it. This event was a piece of strong evidence that such programs are incredibly fragile, even in the context of domestic political changes. The deal lacks a secure confining mechanism. Therefore there is also serious concern over the possible solemnity of the most polluting countries, as they seemingly put no priority on the low-carbon economy. Moreover, some studies distrust the precision of the procedure used in the Paris Agreement for modeling the global systems.

Now, at the end of the 2010s, the clock is ticking faster than ever before. Every single decision we take, whether collective or individual, will draw the next feature. It is no secret that we failed so far both in understanding the world's complex mechanism and unifying our wills to takes severe global actions. Well, it seems that we do not have a choice. Will Un Agenda 2030 and Paris Agreement save us? For sure, not if we choose not to dig deep.

1.1.2 UN's Agenda 2030: A Brief Review

In 2015, the United Nations General Assembly issued the Agenda 2030 as the standard framework for sustainable development ("Transforming Our World: The 2030 Agenda for Sustainable Development" 2018). One hundred ninety-three countries agreed to the document as the globally shared perspective of the near future in 2030 (figure 1.3).

Figure 2 Sustainable Development Goals - SDGs (source: United Nation, 2015)

This document consists of seventeen interconnected general goals referred to as the Sustainable Development Goals (SDGs). The SDGs aim at a variety of today's issues in social, environmental, and economic realms. Each Goal involves a certain number of more detailed objectives to be realized in 2030. These objectives are called Targets, and there are 169 of them in total. There are also 232 Indicators to evaluate the degree to which the countries achieved the Goals.

The SDGs are sequential to the Millenium Development Goals (MDGs) introduced by the United Nations in 2000 and concluded in 2015 (figure 1.4). MDGs encompass a similar structure to SDGs, but they comprised of eight Goals. Most of the Goals targeted social and health issues, and only one of them, Goal 7, addressed environmental problems.

Figure 1.4 The Millenium Development Goals - MDGs (Source: United Nations, 2010)

Although there is evidence of acceptable improvements in certain realms (UN 2016), there is also much criticism of the structure of MDGs. It appears that the authors have chosen the goals in a somewhat arbitrary manner, or at least, the logic behind the selection is unclear to readers. Some scholars argue that the indicators introduced in the document are not strong enough to push the envelope in the most critical parts of the world. Most importantly, there is a substantially small attention to environmental problems (Deneulin and Shahani 2009; Kabeer 2010).

The latter is quite shocking. Mostly because at the time of arranging the MDGs' targets already more than one decade from the official expressions of the concerns about the human influence on the environment had passed (Brundtland 1987). Nevertheless, most of the eleven Targets in Goal 7 involved perfunctory approaches towards environmental sustainability. Moreover, they did not fashion tangible tools for studying the profound interconnectedness between the listed objectives. Therefore, after the completion of the program in 2015, it remained unclear how such an order of targets might create a practical framework to tackle the severe environmental problems.

Although they meant to address such issues inside the Millenium Development Goals, the SDGs have inherited some of their fundamental deficiencies. Three goals (Goals 13, 14, and 15) directly aimed at environmental sustainability, and two goals address it indirectly (Goals 11 and 12). These goals introduce 48 targets in total, which is less than one-third of the overall targets.

The structure of the SDGs seems to be precisely the same as the MDGs: Separate sets of goals subdivided by targets and general indicators. Although this structure is excellent for official reports, it is too oversimplified for being the benchmark of any actual practice. The UN 2030 Agenda, more than anything else, reveals the sectorial point of view of its authors toward the complex problems of today's world.

Ecosystem, economy, and society are all profoundly complex systems which with extensively high levels of dynamism, influence each other in too many ways. Defining separate boxes for tackling their issues would naturally create more misunderstanding than solutions. Rather than listing individual objectives in different realms, the UN should have taken the initial steps towards increasing the genuine understanding of the world's problems and natural interconnectedness between them. Addressing such complex issues demands a comprehensive platform for discovering the essence of the complications, not blind commandments as represented by the SDG's targets.

The severe impotence in this regard is particularly noticeable when one considers the annual reports on the progress of each goal. These documents demonstrate that the investments in environmental sustainability are increasing, and the figures show apparent improvements in specific realms obtained by the SDGs' tools (*The Sustainable Development Goals Report 2016* 2016; United Nations 2017; "The Sustainable Development Goals Report 2018" 2018). Nevertheless, the experts anticipate earlier dangerous environmental events due to the natural disintegration of modern industrial development.

Although each and every target introduced by the Agenda 2030 is socially acceptable and politically correct, the totality of the SDGs suffers from a severe problem of approach. Thus, it is incapable of identifying the roots of today's difficulties. The UN Agenda does not deliver a comprehensive and knowledge-based diagnosis to support its proposed plan. Moreover, it appears that the UN identified the goals and the targets within them independent from each other. One can argue that the problems in some specific Goals are rooted in others.

In such a context, there is an imminent danger that the authors and executors confuse the roots and repercussions, and instead of causes attack the effects. As the previous section argued, the origin of most of the issues that we are facing now is that our economic models are substantially incompatible with the courses of nature. Therefore, in hunt of the solution in any other field, one can only encounter side-effects.

Reconsidering the economic models which led us to this point of history, however, is too revolutionary. It requires an unprecedented level of political commitment, international will, and global collaboration to reach tangible results. This complexity makes such an accomplishment seem way out of reach, especially when we consider the economic and political atmosphere of today's world. The recent withdrawal of the United States from the Paris Agreement shows the aggressive aversion of the big economies for reaching any possible compromise.

In today's world, it is economic development which rules socio-political strength and strategic leverages. Hence, an international collaboration for arriving at a global objective is a fragile Stag-hunt situation where the trust dilemma is so severe. In this situation, a mere hesitation by one country can quickly discourage the others from participating (Gibbon 2013; Mielke and Steudle 2018).

Moreover, as the governments are genuinely under the influence of the capital owners, it would be naive to expect them to make crucial decisions that potentially threaten the interests of the market (Varoufakis 2013). Governments are relatively free on the manner of the execution, and in case of any violation, they would only face the consequences proportioned to their political power. Therefore, it is sensible to anticipate disintegrated and inefficient sets of efforts worldwide disguised as SDG Actions.

The UN Agenda, therefore, is significantly in danger of being misused as a legal base for greenwashing the products in favor of the market. That is to say that the same phenomenon with the most prominent role in polluting the environment becomes the leading influencer of the SDGs.

The critical question is, "what now?" should we rule the SDGs out of our environmental plans? Should we come up with something stronger and more binding?

The logical answer to these questions probably would be that it is almost impossible to substitute the Agenda 2030 with anything else. Although the document bears plenty of internal weaknesses, the main issues that make it not confining enough are external ones. At this time, the priority should be parallel efforts to reach collective political solutions to harmonize economic and environmental interests: A mission that seems to be as necessary as impossible.

On the other hand, the UN Agenda, with all its flaws, is an international achievement. A program upon which almost all countries -many of whom have perpetual conflicting interests - agreed is nevertheless a valuable opportunity to be seized. While the politicians, in an ideal scenario, should focus on tying up the economic growth with environmental protection, decision-makers and scientist have to attempt at revamping the Agenda 2030 and rise with a robust and productive version of it.

In a practical sense, three categories of attitudinal issues seem to exist in the SDGs:

- Neglecting the complexity of the world's affairs, the document groups the goals and targets as ready-made packages to process and does not tangibly address the interdepended relations within them. This aspect might induce fragmented sectorial exercises in contrast to the interdisciplinary nature of sustainability science.
- Targets and indicators are too generic to address the variety of local issues. Therefore, they induce the risk of generating locally insensitive execution plans and disintegrated evaluation systems.
- Accurate characterization of the systems which the agenda intends to modify is not present in the document. This aspect provides too much room for adaptation in execution. There would be an uncountable number of authorities and stakeholders worldwide associated with the SDGs. Thus, one can await an extensive collection of discordant practices leading to many unexpected side-effects.

All these three points form a simple conclusion: there is a lack of a systemic approach in the UN Agenda 2030. Therefore, its line by line application will only lead to fragmented practices that will not create a harmonic whole whatsoever.

Since there is no possibility to modify the agenda itself, at least in a global context, authorities should adopt system thinking in the manner of execution. For doing that, attaining systemic methodological interpretation on the Agenda 2030 is fundamental.

The world needs pioneer studies to accomplish international unity in systemic execution. Conducting such studies, and paving the way for appropriate applications are primarily the role of the academy.

To prevent blind shots and their consequenced side-effects, we need to upgrade our holistic understanding of the systems which through the SDGs we intend to modify. In the document, nothing fills the gap between the targets and the indicators. Nevertheless, in practice, we need appropriate tailor-made strategies to reach the desired performances. Hence, the executors should fill the existing gap in the agenda with comprehensive systemic methods for accurately modeling their contexts and framing the appropriate strategies.

According to systems theory, the components do not influence the system's performance as much as the quality of relationships between the components does (Luhmann Niklas, Baecker Dirk 2013). Accordingly, one should prioritize the structure of relationships in the modification process. This view takes higher importance when the subjects of modification are complex systems. In such a system, the dynamism of the relation is highly complex that makes it too sensitive to any imposed change. Since all the SDGs deal with complex systems, the systemic understanding should necessarily build the base of any execution plan.

This doctoral thesis intends to deliver a theoretical base for such an understanding of the built environment and then use it to approach a critical urban issue: Non-vehicular Mobility.

Agenda 2030 addresses the built environment in Goal 11, “Make cities and human settlements inclusive, safe, resilient and sustainable.” This SDG includes ten targets and fifteen indicators (“Transforming Our World: The 2030 Agenda for Sustainable Development” 2018).

This dissertation uses the framework of the SDG 11, only as an origin, to sketch out a systemic approach for addressing a particular mobility issue. Moreover, it highlights the location of this issue in the profound network of mechanisms in a complex system like the built environment.

1.2 The Role of the Built Environment

1.2.1 A Brief Glimpse of The Environmental Performance of the Built Environment

Urban areas cover only three percent of the earth's land surface (Watts 2010; Miller and Small 2003; Mcdonald, Kareiva, and Forman 2008). However, they seem to have the most prominent role in the problems that sustainability intends to solve.

Cities consume about 80 percent of the global primary energy, and they are guilty of emitting 60 percent of the total world's greenhouse gases (UN Habitat 2008). In other words, cities are the chief cause of global warming and deterioration of nature (Mills 2007; Milhahn 2019). Moreover, urban areas are the main responsible for air pollution and severe health issues caused by it. The rest of the figures in pollution, GHG emissions, and energy consumption chiefly belong to industries that mostly feed cities. Therefore, it is safe to state that the cities, directly or indirectly, are the sole responsible for today's environmental issues.

Furthermore, cites are the crime scenes of vast inequalities and intractable socio-economic conflicts. Today, one billion people live in slum conditions worldwide, and by 2050 the world expects to see at least 70 percent of its urban population in informal settlements (Arcidiacono et al. 2017).

The urban population is increasing rapidly. For the first time in history, more people dwell in cities than in rural areas. Today 55 percent of the whole world's population lives in small or big cities, and this figure will grow to 70 percent by 2050 (Meredith 2018). Northern America, Europe, and Oceania have a more significant share of the urban population (United Nations 2018). However, the urbanization rate in certain parts of Asia and Africa is relatively rapid.

The ever-growing urban population means that today's predicaments associated with cities will be much severe tomorrow. If the global community does not find the proper cure for controlling the performance of the urban areas, this cancer-like phenomenon will presumably cause the earth to collapse.

From another viewpoint, cities are the global symbol of human intelligence, wealth, collaboration, and culture. They are the permanent stages of historical shifts and social movements, the universal home of the modern man decorated with his history and heritage, and the manifestation of collective memories, revolutionary ideas, and intercultural exchanges.

Urban areas are also powerful engines of our economy. By average, about 80 percent of a country's gross domestic product (GDP) comes from the cities (Dobbs et al. 2011). Construction alone is currently one of the most profitable markets, and the experts predict that until 2030, its size will grow by 85 percent worldwide. That will be a tempting $15.5 trillion value, which lures strategic rivals like the United States and China into fighting for more sizeable shares (“Global Construction 2030 Report” 2015). Only these figures make it almost impossible to convince the world’s leaders to adopt strict urbanization control policies.

Today we find ourselves in a conflicting position. On the one hand, we must regard the built environment as the most problematic agent for our future that jeopardizes our existence on the planet. On the other hand, our economy and culture depend too much on the cities to make us reconsider the urbanization. Without addressing the necessity of profit reduction, Agenda 2030 practically chooses both more development and a greener future. Although that is entirely paradoxical and most probably impossible, there seems to be only one possible thing to do: modifying the development methods and our interpretation of SDGs.

Agenda 2030 addresses the built environment in Goal 11, “ Make cities and human settlements inclusive, safe, resilient and sustainable.” Through eight targets, this goal prescribes the cure for the current built environment-related issues in the following realms:

1. Affordable housing
2. Transportation Systems
3. Urbanization
4. Natural and Cultural Heritage
5. Urban Disasters
6. Air Quality
7. Green Public Spaces
8. Policy Making
9. Assisting the Least Developed Countries

So far, SDG 11 gathered 603 international partners who work on this goal, among others (UN 2019). However, it is not clear how the contributions of these partners, which come from many different sectors, are evaluated numerically with the SDG indicators.

A quick look at the targets, more than anything, reveal the arrogance of the authors. They claim that they now precisely illness and the cure. Alas, it not so.

Dividing the issues of an immensely complex system into eight boxes without addressing the profound interconnectedness between them is an unsophisticated move, especially when one considers that almost all the eight realms are among the classic domains, which were subjects of contentions at least from decads. In this regard, the only new offering of Goal 11 is blessing a newly emerged sustainability market with the logo of the United Nations. Unfortunately, this market showed no tangible improvement on a global scale.

With the horrifying consequences of such an attitude that awaits us shortly, it is time to at last revolutionize our paradigm of problem-solving. The built environment, like all the other world's macrosystems, is an exceedingly complex organization. Its performance is readable only in terms of its natural integrity and its identity as a whole. It is time to recognize this profound complexity.

1.2.2 The Enormous Complexity of the Built Environment

Throughout history, we understood and changed the built environment in terms of its components. The buildings, streets, squares, urban landscape, and geographical features were the only alphabets known to us. By using these alphabets, cities made the sentences, which in this metaphor are the dynamism between the static urban elements. However, by increasing the size and intricacy of the built environment, these sentences became exceedingly foreign to us. We understand the components correctly, for they are our creations. Nevertheless, the world these components create is becoming more and more alienated.

Cities, these resultant creatures, turned into monsters who devour the earth's natural resources with ever-increasing hunger. Air pollution, time-killing traffic jams, heartbreaking inequality, and numerous socio-economic conflicts are the inevitable product of these monsters. Cities became the top threat to our future life on earth. Now, at the peak of our intelligence, we sat on the side witnessing and just like Dr. Frankenstein, wondering what went wrong with our masterpiece creation?

The key to understanding our flaw lies underneath the tools we use: components. It seems that we entirely neglect the hidden network of relations, which is substantially more than the sum of the components. We ignore the complexity of the built environment and the gigantic chain reactions activated from the small modifications.

This flaw in our thinking is surprising, especially when we recall that we are no stranger to complex systems whatsoever. We dealt with social organization, economics, genetics, and ecosystems for ages. In studying all these systems, we adopt a more modest and careful approach. Acknowledging the complexity of the ecosystem, for example, we oblige ourselves to increase our understanding of its multi-lateral structure, and we do not rush into a conclusion. While we increase our knowledge, we do not aim at any banal certainty. Why do we not take a similar approach when we work on the built environment?

It seems that there are two accompanying reasons why.:1. The speed of urbanization is so high that changing our approach will create a conflict of interest with economic development, and 2. For whatever reason, we do not recognize the complexity of the built environment. The former demands a political solution, and the latter requires a scientific shift.

Cities, especially from the age of the Industrial Revolution, have become the places of our ideal thinking and free practices. They took the role of Utopia in different forms at different times. Even now, with the help of present-day technologies, we force them to manifest the modern utopia, which happens to be the Sustainable City. We regard the built environment as if it is the product of our collective mind, and we simply write the rules of how it should be. It is time that the scientific shift redirects our attention to what it is.

Instead of the stages of our constantly-changing ideals, cities are complex systems where multiple agents are on continual interactions, which modify the whole in each small fraction of time. The sophisticated network of interactions creates too many layers in forming their performances. These characteristics produce diversified simultaneous reactions unreadable by the human mind. Therefore, it is only a naïve ignorance to define them through their components merely.

Climate change and its associated consequences are alarming events for us. A petrifying future will await us if we ignore the immediate effects of our development manners. For changing manners, we have to revolutionize our understanding of the built environment. We have to recognize the structural attributes and dynamic processes in the cities and our inability to rule them with our conventional analytical approach and, instead of utopian thinking, embrace ourselves with a knowledge-based attitude.

The clock is ticking. We should change the paradigm sooner than later.

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CHAPTER 2

Literature Review

2.1 Scientific Understanding of the Built Environment

2.1.1 The Essence of the Built Environment as an Object of Scientific Investigation

The history of cities starts precisely at the point that the history of human struggle for existence ends. Putting the nomadic lifestyle behind in the past, the early citizens gathered around the big rivers, lakes, and seas where the environment was precious and comfortable, and they could have the basics of survival without the need to travel far. For them, the city was the extended home, the new environment which started to become more convenient, more human, and less natural.

Most of the ancient cities grew slowly as an organic system. In the medieval cities, the form and functions took their time to appear; but when they did, they emerged in the exact points where they were needed (Olwig 2016). In this sense, the built environment evolved naturally, and the primary source of this evolution was the collective intuition of the citizens driven by their daily needs. Apart from ancient poems and literature (George 2010), for tracking the city as an object of study and analysis, we need to look back at the first planned cities, where the human mind hires rationale to observe, study and create the built environment for the first times.

The main characteristics of the earliest planned cities, whether in Greece, Egypt or Mesopotamia was the grid. The grid street pattern found in pre-classical cities like Dholavira and Harappa reveals that accessibility, compatibility with the agriculture-based economy, and easiness of manage were desired attributes in the city scale (Davreu 1978). Furthermore, gird was flexible enough to provide optimum privacy and host sanitation facilities. The Greeks (or Egyptians) employed the grid pattern for the first time in an orthogonal shape for facilitating accessibility and protection (Uphill 2001). In a highly hierarchic society, the orthogonal grid -which has been later adopted and developed by Romans- was favorable to get an order by the social and religious rankings, and also it was convenient to replicate it in the colonies all around the world (Kaminsky 2006).

In the middle ages, the importance of trade and agriculture led to the cities with firm control of authorities on the agriculture lands, and cities grew mostly around the existing nucleus in a radial pattern (Janson, Hitchcock, and Giedion 2006). In the Renaissance about the same characteristics ruled the urban planning; however, the new weapons and military tactics put an essential priority for cities to be easy to protect. Here, we witness the emergence of star-shaped cities, which facilitated the protection and control (Janson, Hitchcock, and Giedion 2006). The post-Renaissance urban planning is mostly characterized by seizing the opportunities to adopt the existing cities to the newly-emerged public needs. These needs were mostly provided usually after a disastrous event, as the Great Fire in London in the 17th century (Thomas 1940), or the physical incapability of the old structure to adapt to the new ways of life, like Barcelona in the 19th century which linked the city to its future (Aibar and Bijker 1997; Martín-Ramos 2012).

As the Industrial Revolution brought many changes to humanity, the built environment had to digest the new form of life and react to it. The dramatic increase in population introduced unprecedented challenges to urban planners. In this era, the visceral understanding of the city is closer to what it is now than any time before chiefly because the cities started to deal with the massive population factor, rapid growth, and the complexities of the industrial world (Condit, Bairoch, and Braider 2006).

This point of history might be the hazy transition zone for the built environment into its modern sense. Indeed, the first planned cities date back almost to thousands of years before, yet the modern cities were facing a level of complexity, which was unprecedented in the past. At this time, urban planning was acknowledged as a scientific and professional discipline. The necessity of preparing prompt responses to the rapid momentum of changes in the industrialized world reduced the cycles of evolutions thickly, and the structural modifications which were used to materialize during ages on the land appeared swiftly on the table of the urban planner. From this point on, cities -as one noble creature of humankind- started to bewilder their creator forever.

The most recognized perspective on the post-industrialized cities was the *Garden City* movement advocating for dividing the city zones into residential, industrial, and agriculture ones linked together with a new urban element so-called the *Green Belt*. This movement was founded by the British planner Ebenezer Howard, and its goal was to create self-sufficient zones and communities and healthier living environments (Howard 2013). The layout of the Garden City was based on a central garden around which civic services placed on definite orbits sectioned through a certain number of wards (Figure 2.1). Hence, the city supported only radial growth where each section and band acquired a predefined meticulous urban function.

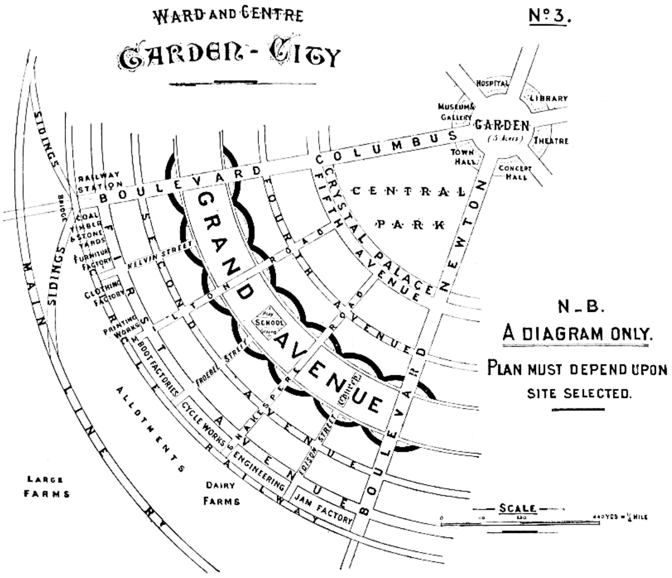

Figure 2.1 Segmental Layout of the Gerden City Conceptation (Source: Garden Cities of Tomorrw by Ebenzer Howard)

Like most of his heirs, the modern pioneers of urban planning, Howard referred to his idea as the manifestation of the Utopian city and claimed that the Garden Cities would reconcile modern citizens with nature (Steuer 2003). In practice, though, quite the opposite took place. Low-density Garden Cities spread over and devoured the lands and degraded nature (Ward 2005). The Radburn street layout introduced in them, especially in the American practices, made them extremely unsafe, low in urban quality, and absolutely car depended (Girling 1993). The detrimental byproduct of the Garden Cities was the suburban form with which the built environment still struggles. Long distances and hostile urban proportions created alien atmospheres where the urban life, as a complex blend of social and economic mechanisms, dismantled into simple spatial boxes labeled with the straightforward functions and smooth relations that worked only in the mind of the planner.

It appears that the problem was Howard being too arrogant to conclude that he knew the city. He probably thought that by a clear-cut design and categorical functional allocation, the built environment becomes tame, controllable, and predictable. A mistake that many others made after him. Back in the modern world, there was a widespread tendency to simplify any given phenomenon, as the only valid scientific paradigm was the analytical approach inherent in reductionism (Mann 2002; Francis 1999). With the analytical approach, humankind celebrated historic and remarkable achievements. In mathematics, physics, and engineering, as well as other realms of knowledge, the analytics uncovered the relations of things. Now it was possible to control the outcome of functioning processes and invent state-of-the-art tools that were operating precisely as the blueprints predicted. It was with the analytical approach that man created powerful engines, fast trains, and accurate watches. The science always delivered, not in the city, in any case.

The scientific reductionists believed that they could describe all the arrangements through analytical observation of the simple relations in their functioning structures (Berntson and Cacioppo 2012). They reduced any given organization to its parts and looked for hierarchic relationships between them. When these little everyday relations have been found, the functioning manner of a broader and more complicated system becomes comprehensible. The modification of the parts and the links between them would allow engineering the system and its behavior to the desired state, a claim that the history confirms on so many occasions. However, these analytics was argued to be applicable in all phenomena. Based on this assumption, the early reductionist in the 18th century went even too far to declare that just like the machines, living organs, and in particular animals are also fully explainable in terms of the hierarchic links between their sub-organisms (Wood 2002).

At this point, it is worthy of clarifying that in this text, there is no intention to directly refer to Ebenezer Howard and any other urban planners as classic reductionist thinkers nor to offer any historical account of analytical approach in science. The goal is to argue the resolution of the scientific lens through which the city, alongside most of the other phenomena, was observed for decades from the late 19th century. The scientific community was not that naïve anymore to believe the living organisms can be explained or recreated by providing mechanical links between the organs. However, the question is how the rational people who would not have attempted to engineer a duck into existence whatsoever, did it many times to the city and got surprised when the result was not what they have predicted? Many factors contribute to answering this question, yet, all of them hint on misclassifying the nature of the built environment in the recent history of urban planning, science, and architecture.

The trend of idealizing the conception of the city continued at higher speeds by the Modernism Movement from the early 20th century. As the essence of Modernism was to reject the past for the traditional ways of life were declared to be too incompetent of serving the modern man, a fine line divides almost all aspects of human culture from what it used to be at this point of the history: form. The form was the best tool to manifest the rebellion of the Modernist against traditions. Visual and performing arts, literature, and music all underwent major formal surgeries in this era. The modern man, especially after suffering the horror of World War One, attempted at building a utopian future. An idealization that must have surfaced in all aspects of his life in a tremendous distinguishable shape (Ball 2018).

In the architecture, Le Corbusier, the central figure of modern architecture, criticized the traditional forms in terms of their mass, surface, and plans and asserted that modern architecture should hire the artistic vision and mathematical laws of nature to bring regular rhythms and sensational satisfaction to its explorer (Stewart and Corbusier 2006). He later translated similar resolutions in urban planning. A great case of modernist view toward the built environment is indeed the scheme of the *Contemporary City* (Ville Contemporaine) by Le Corbusier. The Contemporary City is based on an asymmetric rectangular plan, a number of the cruciform superstructures, highly regular distances between volume and voids, and unusual modes of transportation like even helicopters (Figure 2.2). Not surprisingly, this conceptual plan was presented as the manifestation of the modern utopia. It seems that Le Corbusier interpreted his ideas of architectural rhythm in Ville Contemporaine with extremely formal components and regular distancing. Although he succeeded in delivering a modern urban context and added his formalistic signature on it, his plan went just too wrong. The confusion of the urbanism with architecture, in terms of functionality, is immensely evident in Ville Contemporaine.

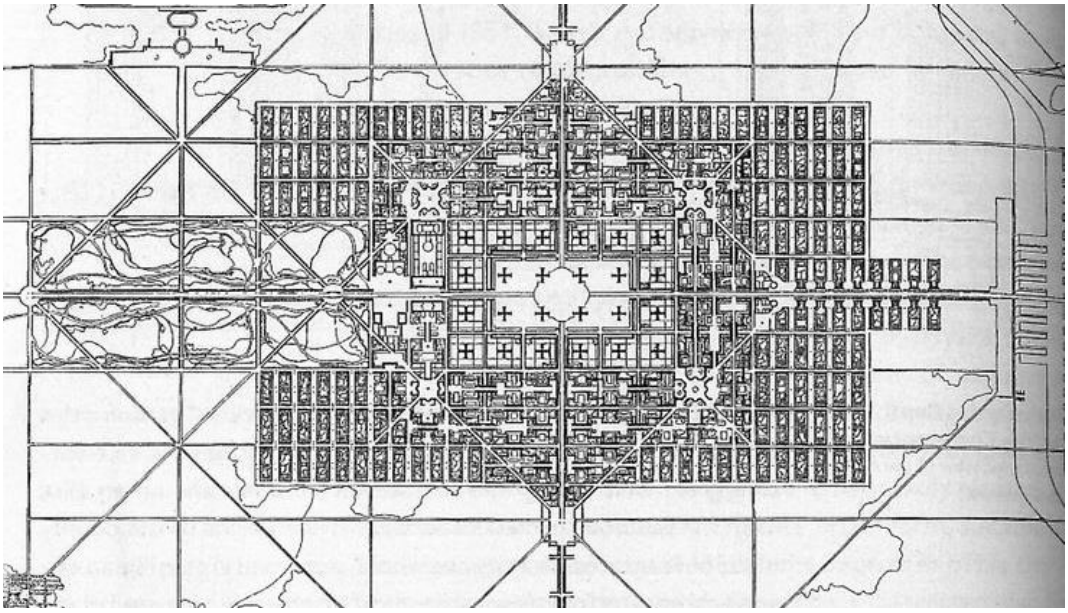

Figure 2.2 The plan of Ville Contemporaine by Le Corbusier (Source: Le Corbusier, 1922)

Le Corbusier, like many minds before after him, failed to observe the fundamental systemic difference between buildings and the city. While the building has some straightforward functionality with a strictly limited number of modifiers (architect and users), the city is a highly complex and multi-final system containing other complex systems (societies, culture, transportation.) subjected to long periods of evolution and simultaneous emergence of mechanisms. The contexts in which these two systems are defined are also immensely different in properties and scale. Hence, architecture and urbanism should be treated differently in analysis and planning. However, Le Corbusier rejected this idea. He believed that the existence of the city should be regardless of context and history, and the city planner should start his work on a blank piece of paper, relatively the same way that he designed his buildings (Cambpell Dace A. 1996).

Fortunately, the Ville Contemporaine has never been built, but the ideas of Le Corbusier widely inspired the Modernistic Urbanism. Many social housing projects in Europe (like New Belgrade in Serbia) and some entire cities like Brazilia are examples of Modern Urban planning.

The formal obsession in planning is vivid in Brasilia. The city plan intentionally resembles an eagle (Epstein 1973), and all the urban elements like road network, spacing, and block morphologies are shaped to provide a rhythm similar to the Contemporary City. Just like its conceptual idle, the Brazilian capital is designed for cars neglecting the human movement and scale. These cities, as excellent modern mind products, disregarded the nature of the urban settlements and only worked on pieces of paper on which they were drawn.

The modernists, however, had other voices too. Aldo Rossi, the Italian architect, proposed alternative perspectives both to modern architecture and urban theories. In La Tendenza (meaning The Trend), the architecture movement established by Rossi, the utopia of Modernism, is firmly rejected, and the Avant-garde architecture is regarded as unrealistic. La Tendenza inspired universal debates over the necessity of the conflict between the traditional values and contemporary forms (Bois and Krauss 2006).

He presented a different view of the essence of the city too. Unlike Le Corbusier, Rossi believed that the city is inseparable from its history and social context. In his view, City is a complex human-made object which is built over time. This perception bears a fundamental contrast with previous Modernist planners who created the cities in a sudden event. Rossi acknowledged the importance of historical evolutions in shaping the cities and believed the urban settlements are more than zoning and theory (Aldo 2010). In relating the city with the buildings within it, he asserts that the architecture and urban artifacts are distinguishable phenomena for the later is subjected to essential changes during time. Therefore, functional control cannot be the principal factor for identifying the city. He defined the city in many layers, of which the permanent structure is only one. The geographical context and sociopolitical history are also of the inseparable layers. Rossi's remarkable book "The Architecture of the City" provided enlightening measures to read the cities more inclusively than the early modernists though they did not offer practical tools for scheming a framework of the development for the contemporary ever-growing cities.

From the early 1960s, the concerns about the performance of the built environment started to increase. Observing the way the cities performed in terms of social interactions, economic growth, and personal mobility, critics began to highlight the lucid contrast between the manners the modern plans claimed to function with their actual functioning practices. Witnessing the alien settings, high crime rates, long distances, and cold proportions, it became apparent that the modern utopia was but a broken promise. The influential American journalist, Jane Jacobs, referred to the previous planning trends, from Garden Cities to Modernistic urban contexts as *Orthodox Urbanism*. She characterized planners and thinkers who were under the influence of Howard and Le Corbusier as the *Decentrists*. Urbanists who promoted regional planning for low-density residential settings outside the central city core for what they claimed to be a healthier urban environment. In her notable book The Death and Life of Great American Cities, Jacobs harshly attacks the Orthodox Planning for destroying the essence of the city as a complex network of things and mechanisms. She accused the modernists of oversimplifying human-life diversity in their wishful abstract utopias. She identified the four generators of diversity which were absent in almost all contemporary city plannings as follows (Jacobs, n.d.):

1. High density
2. Mixed-use developments
3. Morphological permeability provided by short blocks and maximum street intersections
4. Historical diversity of buildings

What is interesting in Jacob's proposal is the measurability of the factors she indicated for a live and diverse city. She goes further and indicates similar means in different urban elements like neighborhoods, parks, and sidewalks and offers individual design principals for them. Her work contains unique viewpoints in investigating urban structures and noble ideas, of which many are still valid and influential in performance-oriented urbanism.

With the rise of concerns over the environment due to the human-induced practices, the contemporary urbanism directed its attention mostly to the environmental performances. While the scientific works attested to the prominent role of cities in environmental degradation, many theories and methodologies emerged to take control of the situation. The recent and present-day sustainable urbanism is vastly reviewed in section 2.2.1 of the present chapter. Movements, theories, and urban archetypes like New Urbanism, Intensification and Smart Cities which offered design principals and tools for minimizing the ecological footprint of the cities in a variety of fashions but monumentally failed in delivering an accurate model of the built environment in which the complex mechanisms and the profound relations that lead to performing behaviors take role.

In the past century, when human life on earth became too complicated and the economic development took a rhythm too fast for man to leave cities to evolve at their own natural pace, urbanists focused on three essential features of the built environment in different periods: 1. Function in the post-industrial revolution; 2. Form in Modernism era; and 3. Performance in post-modernism and contemporary practices. Now, as the consequences of our practices have put the immediate future on a critical perspective, while cities have a significant role in environmental issues and social conflicts, we cannot afford blind shots in urban development anymore. The built environment should be considered as a complex mixture of form, function, and performance and all the interactive networks within them. The first step, it seems to be, to upgrade our scientific understanding of the city as a complex system and identify its systemic properties.

2.1.2 Systemic Understanding of the Built Environment

There are numerous problems associated with the built environment today. Cities are energy devourers and pollutant entities, the stages of economic strifes, and social inequalities. Almost all the environmental threats that the world is facing are directly or indirectly caused by the cities. On the other hand, urbanization is happening fast everywhere, and cities grow, and with them, the urban issues grow bigger. Inside the built environment, we are witnessing severe structural problems like the urban sprawling and the emergence of shantytowns and performance flaws like congested road networks, suffocating pollution, and nature degrading. The failed attempts to control the performance of the cities tell us loudly that we should reconsider the ways we approach it.

It seems that the scientific community, together with the urban management bodies are confused about the structure of the urban-related issues hence whether, with limited regeneration programs or revolutionary urban theories, the mostly attack the effects rather than the causes of the problem. For identifying the problem and its dimensions, there should be a common ground on which the urban scientists and the decision-maker authorities agree and practically distinguish between the root and aftermath for defining the proper courses of action.

Although urban life is full of complicatedness and multi-lateral struggles, the problem is elementary whatsoever: the current models of urban development are generally unsustainable and harmful. In this regard, issues like ineffective transportation, the emergence of informal settlements, or various socio-economic conflicts should be categorized as the effect of the problem. Although sectorial exertions for mitigating such complications are necessary, the primary efforts should be put on addressing the causes.

Just like the effects, the causes are connected in a complex network too. Unrestrained population growth, damaging economics, inappropriate policies, and inaccurate development plans are some of the highly interconnected issues in the cause package. All the areas of development modify the cities in various ways and change them in millions of directions. The problem is that the manners through which the built environment reacts to these stimulants are unclear. That is why even addressing the causes is not enough itself. We need to increase our understanding of the built environment in a systemic way to comprehend the complexity of the problem structure (Figure 2.3).

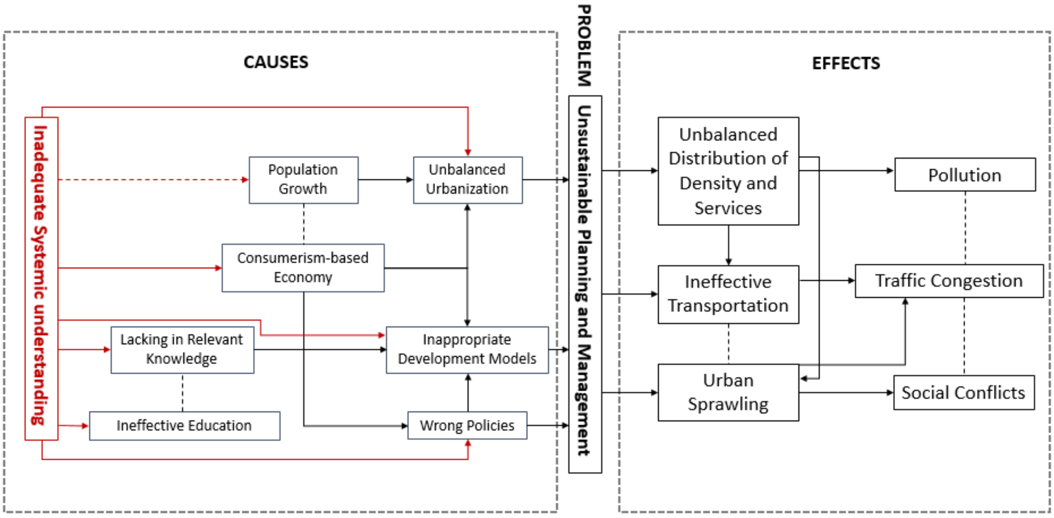

Figure 2.3 A conceptual and simplified problem structure related to the built environment sustainability

As was mentioned in the previous chapter, cities are responsible for most of the earth's energy consumptions and carbon greenhouse gas emissions. As the urbanization rate takes a higher pace every year and the urban populations grow much faster than the rural one, it is safe to state that even the consumptions and emissions which are not directly related to cities mostly happen to feed them indirectly. In this situation, as sustainability is the standard framework for all economic communities, the burden on the built environment is much more substantial. Therefore, sustainability is chiefly an urban issue, and most of the targets within the 17 SDGs are pursuable in urban settlements (Shahrooz Vahabzadeh Manesh and Tadi 2013; Le Blanc 2015).

However, cities have been mostly subjected to one-dimensional modification plans carried out in separate departments. Optimizing transportation systems, zoning, resource allocations, and social justice programs are all pursued in deferent sectors and, even if succeeded in their area, often produced inadvertent results in other urban dimensions. That is simply because urban mechanisms involve multi-lateral interactions and non-linear dynamism through which the whole system reacts to any imposed force. The less complicated built environment models lead inevitably leads to more surprising results and modification "side effects" (Duarte and Rojas 2015).

Strangely, such a sensitive system undergoes massive changes ordered by too many modifiers with a variety of interests in different periods. Planning, architecture, and transportation engineering departments, administration, business, and social bodies introduce large and small-scale authoritarian adjustments to the face of the cities in short and long terms. Needless to say, the innate everchanging urban dynamism that the cities endure every second. Therefore, it is fundamental to have an accurate universal definition of the city that would be comprehensive to all its authoritarian modifiers and representative of its complexity simultaneously.

Cites are defined differently from extensive human settlements (Learmonth and Johnston 2006) to “complex social-ecological-technological systems,” including many actors and interactions defined in “geographical, institutional and governance scales” (McPhearson et al. 2016). A context that hosts numerous interdepended and contrasting mechanisms inducing temporary and permanent adjusting processes. However, as the city is the playground of many actors, a practical definition would be an ontological explanation revealing its structural characteristics and the nature of its functionalities. A definition that provides the space for analogy and propels the observer to the appropriate approach for dealing with the city.

There are enough reasons to conclude that the built environment is a Complex Adaptive System (CAS) (Manesh and Tadi 2011). CAS are systems that include numerous components with a high level of interactivity between them. They have the inherent ability to adapt to and learn from the internal and external forces (Holland 2006; Wolf-Branigin 2008). Any single modification in any given scale opens a series of reaction chained to each other, which ultimately changes the state of the whole system (Tadi et al. 2015). In this regard, cities are fundamentally different from most of the humanmade systems, for it is categorized next to the biological systems with complex behaviors; nearly all the artificial creations are simple systems.

The essential difference between the simple systems and complex ones is in the manner that the relationships between components shape the quality of the procedures. While the components are connected in direct and linear ways, in complex systems, every element is intrinsically is a part of any other; hence, reciprocal loops, ever-changing cycles, and non-linear mechanisms rule the CAS (Holland 2006).

Because of the high levels of interconnectivity between the agents and the mechanisms of the complex systems, it is virtually impossible to imagine a rank of any sort between the components or to pinpoint a typical hierarchy in their procedures. Therefore, the classic analysis, which is based on dismantling the system into its part and simplifying the processes, is not an appropriate approach to deal with a CAS like the city. As it was vastly described in the previous section, the analytical perspectives monumentally failed to address the urban settlements or explain the integrity of their form, function, and performance. For delivering an accurate picture of cities, it seems that we need to change or scientific paradigm to regard them.

Systems Thinking is a paradigm alternative to classic reductionism. In contrast with the analytical approach, systems thinking views the system under study concerning the other organizations and extraneous processes.

While the scientific reductionism is based on independent analysis, systems thinking is centered around the inclusive synthesis. Analysis reduces the system to its components and narrows down the framework, while synthesis is studying the relationship between internal parts and external systems, which involves a contextual expansion process (Hammond D. 2013).

Although the term systems thinking is becoming more and more popular in scientific texts, it is not always defined clearly, and the holistic approach misused and frequently misunderstood (G. K. C. Chen 1975). Systems thinking is studying a system with considering all the necessary interrelated mechanisms and all the influential environments that host the investigated system. Naturally, systems thinking requires an interdisciplinary approach for all the phenomena that are relatable and dependable to broader processes, which include different areas of science (Catalan 2017).

Every system consists of parts that are conceptually separable. The system is more than some of its parts, though for the parts form a network of the relations of which the functioning manner is ruled (Wächter 2011; Meadows 2001). This trait is quite evident in the built environment as it is formed by a specific set of common elements worldwide, though each city has its functioning and performance. Accordingly, the system behavior is expressed in terms of synergy and emergence rather than the sole analysis. The systems thinking, however, is not an alternative to analytical thinking, but it is complementary to it.

For the overall functioning is not separable into individual processes, to approach complex systems, it is crucial to include as many mechanisms as it is possible. Therefore, studying a CAS like city requires simulation rather than simplification (S. Vahabzadeh Manesh, Tadi, and Zanni 2011). However, it is impossible to include the whole complex into the model as the human mind is not capable of processing simultaneous non-hierarchic events.

For the sake of study, CAS is also breakable into its parts, and an optimum level of simplification is acceptable. Although, it should not become more straightforward than is required for understanding the architecture of its functional network (Holling 2001). Accordingly, to study the built environment, definite borders should be defined, and the related subsystems should be included.

Every system is entitled to specific functions and purposes. The built environment, on the other hand, is a multi-final system. It means that from different viewpoints, different functions are observable. This is because the city includes many interconnected processes for various purposes. Natural systems, social and economic systems, and ecological systems are of the active subsystems within any urban context, of which the latter two are complex systems themselves.

Moreover, cities are inherently jointed to other forms of human settlements in suburban, rural, and national scales and are always influenced by a complex network of systemic feedbacks (Figure 2.4). Although different expertise is required for studying these categories, for maintaining the structural integrity, the overall scientific approach should remain the same. Therefore, a correct systemic approach should deliver the basic systemic properties of the built environment.

The existing literature recognizes the following systemic qualities for the cities:

1. Cities are everchanging complex adaptive systems (Garnsey et al. 2013; Fujita and Mori 2002; Bai 2015);
2. They are open systems with a complex network of goods, means and mechanisms exchanges (Kennedy et al. 2015);
3. They are subjected to a large number of conscious or unconscious systemic modifications with parallel, contrasting or extraneous purposes (Science for Environment Policy 2015; Bai et al. 2010);
4. There are a broad set of systems within and outside the cities (e.g., ecosystem, governance, transportation) which their systemic functioning is inseparable from the functioning of other systems(Elmqvist et al. 2013; Pickett et al. 2008; Bai 2007; Ramaswami et al. 2012)

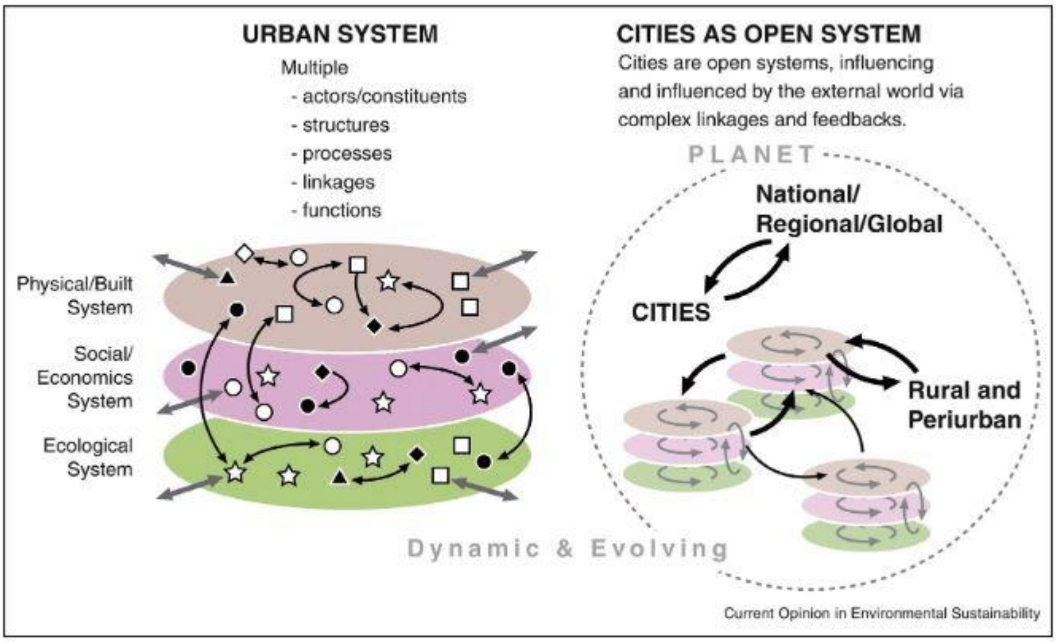

Figure 2.4 City is an open system consisting of many subsystems in constant interaction with each other in different scales (source: Defining and Advancing a Systems Approach for sustainable cities; Bai et al. 2016)

It seems that there is a reluctance to apply the systems approach to the built environment both by scientists and urban management bodies. One important reason is that the traditional urban planning and management historically codified by the conventional analytical approach that regards the city like any other human location as the urban design/planning is often pigeonholed in the same administrations/departments as the architecture (Seitzinger et al. 2012; Inostroza 2015). The fact that these administrations usually consist of hierarchical structures involved in sectorial actions also adds to the formational unwillingness to use the systems approach in urban realms.

There is also a severe inadequacy of conceptual and technical models for scientific inquiries. Approaching a complex adaptive system demands mental models with the ability to include the necessary dynamism inherent in the urban processes and the fine lines between them (Bai et al. 2016; Shahrooz Vahabzadeh Manesh and Tadi 2013). Conceptually, the built environment involves structural elements, functioning mechanisms, and performing patterns. An accurate theoretical model, in any given scale, has to discern and determine these properties and address the quality of linkage between them.

Since the purpose of all imposed modification on the face of the cities is to achieve the desired performance, technically, all the urban models are expected to provide legitimate predictions. Therefore, adhesive to theoretical models, dynamic simulation models should be developed and used together with the management tools to form decision supporting systems. For the urban dynamism is influenced by infinite actors and agents, such models should be able to get a variety of data in high velocities. That, by nature, demands the involvement of many disciplines and expertise. Today, most decision-making models are used mostly in sectorial practices and are not simulative enough to encompass enough variety of data and integrate different processes and deliver systemic attributes. Moreover, the necessary data are for modeling -especially following the sustainable agendas- are not available in most of the world’s cities (Simon et al. 2016).

Sustainability, upon which the future of urbanism should be built, is a matter of multilayered performances. Sustainable urban models have to integrate many different social, environmental, and economic system simultaneously and unveil the structural and dynamic patterns which lead to specific performing manners. In this sense, the systems approach in the built environment is studying a complex-functioning black box -involving twisted non-linear mechanisms- which takes the system structure (forms and arrangements) as inputs and delivers performances as outputs.

The proper model should be capable of integrating large varieties of data and being flexible and reliable in different scales. Furthermore, it should be supported by a strong and accurate theoretical backbone to be interpretable from different systemic viewpoints (environmental, economic, social, and the subsystems within them) and applicable in different social and geographical contexts.

The UN Agenda 2030, as the universal guideline for sustainability, is constructed on goals, targets, and performances. A performance-oriented model should and develop the desired performances indicated in the Agenda 2030 into a more detailed set of indicators and address the ways that structural modification (inputs) can inspire the performing behavior. As too many actors execute the Agenda, it is fundamental that the modeling methodologies and performance measuring follow about the same course universally.

In a CAS like the built environment that involves limitless mechanisms entitled to sustainable performance, the model should maintain the same architecture, but provide a sort of conceptual fractality. In other words, in linking any given urban-related system (for example transportation) to its subsystems (public transportation or even more detailed like the bus system) or to the systems of which it is a subsystem (economic or environmental systems) the integrity of the model should remain the same and only the boundaries change.

Chapter three vastly argues the properties of a theoretical and technical urban model.

2.2 Sustainability in the Built Environment

2.2.1 The Conventional Measuring Methods

With minor quarrels, sustainability is a framework upon which almost all groups of scientists agree. At least, they all confirm that for avoiding the unfortunate future brought by climate change, the global community should act on changing the development paradigms.

The economic bodies have carried out and are carrying out much in this regard. Naturally, the implementation varies from the executor to executor. The question is, however, is there any conventional manner to measure sustainability? Are the existing tools useful enough?

Without any doubt, it is vital for today's world to access sustainability measuring tools, especially when one considers the conflicts in interests that are visible unceremoniously even among the top politicians. While some of the power holders are reluctant to comply with limiting growth regulations, some of the industry owners inclined to create new markets by abusing the sustainability principles. In this situation, the measuring tools should be precise and powerful enough to hinder both groups.

Currently, the mechanisms of measuring sustainability are in evolution. Quantitative-based tools involve sustainability indices, indicators, benchmarks, audits, accounting, reporting, and metrics (Pope 2015; Slater 2005; Dalal-Clayton and Sadler 2005).

Benchmarks are typical reference points formed following specific sustainability parameters. International agencies provide baseline data to measure the status concerning the accepted thresholds (CIA, Agency, and Central Intelligence Agency 2011). These benchmarks currently involve nine super general fields, among which the population, water, and energy make more sharings with the built environment (United Nations Population Division 2011; SIWI 2012; United Nations 2007; "BP: Statistical Review of World Energy, June 2010" 2010).

Indicators are mostly the evaluation metrics mostly developed by the United Nations expressed in its different agendas (United Nations 2017). There are also other frameworks like the *System of Integrated Environmental and Economic Accounting,* which use different statistic modules for environment and economy, which are compatible with the UN's SDGs (United Nations 2007; UN et al. 2012).

Sustainability Indices are aggregate indicators that blend multiple data sources to report the performance status of different fields. They involve economics, health, and environmental datasets together with constructed indicators like happiness, democracy, and vulnerability indices (U.S Environmental Protection Agency and Office of Air Quality Planning and

Standards 2016; Economist Intelligence Unit 2010; Barnett, Lambert, and Fry 2008; "GDP per Capita" 2019; McGough 2012).

Auditing and reporting involve different global standards for monitoring the development procedures in different fields. They attempt at different confining mechanisms, which, depended on the context of practice, vary much in success levels (Nowrot 2009; Pope 2015; Jock, Thomas, and Henrichs 2010; Corbett and Kirsch 2001; The Natural Step 2000; Jasch 2000).

There are hybrid methods that work on measuring the environmental footprints of the development procedures and apply standards for reporting the stages of production accordingly (Gray 1992; El Serafy 1997). One of them that has found its place in the built environment is Life Cycle Assessment (LCA). LCA is a quantitative technique that measures the environmental impacts of the products and services throughout their whole life-cycle from extraction (cradle) to disposal and recycling (grave) (Assessment 2001). The LCA method also provides flexibility for monitoring selected stages in between the cradle to grave.

Life Cycle Assessment involves four general phases: 1— goal and scope definition; 2— inventory analysis; 3— impact assessment; and 4— interpretation (figure 2.5).

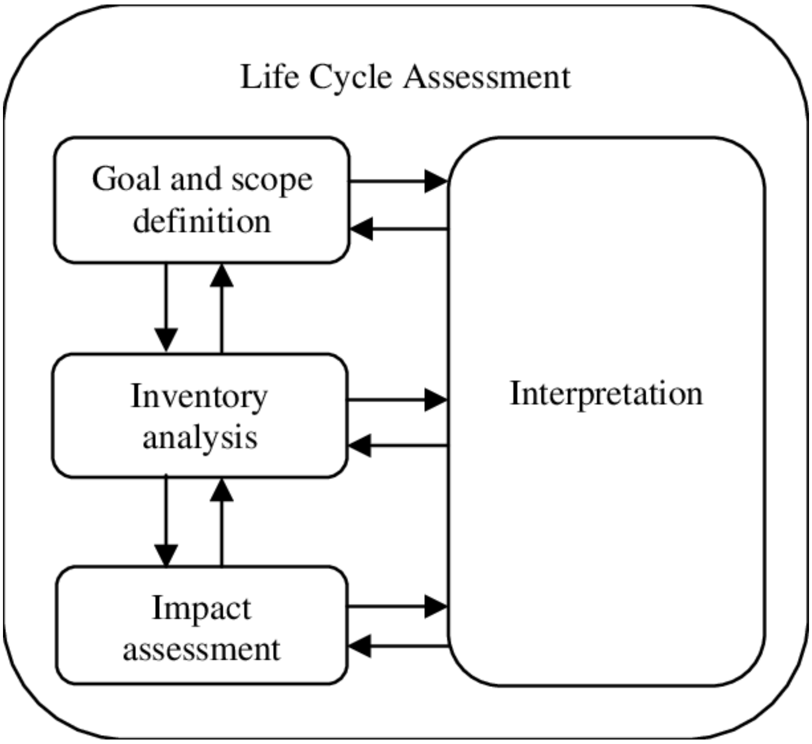

Figure 2.5 The Phases of Life-Cycle Assessment - LCA (source: Research Gate https://www.researchgate.net/figure/Phases-of-life-cycle-assessment-17_fig1_282237361)

The first phase usually uses international standards (e.g., ISO), which involves documentation of scope and goal clearly defined and elaborated. The inventory analysis in phase two engages the studies of inventory flow like the inputs and outputs of energy, water, and material releases. The standard-issue here is that it is incredibly troublesome to access specific flow data in certain areas (Steinbach and Wellmer 2010). As the LCA phases are substantially integrated and inherently data-depended, this flaw might affect the whole measurement immensely.

The third phase aims at the evaluation of the potential environmental impacts according to the life-cycle flows. This state involves the identification of the impact categories and indicators and the development of models concerning the input/output characteristics. As these flows might include a wide variety of materials and processes in different kinds and units, they are usually translated into one flow unit (mostly carbon emission) as the shared currency of the environmental costs (Curran 2008).

The interpretation phase presents the results of the previous phases and delivers a conclusion to the study. It uses a set of evaluation tools to check the integrity and sensitivity of the measures, highlights the limitation of the study, and bears technical recommendations for future developments (Hauschild, Rosenbaum, and Olsen 2017).

Although praised as a potent apparatus in many fields, there are also inevitable criticisms of the Life-Cycle Assessment measures too. LCA necessarily embodies energy analysis. However, it is naturally incapable of resolving the existing conflicts in energy cycles, production and recovery, and renewable energy technologies. (Liamsanguan and Gheewala 2008; Roberts et al. 2010; Pehnt 2006). This aspect brings much vulnerability to results quantified by LCA measures.

There is also the classic issue of the veracity or availability of data (Nadav 2010). Experts also believe that even in case of availability, some factors are so complex that it is impossible to reduce them in sheer numbers.

The chief weakness, however, lies in classifying the boundaries (Ulrich and Reynolds 2010). An appropriate view of the natural interconnectedness of the systems is absent in LCA, and its rigid boundaries and classification methods create much room for inaccuracy and even abuse (Gaines and Stodolsky 1997). Powerful beneficiaries might play with the boundaries and data to shift the assessment in favor of their products.

Some studies hired Life-Cycle Assessments for studying the built environment. In building engineering, the European Commission defines the scope of the LCA modeling, as stated in the CEN TC350 Standard (European Committee for Standardization 2011; CEN 2013). Accordingly, the scope of the measurement includes five stages of building's life-cycles: 1— Production Stage; 2—Construction Process Stage; 3—Use Stage; 4—

End-of-life Stage; and 5—Benefits and loads beyond system boundary (figure 2.6) (Gervasio and Dimova 2018).

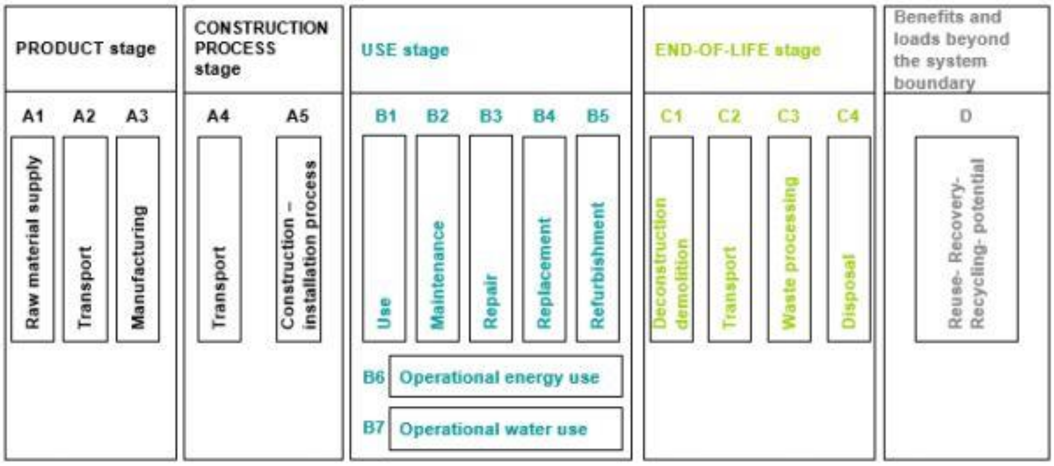

Figure 2.6 Scope of the LCA of buildings according to CEN TC350 standards (source: JRC Technical Reports: Model for Life Cycle Assessment [LCA] of buildings)

This scope inevitably is sensitive to the same boundary critiques and energy issues as there are vast uncertainties about energy production units also used in buildings energy engineering(MacKay 2013).

In the classification of the requirements and indicators, there is particular stress on the role of the design process (figure 2.7). The European Commission asserts that accurately implemented design process provides higher chances of minimizing the resource consumption, hence the environmental impacts (Gervasio and Dimova 2018). This conclusion puts much weight on the shoulders of building engineers as though the sustainability incepts in the design decisions.

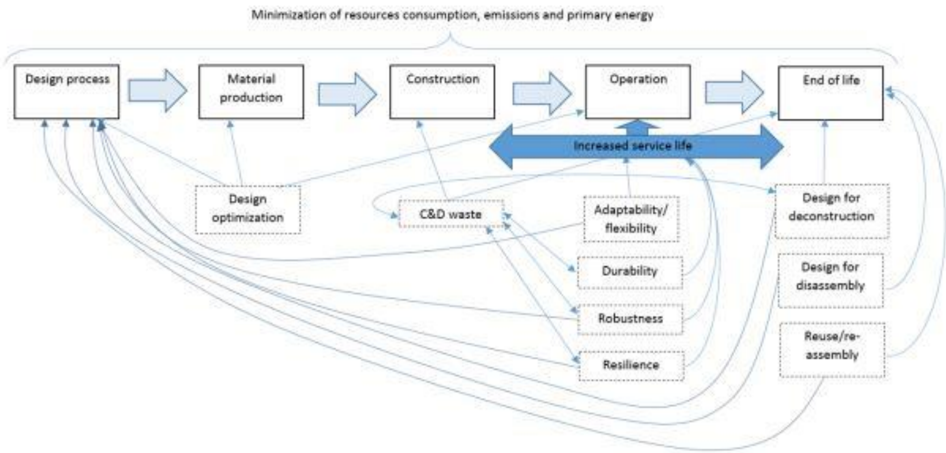

Figure 2.7 The role of different aspects of structural design in resource consumption during the buildings' life-cycle (source: JRC Technical Reports: Model for Life Cycle Assessment (LCA) of buildings)

The literature also embodies LCA studies on the urban scales. A quick view reveals, more than anything else, the variety of angles and methodologies that these works adopt to present their case studies. In this regard, one might argue that in a complex system such as a built environment, the objectiveness of LCA is not easily readable. Many of these inquiries, however, highlight the importance of morphology, geographical context, and the existing infrastructure of the study cases in their environmental performances (Roux et al. 2016; Cabeza et al. 2014; Petit-Boix et al. 2017). Therefore, in the built environment, the accounting methodologies like Life-Cycle Assessment lose their roles as the control mechanism and turn into design aid tools.

Thus, when it comes to cities and the building sector, the decision-makers should predict the sustainable measure in their studios. For integrated characteristics of the built environment, it is also vital that these design measures consider the flexible boundaries which cover the architectural scale, neighborhood scales, and urban zones. Because of the large share of the existing infrastructure, the designers, have to hire a multi-scale and modification-based attitude towards the design.

Acknowledging the subtotal outcome of the sustainability practices in architecture, building engineering, and urban design heretofore, the scientist, must reconsider the old attitudinal angles and test more integrated paradigms.

2.2.2 Sustainable Architecture

According to the official reports in the United States, the building sector accounts for about 40 percent of total energy consumption that makes it the top consumer surpassing the industrial sector, which used to hold the title until the end of the twentieth century (U.S. Department of Energy 2008). Other developed countries expect to have about the same figures. The global estimations assume that twenty percent of the residential and commercial buildings consume twenty to nearly forty percent of the world's primary energy (World Energy Council 2016; EIA 2016). As fossil fuels are the shapes of more than 80 percent of the energy supply of the buildings today, and experts foresee that this situation will longly continue (WEO 2018; United Nations 2018), we can name the buildings as one of the primary environmental pollutant entities.

Thus, the world witnessed organized movements to tackle this critical issue. Acknowledging the rapid rate of urbanization, hence the number of new buildings and aging of the vast number of existing buildings, experts reasonably target the building sector for modifications.

Sustainable architecture is an environmentally-driven building design paradigm practiced widely, especially from the 1990s on, in different forms and methodologies. The mission of sustainable architecture is to minimize the environmental footprint of the new construction and retrofit the existing building texture.

As the previous section argued, the central pressure for energy efficiency in buildings is on the design phase. Therefore, sustainable architecture combines a variety of strategies, from the blueprints of the design, to attack the consumption manner from different angles. The general plans are the following:

- Increasing the efficiency of the heating/cooling system;
- Energy production and using renewable energy sources;
- Sustainable building materials;
- Waste and water management;
- Envelop design and sustainable installation and building placement.

In the developed countries, the urban decision-makers couple these strategies with building regulations and oblige the constructors to comply with the new building rules.

Energy-efficient buildings are promising markets both for the customers and the building industries. One the one hand, such buildings demand less energy to function and, despite the higher initial costs, satisfy the owners with the low energy bills. On the other hand, their popularity feeds the related industries. In many countries, customers and constructors receive attractive intensives for investing in green building markets.

Although there is undeniable evidence of the effectiveness of the green architecture movements, there are certain doubts about its overall contribution to sustainability (Bianchini and Hewage 2012; Jarzombek 2003).

One of the main issues is related to the control mechanisms. While constructors should satisfy international standards like LEED (Leadership in Energy and Environmental Design), it seems that these design codes provide much flexibility to lead to weight the financial profit rather than supporting long-term sustainability. Moreover, as the next section presents, the scoring evaluation systems like LEED are incapable in many terms to create integrity between the control checkpoints indicated by them (Scofield 2009).

The offering of green architecture to the sustainability of the built environment, too, is still unclear. The growth of investment in sustainable architecture only represents the popularity of industries and the growing market size. For a realistic view, one must compare the performance of the built environment, and consequently, the whole world with the introduction of green architecture.

The official data show an increase in green building projects globally and foresee even more growth in the upcoming years (figure 2.8). The business benefits from the green building investments are also continually growing (figure 2.9) ("World Green Building Trends 2018" 2018).

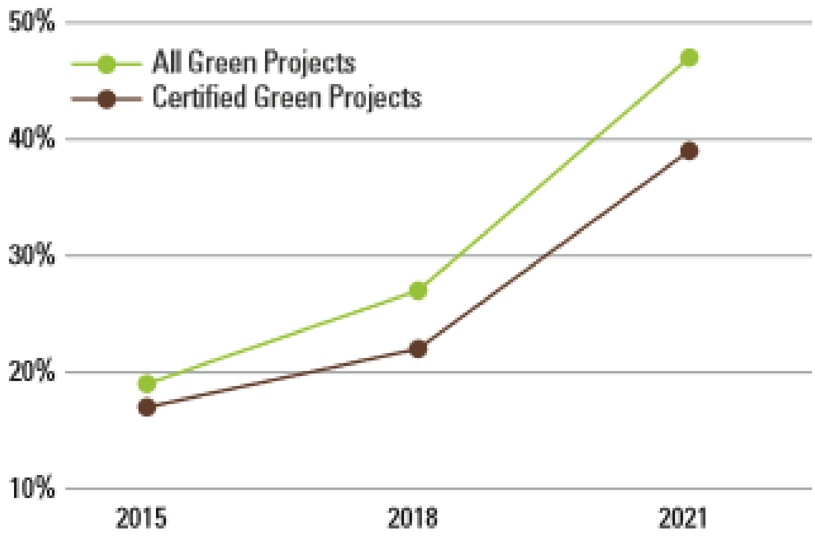

Figure 2.8 60% Green Projects vs Certified Green Projects (source: Dodge Data & Analyitics)

	New Green Building		
	2012	2015	2018
Decreased 12-Month Operating Costs	8%	9%	8%
Decreased 5-Year Operating Costs	15%	14%	14%
Increased Asset Value (According to Owners)	5%	7%	7%
Payback Time for Green Investments	8 Years	8 Years	7 Years

	Green Retrofit		
	2012	2015	2018
Decreased 12-Month Operating Costs	9%	9%	9%
Decreased 5-Year Operating Costs	13%	13%	13%
Increased Asset Value (According to Owners)	4%	7%	5%
Payback Time for Green Investments	7 Years	6 Years	6 Years

Figure 2.9 Business benefits expected form green building investments in new buildings and retrofited buildings (source: Dodge Data & Analytics)

However, by taking into account the role of the building sector in energy consumption, no considerable change in the energy consumption figure is predicted ("International Energy Outlook 2017" 2017), and almost all forms of pollutant energy consumption are in increasing trends (figure 2.10).

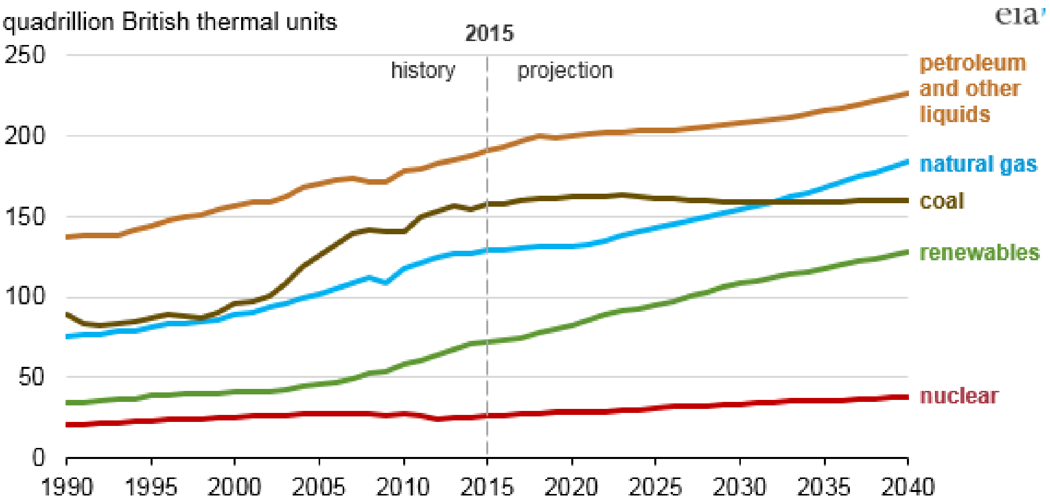

Figure 2.10 World energy consumption by energy source 1990-2040 (source: International Energy Outlook 2017)

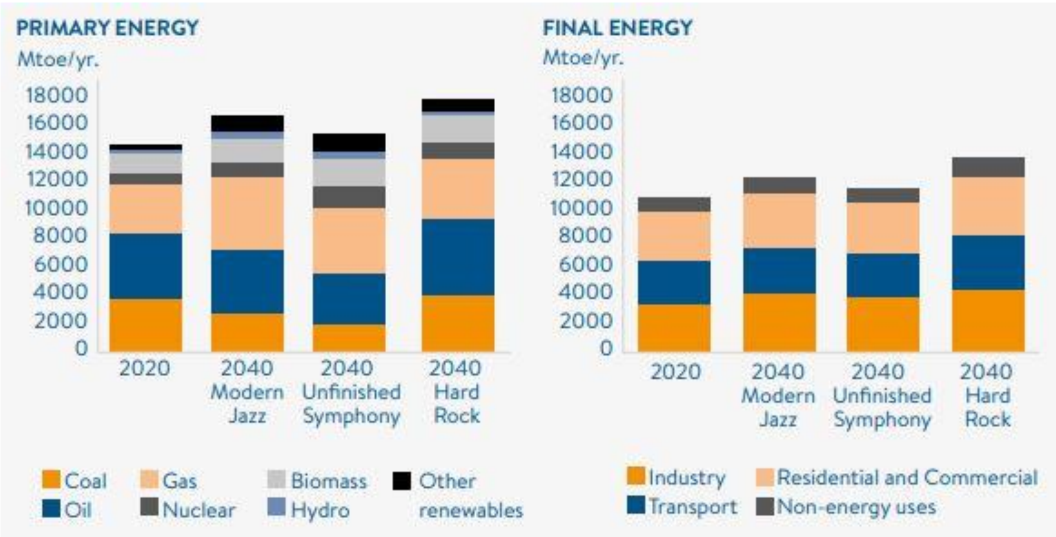

Figure 2.11 Primary Energy by Source (Mtoe/yr.) and Final Energy by Demand Sector. Modern Jazz: A market-led, innovative, and digitally disrupted world with a faster paced and more uneven economic growth. Unfinished Symphony: A firm, coordinated, policy-led world, with long-term planning and united global action to address connected challenges, notably a low-carbon future. Hard Rock: A fragmented world with inward-looking policies, lower growth, and less global cooperation. (source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy, 2019)

Moreover, experts predict that even in different scenarios of green development, the building sector maintains its significant share of energy demand (World Energy Council 2019) (figure 2.11).

These current facts and future predictions seriously question the overall effectiveness of sustainable architecture movements how a significant shift in design and technology in one of the most problematic sections might affect so little the overall sustainability of the planet?

If practiced properly, nobody can deny the improvement achieved by sustainable technology and the energy efficiency of the green buildings. Thus, this thesis does not mean to present a scientific objection to green architecture, but, raise the awareness that merely local and segregated strategies cannot tackle the issues of the built environment as a hugely complicated system.

Sustainable architecture can reach its optimum potential solely with a strong relation to the surrounding context. Cities are the host systems of which the buildings are only the subsystems. Any action for improving the performance of any piece of the built environment must adopt a holistic view which considers the interconnectedness between subsystems. Adding high-performance elements like green buildings to a host system that does not provide the performance capacity is like to add high-tech hardware on a computer motherboard, which is not competent enough to support it. In this sense, sustainability is an urban issue (Manesh and Tadi 2011).

2.2.3 Sustainability in Urbanism

Urban systems became the stages of sustainable practices, especially in the recent three decades. Besides the urban planners and designers, cities attract the attention of almost all disciplines fort their devastating energy consumption figures, highly accelerated growth rates, and exclusive social and economic fabrics.

As the first chapter discussed, the built environment is responsible for the majority of greenhouse gas emissions, the most significant share of energy consumption pollution production, and many social issues. On the other hand, the economic and political importance of the cities and the role of their growth in the overall development of the countries create too many conflicts of interest for the authorities to put a deliberate stop o to the urbanization.

Most of the systematic attempts for sustainable urbanism have targeted the static elements to control the dynamic features of the cities. However, new technologies, in recent years, made it possible to collect and process big data on urban dynamism and study the built environment more directly.

One of the earliest movements in reaction to the urban issues and claims for sustainability in urban design was New Urbanism. It claimed for walkable, which delivers diversity both in the urban types of uses and housing types (Ellis 2002). New Urbanism introduced principles of urban design partially formed some of the evaluation concepts of LEED Neighborhood Development (Boeing et al. 2014). The followers of this movement considered it a solution for the sprawling issues and advocated it as a modern utopia in which a magical design provides perfect balance among different social classes, land uses, housing typologies, transportation modes, and ecosystems ("Charter of the New Urbanism" 2000). Accordingly, new urbanism designers build may projects, especially in the United States, where they struggled with sprawling issues.

The magic tool of bringing the revolutionary changes was nothing but a set of principals summarized roughly like the following (Grant 2015; Ellis 2002; Kullmann 2015):

- Existence to central elements like a square at the neighborhood;
- Allocating the residential density around the central element;
- Variety of housing types;
- Existence of vital types (shops, schools, offices) of uses in each neighborhood;
- Existence of car parking for each dwelling unit;
- Existence of enough pieces of green spaces;
- Existence of streets which support cars, bicycles, and pedestrians at the same time
- Existence of community places.

The principals seem very much pleasing for any audience. New Urbanism promised almost everything that the modern citizens needed. Nevertheless, this promise was too good to be true.

The first glance at the principals reveals that New Urbanism is tailor-made solely for small scales in the developed countries. The requirements for a neighborhood to comply with these principals could be very expensive. Moreover, these principals are too generic to be used at large developments. Applying new urbanism for developing big cities would inevitability results in unified pieces that are unable to create the integrity of a whole.

Thus, the instructions of the New Urbanism, even if capable of solving problems, cannot help the significant developing contexts where the role of the cities in environmental problems are much severe.

Furthermore, New Urbanism is basically for new developments and offers less for modifying the existing context. However, the portion of new developments to the existing urban areas is negligible. As the existing urban areas cover more than 3.5 million square kilometers of the world (Cox 2010), an exact solution should be modification-based.

Most of the New Urbanism projects are medium-sized areas in the United States Like the Seaside project in Florida, Mueller Community in Texas, Mesa del Sol in New Mexico, and also some European projects in England, Netherland, and France.

These projects have received many criticisms from different angles. Many experts pointed out that there is no evidence base for the improvements that the followers of New Urbanism claimed (Boeing et al. 2014; Popkin et al. 2004; Subak 2018). Hence, some reviewers like Marshall accused it bitterly of considering target markets more than urban sustainability (Marshall 1999). Marshall believed that New Urbanism is the same old sprawl development disguised and sold deceptively (Mahrsall 1996).

Furthermore, many New Urbanism projects are too car-depended to be considered as green whatsoever. This aspect is against one of the central principles of this movement (Ellis 2002). However, the developers preferred vehicular mobility over the pedestrian and cycle-ways in many cases (MELIA 2008).

Overall, New Urbanism suffers from a significant attitudinal problem. Its commandment-like principals do not acknowledge the complexity and dynamism of cities; hence, they are not capable of creating natural integrity in practice. New Urbanism promises a modern ideal, without adequate knowledge of the system that it tries to idealize.

Another movement, becoming much popular also in the 1990s, is Smart Growth, also known as Urban Intensification. Unlike New Urbanism, the promoters of Smart Growth base their idea upon scientific observations. However, they issued commandments too.

The followers of Smart Growth used studies like the ones of Peter Newman and Jeff Kenworthy in late 1980 to advocate their arguments of intensifying the urban areas Newman gathered evidence that the population density has a non-linear inverse ration to energy consumption in the transportation sector (P. W. G. Newman and Kenworthy 1991; P. Newman and Kenworthy 1989).

In general, intensified urban settlements create more chances for diversified and efficient functional distributions. Therefore, the distances are closer and, naturally, the travels are shorter. These characteristics, supported with appropriate urban design, can provide a fertile context for non-vehicular movements and adequate public transportation.

The worshipers of Smart Growth have aimed at multiple targets and combined different tools around the central idea of intensification. They argued that a compact neighborhood design, appropriate functional distribution, and adequate public transportation bring livability, environmental friendliness, and safety to the neighborhoods (Architects 2014). Smart Growth designs, many times, use Transit Oriented Methodology (TOD) to increase the accessibility and provide a balance between public transportation and population density (Nahlik and Chester 2014). For minimizing energy loss, they occasionally include local energy distributors inside the neighborhoods.

One can summarize the chief principals of Smart Growth as following (Porter, Dunphy, and Salvesen 2002):

- High-density mixed-use development
- Providing jobs opportunities
- Compact building design
- Walkable neighborhoods
- Housing diversity
- Green open spaces
- Creating senses of place
- Community engagement
- Sustainable construction
- Economical viability

Smart Growth is successful at some levels but not proved itself as a comprehensive solution. It attracted severe criticism of its multiscale ineffectiveness. Wendell Cox, a policy analyst, testified before the American officials that besides the urban density, Smart Growth intensifies the very same problems that it tends to solve (Cox 2002).

There is an inconsistency associated with Smart Growth, known as the Paradox of Intensification. Steve Melia and his colleagues have elaborated on this phenomenon in a prominent study titled the same. The authors gathered data on US cities and some other parts of the world and compared their attributes like population density, VMT (Vehicle Miles Travelled, also known as VDT: Vehicle Distance Travelled), accessibility to public transportation, proximity to urban centers, and street connectivity. They have found that while the intensification reduces the motorized traffic and its associated problems in the city scale, it increases these issues, sometimes up to 16 times, within the areas where intensification takes place (figure 2.12) (Melia, Parkhurst, and Barton 2011).

	Per capita (by residents of the intensified area)	Within the intensified area	Globally
Vehicle miles travelled	↓	↑	↓
% of trips by car	↓	↓	↓
Traffic volumes		↑	↓

Figure 2.12 Transport effects of urban intensification as predicted by the paradox (source: Melia et al., The Paradox of Intensification, 2011)

The problem with Smart Growth, however, seems to be more profound. Smart Growth uses urban density as the central driver of modification, while density is only a structural factor among many. These attributes, like connectivity, diversity of kinds in types of uses, the capacity of public transportation, and morphological organization do not perform separately. Nevertheless, they form a complex network of interaction where the urban dynamism is not reducible to its parts.

By neglecting this infinite complexity of the built environment, Smart Growth offers a single prescription for all problems. This flaw roots in the universal tendency of the human mind to find simple solutions for complex problems. Alas, this search is always fruitless.

Each small piece of the built environment is unique in its way, and the exclusiveness of its characteristic resembles the DNA structures of the biologic systems. Any proposed modification should target the uniqueness of the context and aim at its one-of-the-kind problems. Increasing density might be useful in specific urban systems, but it is not the magic potion that works everywhere.

Improving the performance of any given system requires adequate knowledge about it. Proposed methodologies cannot skip the necessary stage of the urban diagnostics. As the built environment is an ever-changing Complex Adaptive System (CAS), the solutions to the problems should differ context by context. Therefore, instead of offering instant cures, the nobility of a decent urban paradigm lies in the accuracy of the diagnostic methodology it offers.

Other movements and methodologies like landscape Urbanism and LEED Neighborhood Development suffer from similar attitudinal imperfections. They are unable to address the intrinsic complexity of urban systems and the profound integrity of their mechanisms. Hence, at their best, they become inflexible rating methods, which pretend the whole equals the sum of the parts (Berardi 2013; Kim 2015).

A pervasive diagnostic-based movement emerged rather recently is Smart City. According to the definition, Smart City is an urban area that uses monitoring strategies and the Internet of Things (IoT) to manage various urban dynamism. The data-gathering systems collect a variety of information on urban mobility, services, devices, and, most importantly, citizens to manage traffic, public resources, utilities, water and energy units, waste treatment, and criminalities (Zanella et al. 2014).

Smart Cities, supposedly, function in three interconnected levels (Deakin and Al Waer 2011; EC 2007):

- To support the existing urban infrastructure with electronic data gathering systems, data analytics, Information, and Communication Technology (ICT) and Artificial Intelligence (AI).

- To reinforce the local communities by information support, providing open participation opportunities for them, and co-management.
- To increasing the adaptivity of the response by learning technologies and the integrity of management strategies.

The last point is, probably, the most central characteristic of the Smart City. Increasing the adaptiveness of urban management by observing the manner that the cities function trough data is a humble, yet influential position. The main difference between the Smart City and movements or methodologies like LEED-ND, New Urbanism, Landscape Urbanism, and Smart Growth is this position. While the mentioned movements originate from scientific-like presentiments, Smart City chooses knowledge-based inception.

Some of the Smart City projects in Barcelona, Copenhagen, Amsterdam, and Milan showed promising improvement in urban management (Trivellato 2017; Batty et al. 2012; Bakici, Almirall, and Wareham 2013; Zygiaris 2013). However, a quick look at the list reveals that most of the successful projects are European mid-sized cities. There are not enough studies to size the improvements of Smart City practices in Lahore, Islam Abad, and Shanghai. Dubai, Abu Dhabi, and Doha, too, are testing the Smart City principles in individual projects, but the projects are incomplete, and there are hardly impartial reports of possible changes in existing parts of these cities.

Today, the ever-growing existing megacities in the developing world are the main battlefields of sustainability. Smart City development firmly depends on inclusive intelligence, physical, and economic infrastructure. In developing countries, where the urbanization has the most rapid rate, new developments use the existing types of infrastructure. The financial and political costs of infrastructure shifts for the decision-makers could be too high. Therefore, revolutionary movements like Smart City will not find many opportunities to succeed in these critical contexts.

There is also a concern that Smart City is commercialization concepts that its main target is to find new markets for big ICT and telecommunication companies. These economic bodies are the real owners of Smart Cities, and decision-makers and environmental activists can only be the users of their tools. Like any other business organization, the only goal of these companies is to increase their profits, not necessarily protecting the earth. Hence, in a possible state of conflict in interests or profit reduction, they would change their plans with no hesitation.

Smart Cities, moreover, seems to suit urban management more than development. Of course, the big-data gathered from the cities could also help much to learn about the urban systems and use this knowledge for design and modification. However, it seems that only the companies decide the standard for data collections. They also do not tend to share their data easily for the designers, and if they do, the arrangement would be more likely to prioritize the interest of the companies. Hence, Smart City is only a robust commercial filter for urban sustainability, not an environmental-oriented scientific paradigm.

Furthermore, sustainability is solely defined on a global scale. There are severe warnings about the almost immediate consequences of our actions. On the other hand, many urban developments are happening rapidly and regardless. What the world need is a universal understanding of the urban system and integrated confiding mechanisms for the developments to minimize environmental footprints. Undoubtedly, the data is necessary and a great help. However, the solution should incept in scientific labs dedicated to the environment rather than profit-seekers and traders.

The right knowledge of the built environment should recognize its complexity and multi-finality. There are millions of systems, static and dynamic, active inside the urban areas that are serving millions of porpuses. The scientific community has to change the paradigm to examine these systems in integrity with each other.

The approach proposed in the present study is a systemic approach that acknowledges the built environment as a Complex Adaptive System, and using systems thinking interprets its dynamism through the morphology-generator subsystems. These subsystems themselves encompass many aspects with a high level of interdependency. The next chapter introduces the scientific background for reading these subsystems and the possible ways to measure and evaluate them.

As it is impossible to cover all the subsystems and their associated mechanisms, this doctoral thesis focuses on non-motorized mobility.

The following section justifies this selection.

2.2.4 Non-motorized Traffic

There are many layers in the urban performance. These layers can be nested in environmental, social, and economic categories and the areas in between to make the behavior of urban contexts readable in terms of sustainability.

How much is the share of a particular city in the GDP of a country? What is the average time per capita spent in traffic jams daily? How effective is the public transportation system? How many people are living in shantytowns formed in the surroundings of the city?

The answers to all these questions reveal specific characteristics of the performance of urban systems. Thousands, or maybe millions of more questions should be answered to from a half-completed performance indicator matrix of an urban system. The resolution of such a matrix improves by zooming in in urban scales and using shorter periods; in the end, the more performance data in wider varieties and velocities, the more accurate the set of indicators might become.

Naturally, the performing behavior of any system is rooted in its functioning mechanisms (Wächter 2011). Unlike the performance indicators that are independently readable, specific in concept, and carrying individual meanings, the performance mechanisms, especially in complex systems, blend with and depend on each other.

As it was described in previous sections, there are no direct cause and effect relationships between functioning mechanisms and performances. Hence, it might be declared even single traits in performing the behavior of a CAS are the results of interactions and overlapping of all the functioning mechanisms. In this scene, studying the functioning behavior of an urban system for the sake of understanding its performing patterns demands a conceptual boundary in which all the related mechanisms are considered.

According to definitions, the built environment is a multi-final system meaning that its function can be interpreted differently from different scientific viewpoints. It can be considered as a human settlement, economical engine, consumption entity, political zone, and of course, many other purposes can associate with it. The goal of this research, however, is to confirm that the city's performance (mostly environmental performance) can be systemically read in its morphological structure. Therefore, the boundary of the city, here, is formed by its morphological and morphology-generated elements within which the environmental-oriented functioning processes take place.

In such a context, too, limitless performing indicators can be identified, though the functioning mechanisms are considerably less. Within the mentioned boundary, the urban processes are influenced by spatial systems, links and mobility patterns, and land-use characteristics. In this direction, the attempts should be made at providing a framework in which different functioning manners -influenced by the city's morphological environment- are pictured.

It seems that these functioning processes can be categorized in and between the following categories (S. Vahabzadeh Manesh, Tadi, and Zanni 2011):

1. Spatial arrangements
2. Street systems interfaces
3. The distribution quality of types of uses

As an extraordinary dynamic system, most of the functions taking place in the categories, as mentioned earlier, are influencing or being influenced by different characteristics of flow. Even the static elements convey properties like density and land-use, which affect the urban flux by creating origin-destination orders and the quantitative indices of urban travels like transportation boarding and efficiency. Therefore, it is safe to state that the quality of urban movement is the central theme in all the morphological-oriented readings of the urban functions.

In terms of environmental sustainability, too, urban mobility would easily take priority; with the rapid rate of urbanization worldwide, mobility is the source of main challenges for most of the municipalities and urban management bodies. The main mean of internal urban travels are cars, and regardless of slight difference differences in trends due to the income levels, size of the cities and political histories, car ownership is inordinately growing with regard to the economic growth worldwide (Figure 2.13) ("Cities on the Move: A World Bank Urban Transport Strategy Review" 2003)

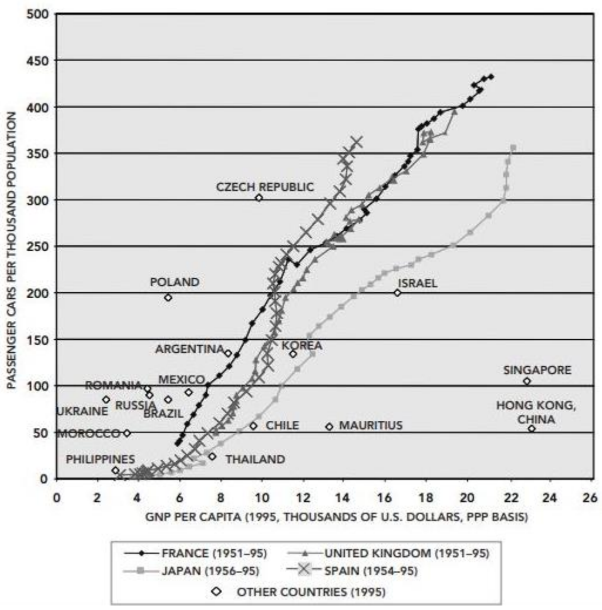

Figure 2.13 Car growth from 1950s to 1995 in certain countries (source: Cities on the move: a World Bank urban transport strategy review)

Oil is, and going to be for long, the most used source of energy globally (BP 2018). Among the oil products, fuel (as used for cars) has the highest share in demand. Regardless of predicted positive changes in the advanced economies' trends in fuel demand, the demand trends of the developing countries are expected to grow steadily (5.40 MB/d in 2040). This happens while the net change of the oil demand in the building sector -which use to have up to 40 percent share of urban energy consumption- drop by 1.12 million barrels per day from 2017 to 2040 (WEO 2018). A very high percentage of transportation fuel is being wasted in traffic jams; as in 2014, an amount of 3.1 billion of fuel gallons has been wasted in Texas traffic jams only (Schrank. et al. 2015). Here, the factor of non- traffic choices might come to play as Texas is considered as a US state with highly motorized-oriented transportation infrastructure.

In this situation, it is evident that moving towards non-motorized-oriented planning is not merely a choice but an absolute necessity. Focusing on healthful modes of mobility supported by an accessible and affordable public transportation system would not only save astronomical sizes of energy but also enhances the economy and society in many ways.

Annually about 4.6 million people die due to urban pollution-related diseases worldwide (World Health Organization 2015). This statistic exceeds the number of mortalities due to accidents, which itself is related to cars chiefly. Although a fraction of urban pollution is associated with indoor contaminations, cars are easily the primary source of pollution in the world’s cites. Non-motorized traffic would play the most prominent role in mitigating the catastrophic effects of air pollution and increase the healthiness of the citizens.

Non-motorized means of mobility, moreover, positively change the overall social health by encouraging the urban inhabitants to boost their physical activities. Much research examined the direct relations between the convenience of urban environments for non-motorized modes of mobility and the overall health of the society (Holman, Donovan, and Corti 1996; Stokols 1992; Giles-Corti and Donovan 2002). Besides individual intentions, specific characteristics of the urban environment can strongly encourage people to walk or ride bicycles for transportation or recreational reasons and break the tedious habits of long sittings, which have become a typical feature of modern life (Pikora et al. 2003; Winters et al. 2010).

Furthermore, non-motorized traffic, mainly walking, benefits social life at many levels. Safe and favorable streets that host walking traffic can hugely increase the chance of social interactions. In his remarkable book, *Life between Buildings*, Jan Gehl asserts that “life happens on feet” and argues how appropriate urban form and intelligent distribution of urban function can actively stimulate the non-motorized modes of mobility that directly affect the social interactions in the urban contexts (Gehl 1987).

Gehl lists several structural prerequisites for neighborhoods to attract walking flows that result in social interactions. In his view, there are specific measures and scales regarding the width of the passages and the size and placement of the spatial objects to which humans relate. He criticizes modern planning for creating the exact opposite of what could be humanitarian in urban form. However, importantly, Jan Gehl believes that the livability of the neighborhoods is heartily tied to the way that different types of uses form an activity network (Campos 2012; Gehl 1987; Elmqvist et al. 2013).

Jan Gehl categorizes the daily activities of citizens hosted by urban structure into the following groups (Gehl 1987, 2007):

1. Necessary activities
2. Optional activities
3. Social activities

Necessary activities are basic ones that generate most of the urban trips and are crucial for travelers. Job destinations and services (hospitals, banks, schools) are clear examples of necessary activities. Regardless of location, distance, or the condition of the links, the essential trips take place in regular or irregular patterns.

Among them, traveling from residences to the job locations, and vice versa, take the most significant share of the urban trips. People all around the world must choose between their private cars, public transportation services, or non-motorized modes of mobility to reach their job and get back to their apartments daily. Although contextual geographical and cultural parameters might influence the preferences of the local population preferences, it seems that these choices are primarily affected by the characteristics of the urban environment. A desirable arrangement of the urban elements can highly increase the share of healthful modes of traffic and arouse walking and cycling for the sake of transportation.

Optional activities are ones that are arbitrary and mostly used for recreation. Gehl discusses that these types of uses might be successful only if they are at optimum distances from the important ones. If the optional activities exist in walkable radiuses from the necessary types of uses, and the support of some specific structural attributes existed, then the social activities are expected to take place automatically (Gehl 1987).

Gehl's research delivers the conclusion that clustering a variety of functions in short distances from one other is vital for inducing the non-motorized traffic. Accordingly, different urban functions form a network that rules the mobility inside the neighborhoods. Naturally, there are several urban elements that should support this network. Moreover, there should be specific methods to evaluate the performance of a given context in this regard.

Jan Gehl classifies a few physical attributes thereof. The dimensions of the paths, as mentioned before, is an essential structural attribute here. He argues that primarily, the walkable links should provide a humanly hospitable space. Accordingly, the width of the passages is a variable of sizes and directions of the traffic that they expect to convey. The length of the links, however, depends on the structure of the functional network and distances between functions (Gehl 1987).

It is also crucial for the links to follow an even course as humans, Gehl asserts, naturally, prefer to move horizontally. Therefore, if the non-motorized mobility is in priority, elevated bridges and underpasses are not desirable forms of connection and should be avoided as much as possible (Gehl 1987).

Gehl highlights the importance of security for walking and argues how the morphological structure of the neighborhoods can provide inviting and secure environments for non-vehicular traffic. He hints on the role of the hierarchic void system in integrating and protecting the non-motorized flow (Gehl 2007).

However, despite all the morphological references, the findings of Jan Gehl do not go further than design advice in architectural scales. His works mostly idealize a few midsized European examples which historically benefit from old non-motorized structures. Whereas, the primary sources of the problem today are ever-growing large cities with vast distances between their functional kernels. Cities in which their rapid development history is empty from long-term systemic attempts for non-vehicular mobility.

Gehl's work might be successful in unveiling essential architectural characteristics for urban environments to walk in but monumentally fails in addressing the interactive forces caused by complex functioning behavior of the built environment. The condition of passages and architectural features in between the functions matter much as non-motorized mobility takes place in small scales and slow paces. However, intrinsic urban traits, structural foundations, and complex dynamisms enable cities to host millions of inter-scale feedbacks impossible to pinpoint in architecture and neighborhood scales. Density, accessibility, the overall connectivity of the street network, and the effectiveness of the public transportation system are fundamental urban processes that rule the overall flow in the cities. Studying mobility in neighborhoods and streets, detached from the whole systems of which they are but parts, would necessarily lack a systemic approach.

Furthermore, Jan Gehl does not suggest any measuring tool for the evaluation of non-vehicular mobility. As mobility, in any form, is the source of many essential functional attributes, any structural proposal without a suggestion for performance measuring mechanisms is substantially incomplete. Any sustainability-oriented inquiry should target the performance of the studied systems and provide a base for measuring or predicting the output of imposed modifications. However, we cannot criticize Gehl in this regard, for he conducted most of his research when sustainability was not a pandemic topic among architects. His work, nevertheless, sets up a strong foundation for social-friendly architecture.

After Gehl, especially from the 1990s on, many scholars examined the influence of certain urban elements on the non-motorized mobility. Although the studies covered a diverse range of contexts and purposes, they exhibit many common findings. From the existing research, we can classify prevalent motives among different groups of citizens and, most importantly, the essential urban elements that shape the non-motorized patterns of mobility in the cities.

Walking and cycling take place in urban areas for leisure or transportation. Although separate sets of social and physical factors rule the chief motives, the primary factor that postulates non-motorized mobility is the existence of suitable links. The scholars agree that the condition of footpaths, for walking, is a significant role player. People favor walking in well-conditioned footpaths, which conduct the walking flow separately from vehicular movement (Holman, Donovan, and Corti 1996). In this regard, supportive footpaths are either entirely pedestrian streets or ample-sized sidewalks that host the walkers without interruption of the motorized streets. Protection from vehicles is an important safety factor for sidewalks (Rapoport 1987). The presence of parks, trees, and desirable aesthetic features are also in many lists for evaluating the paths (Atash 1994).

Although the design characteristics of footpaths in architectural scale matters, it seems that connectivity is a better tool to evaluate the non-motorize mobility support in urban scales. Studies show that the non-motorized flow is much stronger in urban contexts, which benefit from continuous and integrated street networks (Southworth 2005; Ilani Bilyamin and Hussaini Wahab, Mohammad, Kamarudin 2017; Nelessen 1994; Bill Hillier and Iida 2005; Atash 1994). Unlike the condition of the passages, aesthetics, and even land-use, which are spatial features with small scale influence, connectivity is a morphological trait with a broader significance.

At this point, it is safe to state that the non-vehicular movement studies -and strategies- are either attraction based, or connectivity based. There are mathematical models for conducting quantitative studies on connectivity. Attraction, on the other hand, is merely an architectural quality that is evaluated by indicators that can relate to a vast number of other factors too.

One of the most recognized evaluation methods for connectivity is the *Axial Analysis*, developed by Bill Hillier and colleagues in the early 1990s at University College London. Axial Analysis examines the integrity inside the street configuration. Based on graph theory and the mathematical concepts like *Mean Depth*, Axial Analysis evaluates the global connectivity of a given network. In this regard, Hillier asserts that the urban form, especially the arrangement of the streets and paths, is a primary factor to generate or halt the pedestrian movement (Bill Hillier and Iida 2005; Bill Hillier 2009, 2002). Hillier notes that the primary variable that rules the movement is the distance. The distance itself is a variable of other elements like compactness, spatial patterns, and centrality, which create the urban form (Bill Hillier 2002). Therefore, the pedestrian movement is mainly the product of city form. Hillier demonstrates why the connected grid system is the most favorable form to conduct the non-vehicular traffic. The chief characteristics of a grid system, enabling it to host smooth movement, are continuity and geometric regularity. In this sense, almost all urban grids are deformed-grid systems (B. Hillier et al. 1993). The abundance of intersections and continuously connected paths are feeding the system in bilaterally (figure 2.14). For the pedestrian movement happens inside and between the segments. The continuity of the secondary routs inside the segments is the key difference between a regular grid system and a Radburn layout.

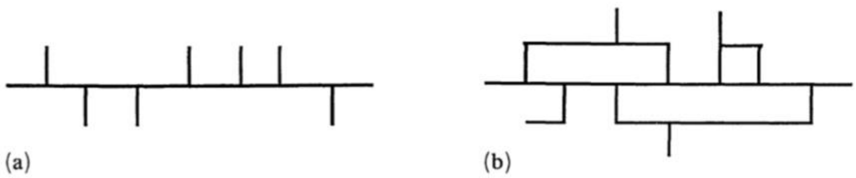

Figure 2.14 Shorter connectivity of the "Main Street" in layout b compared to layout a. The continuous bilateral elements form a deformed-grid system and increase the overall connectivity. These simplified examples demonstrate the fundamental difference between grid systems and Radburn layouts. (source: Natural movement: or, configuration and attraction in urban pedestrian movement, Hillier, Penn, Hanson, Grajewski and, Xu; 1993)

Accordingly, we can conclude that the passage architecture only matters when the route integrates into the overall street network. Systemic integration, especially when the non-motorized mobility for the sake of transportation is the subject, is the prerequisite of attraction in any kind. Connectivity, in the sense of integration, has a fundamental and direct relationship with safety. People feel safer to walk in passages that host more people for their natural connectivity.

The advantage of integration over the passage architecture is evident in informal settlements where the quality of the streets is usually poor, but the pedestrian movement happens in certain streets that rank higher in global connectivity; whereas, the less integrated links are favorable for criminal activities, for they are more complicated to reach, hence, simpler to control (Tadi et al. 2015).

In 2003, the journal of *Science and Medicine* issued an article by *Terri Pikora* and colleagues recognized vastly in the scientific community involved in non-vehicular mobility studies[1]. The paper was an inquiry into the substantial prerequisites for an urban environment to encourage walking and cycling. The authors based their arguments on the existed literature on the necessity of physical activity to increase health in urban areas. The study lists the determinants of non-vehicular traffic indicated by many academic works conducted before. Factors like safety, aesthetic features, and the condition of the passages upon which almost all the relevant scholars agreed. However, the nobility of Pikora’s study is an attempt to create a comprehensive framework of such factors by evaluating the relative weighting of each element to the others.

The authors combined semi-structured interviews and a Delphi Study for evaluating environmental factors that might encourage citizens to walk or

[1] Developing a framework for assessment of the environmental determinants of walking and cyclin

ride bicycles. They have developed a model out of urban environmental factors influencing the walking for recreation in neighborhoods (fig 2.15). Then they used the same model to weigh the relevant factors for walking for transportation, cycling for recreation, and cycling for transport. Pikora and colleagues classified the factors into four features: 1. Functional; 2. Safety; 3. Aesthetics; and 4. Destination (Pikora et al. 2003). Then, they went further and detailed the elements and items associated with each feature.

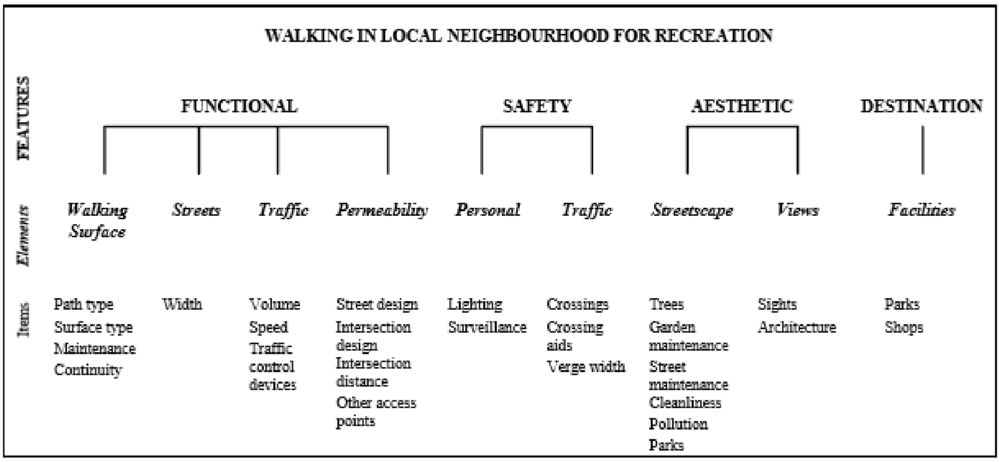

Figure 2.15 The model of urban environmental factors influencing walking for recreation (source: Developing a framework for the assessment of the environmental determinants of walking and cycling, Terri Pikora and colleagues 2003)

The authors carried out studies on recreational movements for the sake of delivering knowledge on physical activities. However, since the main quest of this doctoral research is to provide a framework for improving the environmental performances of the built environment, the ideal non-motorized mobility forms, here, are those that can replace the vehicular ones. Thus, this dissertation focuses mostly on walking and cycling for transport.

The result of the study shows a significant effect of the urban facilities (shops, services, public transportation stops) on both walking and cycling with the purpose of transportation. Factors that are not role players for recreational movements (Pikora et al. 2003). This result obliquely confirms the findings of scholars, like Gehl, who insisted on the importance of functional diversity for non-vehicular mobility.

Accordingly, the favorable streets must host a variety of functions, while shops ranked the highest among them. Therefore, the arrangement of types of uses, in the street-level, where usually the shops are located, is a determinant, not only for walking but also for cycling. We can conclude that an ideal form to secure such requirements is a compact urban form with a certain level of mixed-use functional distribution. A robust urban factor on which many research works insisted (Handy et al. 2002; Boarnet et al. 2011; Giles-Corti et al. 2009; Karusisi et al. 2014).

Mixed-used development is essential for several reasons. Because of the functional diversity, inherent in such contexts, the distances are relatively shorter. Furthermore, the classic exchange of origin-destination in working hours is bidirectional in the mixed-use urban environments; therefore, the commuting time, at least partially, is shorter. This condition affects the choice of transportation mode if other factors agree.

Another critical factor, profoundly influencing the non-motorized traffic, is permeability (Pikora et al. 2003). The permeability of streets, the way Pikora's study suggests, highly corresponds to the concept of connectivity mentioned earlier in this section. This element measures items like intersection distances and access to other points, which are the traits of well-integrated links in the street network. However, as the methodology of this study involves interviews, though from experts, like all the items, the concept of permeability contains intuitional meanings here. Therefore, the authors included items like street and intersection design, which might convey ambiguous qualitative features.

The authors have considered two categories for safety — protection against motorized traffic, and personal security. Essential elements to assure the former are safe crossing and ample verge width. For biking, separate and continuous lanes and driveaway crossovers come to play too. Personal security, on the other hand, depends on public lighting and surveillance as both items score equally if the subject is walking for transport (Pikora et al. 2003).

Again, it is worthy to note that surveillance could be an essential byproduct of connectivity. If the street network configuration supports a high-level pedestrian flow through the integrated links, peer pedestrians provide natural surveillance. Hence, it is safe to state that many items and elements in Pikora's study are redundant if a quantitative evaluation of connectivity existed.

In the aesthetic features, the study concludes that for cycling for transportation, only the level of pollution matters. In walking for transport, the cleanness of the paths accompanies pollution (Pikora et al. 2003). However, as the study considers equal weights for all the main features, it is not possible to evaluate the overall role of each element and item in shaping the big picture.

Altogether, Pikora's study reveals many aspects associated with non-vehicular mobility, yet, leaves many questions unanswered. The sets of features are subjective to citizens, and a comprehensive scientific model is lacking. Fundamental urban features, like density and connectivity (in the technical sense), are absent, and the study does not verify its findings. In this regard, the article seems to advocate a democratic vision for measuring the movement patterns in the built environment.

Moreover, about many fundamental urban features, like density, outdoor comfort zones, spatial configurations, accessibility, and origin-destination dynamism, the study remains silent. On such subjects, this practice fundamentally lacks in a systemic view towards the built environment and neglects its indispensable complexity. Any scientific inquiry into the performance of a complex adaptive system, like the city, requires at least a conceptual model in which the integration between elements, though limited, defines the processes. Pikora's article fails to address such relationships even between the factors which the authors chose themselves. Hereof, one can criticize this study as an arbitrary list of characteristics weighted subjectively.

Here is worthy of expressing the distrust over the methodologies based on weighting the individual factors in urban areas. Since the built environment is a complex system involving too many interrelated elements, circumstances, and mechanisms, it seems that an appropriate manner of studying it would be developing a model to directly correlate different structural arrangements, the way they are, to the performance patterns. In this regard, weighting a group of selected factors oversimplifies a complex system and increases the risk of generalization of results, which should never be generalized. Pikora's study suffers in this regard.

Nevertheless, the paper confirms certain elements suggested by other scholars and adds useful details to evaluate non-motorized links. A productive vision suggested by this study is the distinction between cycling and walking for recreation or transportation. In this sense, it may help to fulfill design principals both for sustainable mobility and social-friendly urban environments. Further research could use these principals for testing their degree of influence and find possible correlations between them and other urban features.

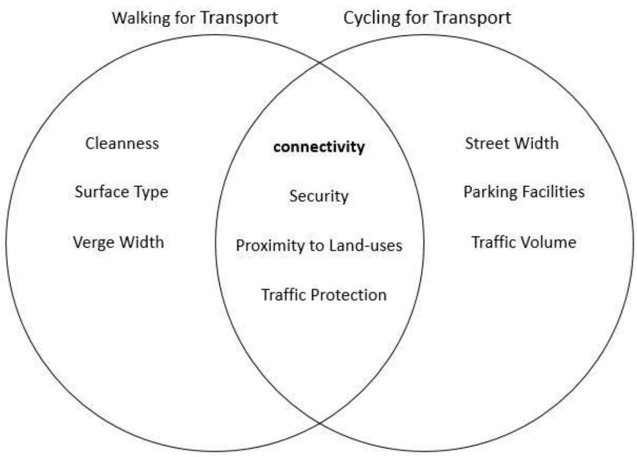

Figure 2.16 Urban environmental factors influencing walking and/or cycling according to Pikora's study

Referring to many studies and the correlational analysis they carried out, Sealnes and colleagues argue that population density is one of the most dependable correlates for non-motorized transportation (Ross and Dunning 1997; Cervero 1996; Frank and Pivo 1994; P. W. G. Newman and Kenworthy 1991; Saelens, Sallis, and Frank 2003). One of their references was the famous research of Newman and Kenworthy that demonstrated the opposite correlation between the population density and the energy consumed in the transportation section (fig 2.17) (P. W. G. Newman and Kenworthy 1991). The compact land-use arrangements provide the chances of short distances and higher connectivity.

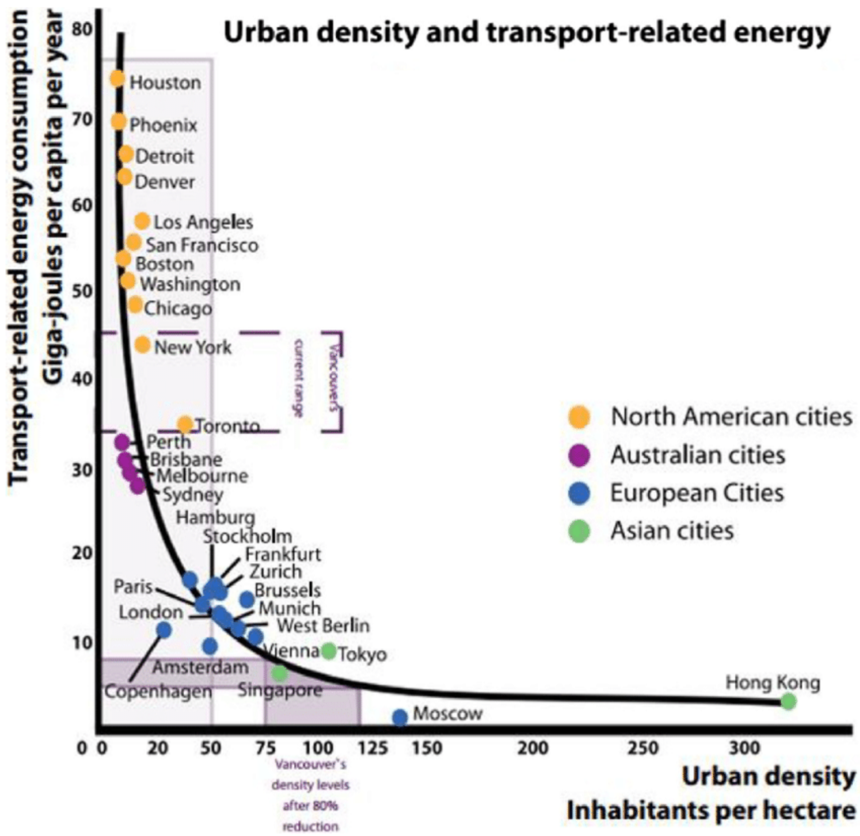

Figure 2.17 The relationship between population density and transport-related energy consumption in 32 major cities worldwide (source: Transport and urban form in thirty-two of the world's principal cities, Newman and Kenworthy; 1991)

Interestingly, employment density also comes to play as an independent positive correlation. This variable seems to be a suitable determinant to evaluate the land-use mix (Saelens, Sallis, and Frank 2003). According to Saelens, citizens tend to walk in high-density mixed-use neighborhoods where they have high accessibility to a diversity of urban functions (Cervero 1996; Hanson and Schwab 1987). These findings imply that the ration of employment density to the total density could be an attribute to measure the land-use mix.

The Saelens' study, too, highlights the role of the non-vehicular infrastructure in walking and cycling share (Saelens, Sallis, and Frank 2003). Their article refers to much research asserting that the quality of the paths and their continuity have a direct influence on the transportation choice (Saelens, Sallis, and Frank 2003; Kitamura, Mokhtarian, and Laidet 1997).

The study proposes an "ecological model of neighborhood environment," which concludes different factors influencing the non-vehicular traffic choices in the built environment (fig 2.18).

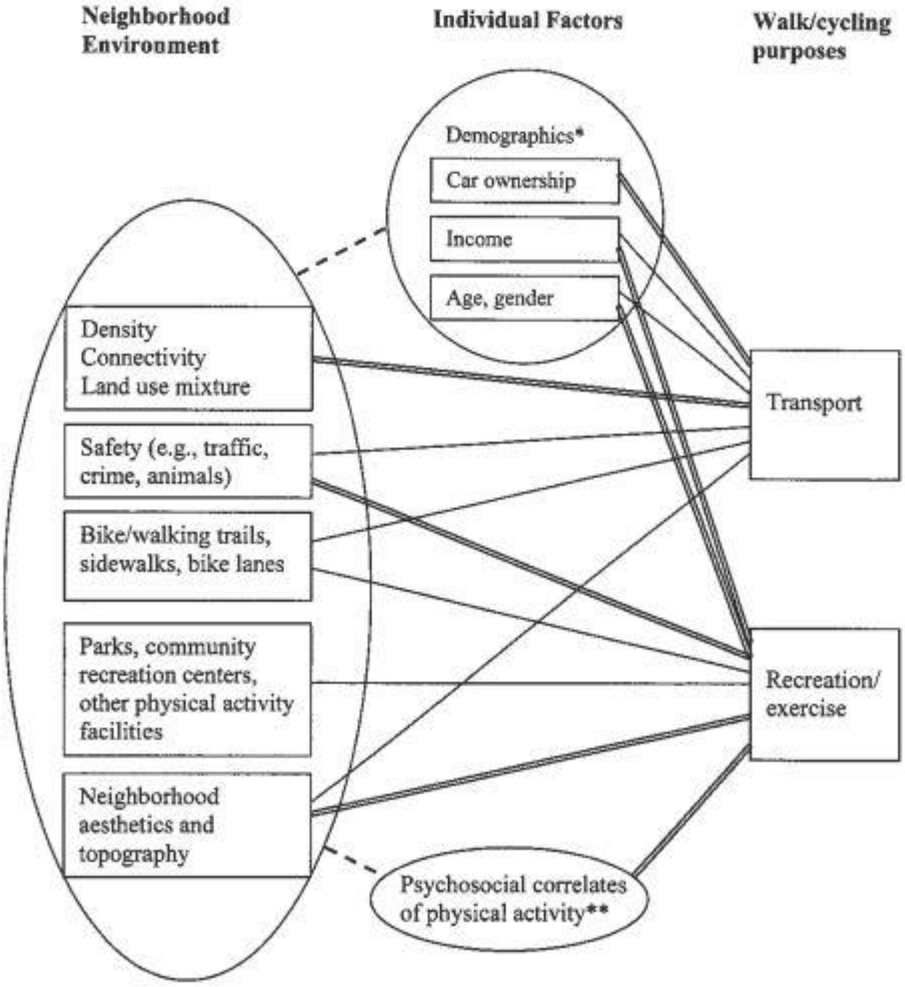

Figure 2.18 Proposed ecological model of neighborhood environment influence on non-vehicular traffic (source: Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literatures, Brian Saelens et al., 2003)

According to the model, the chief urban factors influencing non-motorized mobility for transport are density, connectivity, and land-use mix, while the main individual factor is the car ownership (Saelens, Sallis, and Frank 2003). However, one might argue that there should be a reciprocal relationship between car ownership and neighborhood factors. In theory, as the level of convenience for non-motorized transport increases, car ownership is expected to decrease. In this sense, this individual factor, in large enough statistic samples, could be a performance indicator rather than a propelling determinant.

In general, Saelens and colleagues provide a comprehensive framework for walkable/cyclable neighborhoods with stress on high-density mixed-use development as the chief prerequisite. The article also covers several aspects of link quality and differentiates between transport and recreational purposes. However, environmental factors like temperature comfort ranges are absent in this study.

There are several studies on the influence of the outdoor temperature on the urban pedestrian flow. As the comfort parameters vary, sometimes considerably, from place to place, these practices, by default, are local-based inquiries. Most of these studies consider a variable named Predicted Mean Vote (PET) as the determinative factor, which is an empirical unit to measure human comfort.

Robust research results show that variables like the temperature difference and wind speed could significantly affect the urban pedestrian flow (Keller et al. 2005; Nikolopoulou and Steemers 2003; Nikolopoulou, Baker, and Steemers 2001; Fallis 2013; Spagnolo and de Dear 2003; Hwang and Lin 2007; Brager and De Dear 1998; Eliasson et al. 2007; Knez and Thorsson 2006). Many scientific attempts exhibit the comfort ranges in different climates worldwide (Nikolopoulou and Lykoudis 2006; Lai et al. 2014; Provençal et al. 2016; Watanabe et al. 2014; L. Chen et al. 2015; Majidi et al. 2018; Middel et al. 2016). The results show that although the comfort ranges are not constant, they are quantifiable in any environment.

These studies highlight the fact that human comfort accounts for a considerable extent in the choice of transport; hence, it should be an inevitable part of any model measuring non-motorized mobility. Another factor associated with human comfort is the slope of the non-motorized link to which minimal literature exists (Sun et al. 1996).

2.3 A Framework for Future Development

2.3.1 Future Development in the Built Environment and its necessities

Whether we deny or not, there are apocalyptic consequences strictly connected to human actions on earth. The development of the built environment has the most significant share of these actions. Currently, the urbanization pace is much faster than our agility to respond appropriately. Despite the political hype, the attempts for sustainable development had no tangible results yet. The urbanization is a profitable area, and, especially in the developing world, its role in economic development is too important for the politicians to reconsider fundamentally.

The international programs like the Agenda 2030, and the Paris Agreement, too, were not sufficient enough so far. The decision-makers have planned them exclusively, and the confiding mechanisms inside them offer minimum obstacles. The issues of today's world are profoundly complex and interconnected. There are serious doubts about the ability of these programs to address this degree of complexity and interdependency. Therefore, one might expect that these official attempts serve the market more than the environment.

The high grade of interconnectedness is also present inside the boundaries of the problematic systems, and the built environment is of the most problematic and complex ones. The political, theoretical, and practical movements to improve the environmental performance of the cities have been either misguided, incomplete, monumental failures, or frauds. The main reason is the reluctance of these movements to view the built environment as it is. It seems that the only way in front of us to have environmental-friendly future cities is to reach to a universal and robust understanding of the built environment and its mechanism. For that, we have to confess our classical ignorance about it and start to observe it objectively.

The built environment is a Complex Adaptive System and one must approach it like one. For actual sustainable development, we need to shift to new paradigms that can address the relation of things without reducing them and maintain their validity in cross-scales. Accordingly, the appropriate approach for studying the built environment seems to be the systems thinking.

We have to work on modeling the urban systems in terms of the interdependency of their components and mechanism. Our models should be able to include as many influential factors as possible and deliver predictions with high accuracy. Only then will we possess enough tools to define policies for growth and management. Only then will we have precise measurements that we can use for the base of potent confining arrangements.

We might be far from that by now. However, we should start at some point.

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CHAPTER 3

Theoretical Background

3.1 Integrated Modification Methodology

3.1.1 Integrated Modofocation Methodology: An Introduction

Integrated Modification Methodology (IMM) is Integrated Modification Methodology (IMM) is a procedure encompassing an open set of scientific techniques for morphologically analyzing the built environment in a multiscale manner and evaluating its performance in actual states or under specific design scenarios. It is a holistic attempt to approach sustainable development in the built environment. The purpose of IMM is to bridge between the planned interventions and the desired urban performances by offering a systemic process to assess, modify, and retrofit the morphological organizations in a multiscale manner (S. Vahabzadeh Manesh, Tadi, and Zanni 2011).

IMM started as a set of academic studies at the Department of architecture, built environment and construction (DABC) in Politecnico di Milano. Those studies criticized the analytical approach frequently used to study and evaluate the built environment by most of the sustainable development methods. IMM considers the built environment a Complex Adaptive System (CAS) in which the relationships between the parts are highly complicated in a way that a mere local modification starts a chain-reaction and ultimately changes the entire system. IMM urges a holistic simulation of such a system rather than simplifying the complex mechanisms within the cities with reductionism (Tadi et al. 2015).

IMM hires on systems thinking and tends to deliver knowledge-based measurements to explain the structure of the built environment and its hidden mechanisms that rule the behavior of the urban systems9. For a sustainable Development, Built Environment seems to be an appropriate system to work on for it encompasses most of the aspects of man’s life; hence, it offers a good starting point (Bai et al. 2016).

Built Environment involves a set if highly convoluted processes. It is an open system which involves many profound relationships between social, economic, and environmental subsystems (Decker et al. 2000; Bai 2016). The accurate way to look at cities is to consider them as Complex Adaptive Systems (CAS), which are ever-evolving and self-organizing (Manson 2004; Fujita and Mori 2002). This notion brings some aspects of the approach of studying the built environment. Complex Systems do not follow the classic cause and effect relations between modification and performance, and they should be subject to the simulation without compromising the main elements of their complexity (Holling 2001; Abel 2013). It is also crucial to acknowledge that the morphological, social and economic processes are in constant interaction together and this interaction causes a profound network of feedbacks, which is necessary to consider for approaching sustainability (Glaeser and Kahn 2010). Therefore, any simulation methodology should provide much flexibility to be adaptive to different readings of the model (Leichenko 2011).

IMM's systemic view is a scientific attempt to deliver a compatible model of the interactions between the morphological subsystems used for diagnosis of the problems in the actual functioning state and predicting the performances of the intervention's plans. Although the focus of this methodology is on urban morphology, its multilayer and synthesis-based logic behind its procedures can be easily interpreted and applied in different conceptual scale to involve the social and economic feedbacks (Bai et al. 2016).

Despite the general studies in urban sustainability, which are either element-based approaches or are limited to a single attribute, IMM offers a comprehensive view of the structural attributes and their complex networks and targets at the measurable factors through which those attributes influence the performance of the built environment. Heretofore, lacking in such an approach led to incapable scoring systems for assessment and creation of an urban structure that are either suburb-like or overly densified.

Based on system thinking, the primary purpose of IMM is to introduce modification scenarios for morphologically transform the built environment - in different scales- into ecologically better-performing systems. In general, IMM consist of analysis, assumption, modification, and retrofitting phases forming an iterative nonlinear process to develop an urban/architectural project from the investigation in the actual situation and master planning to the prediction of the performances of the proposed design. The underlying theoretical assumption in IMM is the recognition of the built environment as a Complex Adaptive System (Manesh and Tadi 2011).

In this regard, the city is not a mere aggregation of buildings and roads but a convoluted organization of physical and functional features in which everything profoundly interacts with everything else. Naturally, the collective behavior of a CAS is different from the sum of the individual elements making it. Any local alternation in one single element produces a chain reaction that involves many other parts and ultimately changes the global circumstances of the entire system in different periods. IMM uses this very quality of the complex systems to modify the behavior of the whole with local intervention scenarios. To be consistent with the nature of the CAS, IMM adopts holistic, multilayer, and multiscale manners of study as its main elements of the approach. The goal of IMM is to enhance the performance of an urban system concerning the local situation.

With this approach, each system, absolutely unique in its organization, is comparable only with itself and the systems within itself. Hence, the most fundamental prerequisite for working on a system is to gain a comprehensive understanding of its uniqueness in form and function. Accordingly, the central intention of IMM is to unfold the systemic arrangement of the built environment form, from which all the structural attributes, functional characteristics, and performing patterns origin. Once such understanding exists, the rest is just a matter of learning to play with the local system's rules. Based on morphological and functional arrangements, IMM schemes a local system mapping used both to investigate the actual base and predict future scenarios.

Having the horizon of the UN Agenda 2030 as the standard guideline for sustainability, it is fundamental to develop tools to measure the advancements in the Sustainable Development Goals (SDG) and the targets associated with them. As has been mentioned earlier, encompassing most of the aspects of human life cities are probably the most critical systems to become sustainable. The predicament in SDGs is that the importance of actions and strategies to which naturally are placed between Targets and Indicators are missing. IMM could be a methodological interpretation from SDGs to address this issue in Goal 11, and its approach could be replicated to achieve overall sustainability in other SDGs too.

3.1.2 City as a Complex Adaptive System

IMM recognizes the built environment as a Complex Adaptive System (CAS) comprised of numerous subsets and many variables interacting on various levels, various scales, and a diverse set of subcategories. Rendering the CAS's nature, local action in an individual subset will produce a chain reaction within the network of its parts and trigger a process, consequently leading to the global change of the entire system. In other words, system agents adapt themselves in response to the complex network of reactions from individual changes.

What does it mean that IMM regards the city as a Complex Adaptive System? How is a complex system different from a simple one?

According to the definition, a Complex Adaptive System (CAS) is a non-linear dynamic system with a high level of interconnectivity between its parts (Wu 2014). According to Miller, in a CAS, a complete understanding of the parts does not lead to the understanding of the whole (Miller and Page 2009). Although to some extent, this remark is valid for any system, it means that in a CAS, the relationships between parts are inseparable from the parts.

CAS is a complex hierarchical configuration of different sub-systems and elements working together as a whole; therefore, the hierarchical nature of CAS requires a multi-scale approach if one intends to improve the entire system's performance (Salat et al. 2011).

The root of such complexity is in the dynamic network of interactions inherent in the CAS. In a complex system, every part is related to every other part in a non-linear manner that makes it difficult to determine. This non-linearity, more than technical issues, invokes reasoning issues. The classic scientific outlook, as argued in the previous chapter, hires logical tools to unveil the hierarchic orders between the known elements of a phenomenon. Knowledge, in a typical scientific approach, is the ability to relate and explain elements in terms of each other and discover causalities in the processes. This outlook naturally seeks understandable cause-and-effect relationships that involve forms of simplification and reduction.

Simple systems react correctly to the cause-and-effect approach. What makes them simple is the straightforward relationship between parts. Their elements, though so many, are connected linearly, and their procedures involve hierarchic actions for functioning. It means that one can explain the role of a subsystemic connection regardless of the whole. This trait, however, does not imply that the relationships between parts are independent of each other. Malfunction of subsystemic relation, though limited, inevitably result in failing the whole system, but the mechanisms usually could continue until the previous hierarchies. In other words, functioning phases follow their previsioned order.

All the systems that humans intellectually create are simple. Human logic is necessarily linear and hierarchic-based; therefore, consciously, it can only design hierarchic systems. Even the most sophisticated artificial creations which involve numerous interconnected elements and processes are not complex systems. The human mind might be able to understand, produce, and control multilateral mechanisms, but is not capable of comprehending, let alone producing simultaneity.

Nature, on the other hand, creates only complex mechanisms. Climate, ecosystem, and life are deep forms of complex adaptive systems. Interestingly, these systems are not separable from each other by the traditional systemic boundaries, and they are all connected, forming larger systems (D. Meadows 2001). These systems, too, consist of individual parts, yet, all parts relate to other parts in a non-linear way, and the systemic procedures happen simultaneously. Therefore, fully modeling them for the order-based form of intelligence impossible (D. Meadows 2001; D. H. Meadows et al. 2018).

Humans, nevertheless, can modify complex systems. They consistently did it from the dawn of history, and the main problems they are facing today, like global warming, are the consequences of such blind modifications. For the convoluted multilateral nature of connections between the part and processes of the complex systems, mostly incomprehensible to human intelligence, any modification might produce unforeseen consequences that we often regard them as side effects.

The intrinsic network of relations inside a CAS transmits any forced local adjustment to other parts and generate chain reactions that ultimately change the whole (Tadi et al. 2015; Miller and Page 2009). This characteristic is what makes such systems adaptive, meaning that each part adapts itself to the changes received from other parts through the innate connection chains. The “side effects” arise from the adaptive nature of CAS.

To avoid side effects, at least to some fair degree, we need to build inclusive simulative models rather than reduction-based streamlined ones (Manesh and Tadi 2012). The general engineering outlook, which intends to dismantle a system into separate processes, is not enough to understand complex adaptive systems, and it seems that to deal with CAS, we need to change the paradigm.

Accordingly, IMM intends to base system thinking as the primary approach to regard the built environment and propose simulative models for studying them. IMM considers the city to be a complex adaptive system and claims that the principals ruling it are the same as which rule natural systems.

Here, one might argue that the built environment is an artificial creation; hence, it is not comparable with natural systems and biologic entities. It might imply that as a humanmade system that involves elements and mechanisms designed from scratch, the city, necessarily, is of the same essence as man’s other productions.

Indeed, the city is not a natural organization. However, complexity does not necessarily depend on having an organic essence. Although cities took shape by human design intelligence over different periods, they involve multiple actors, exchange mechanisms, resources, and events impossible to predict by the modifiers. In the functioning processes of urban settlements, there are too many elements, stages, and networks for considering them simple systems (Bai et al. 2010; Loorbach et al. 2016; Bai et al. 2016). Cities emerged in ages through turbulent rhythms of development driven by many conflicting goals. Billions of minds and mechanisms are modifying them daily. In this sense, they are a perfect mixture of conscious and unconscious forces resulting in intended and unintended aftereffects (Glaeser and Kahn 2010; Bai, Chen, and Shi 2012; Güneralp and Seto 2008).

The main element of the approach of Integrated Modification Methodology, therefore, is to recognize this immense complexity. Rather than focusing on the elements and scalar boundaries, IMM makes scientific inquiries into the inter-scalar relationships between the parts without intention to reduce them into comprehensive linear affiliations. Therefore, instead of blending hierarchic explanation for non-hierarchic phenomena, IMM studies methods that make it possible to contain all the necessary role players and deduce logical conclusions without oversimplifying the system.

The key to this goal is to develop a framework that relates the system's structure, inclusively and impartially, to the performing behavior. For the relationships between elements that define the systemic structures, we can sustain that different structural characteristics induce different performances. Accordingly, instead of investigating chronological orders in the city's functioning procedures, IMM attempts to identify the direct connections between systemic arrangements and performing patterns. Thus, it is necessary to hire a system thinking approach that includes all the necessary processes, subsets, and broader boundaries that might affect the behavior of the built environment in specific directions.

3.1.3 System Thinking in IMM: Investigating the Morphological Structure of the Built Environment

With an extremely high level of complexity, cities are always in the state of transformation. The forceful dynamism within their arrangements produces multi-layered reactions for any single action.

Rest on the form of adjustments, the whole CAS changes in a long time, brief time, or immediately an all these levels of time-related transformation take place simultaneously. From this perspective, cities are ever-changing entities, and transformation is a continuous process. There are specific patterns of transformation in each specific context though that is inherent in that very system's particularities. In other words, if two different urban systems undergo similar intervening actions, their reactions would not be the same, and therefore, the transformation results in any given period would be undoubtedly different. Thus, to plan for any modification on an urban system, it is fundamental to learn about that system's structure.

Accordingly, IMM focuses on the systemic arrangements of the built environment and proposes holistic procedures to transform the urban systems into better performing entities based on the unique qualities that each context offers.

According to the System Theory, there are four properties common in all types of systems:

1. They are composed of elements;
2. There is a relationship between elements;

3. There is a particular function associated with any system (however, many systems including built environment are multi-final systems meaning that numerous functions are associated with them);
4. There is a boundary defined for any system. It is crucial to notice that the functioning manner of any system is a direct product of the relationships between the parts. Therefore, the way that the elements relate to each other plays a much more decisive role than the items themselves.

All the cities on the planet composed of common elements such as buildings, parks, roads and streets, transportation means, parking areas, yet no two towns are to be found to share the same performance. For the functioning manner roots from the somewhat hidden dimension of relationships, any attempt for controlling the performance of the build environment systems by solely working on the level of the elements will be ultimately facing methodological conflicts in theory and unforeseen consequences in practice.

IMM involves a nonlinear phasing process involving the following structure:

- Phase I. Investigation: Analysis and Synthesis
- Phase II. Assessment and Formulation
- Phase III. Intervention and Modification
- Phase IV. Optimization

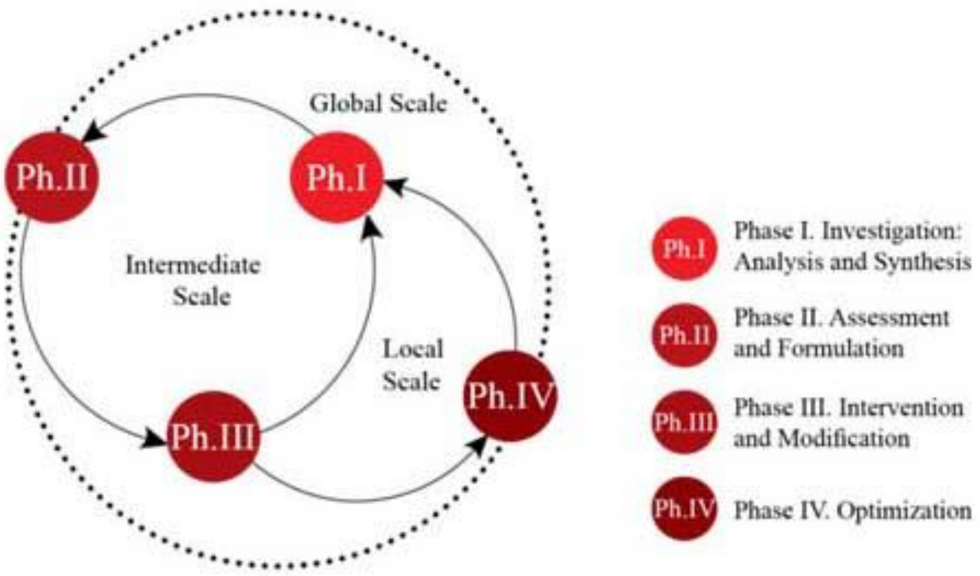

Figure 3.1 Phasing Process in Integrated Modification Methodology (IMM Group's website: http://www.immdesignlab.com/informazioni/)

In the first phase, the built environment system is broken down into its subsystems, and the relationship between those parts is investigated. Accordingly, the performance of the system is evaluated in the second phase, and intervention plans are formulated. In the third phase, design/modification scenarios are tested with the same means that the actual context was investigated, and the last stage is dedicated to overall optimization through the definition of local retrofitting strategies.

Heretofore, IMM defined the main morphological subsystems (Horizontal Investigation), theorized the synergy between them and outlined the structural attributes emerging from their symbiosis (Vertical Investigation), and relied on a long list of indicators to evaluate the performance. The concentration of the current research would be on redefining the fusing mechanisms that shape the structural attributes of the system (Phase One) and the manners that these mechanisms are described to govern the performance of the order (between Phase One and Phase Two).

The generic morphological subsystems recognized by IMM are namely: urban built-up, urban void, types of uses, and links. The first two include all the physical elements such as buildings, parks, roads, canals, parking areas. They could be compared to a computer's hardware. The latter two, however, are the functional elements like the means of transportation, jobs, and services, which could be associated with the software in the computer metaphor. It is necessary to note that the capacity of the system results from fusing the physical and functional elements.

The synthesis of the subsystems results in structural attributes regarded in IMM as Key Categories. Key Categories are morphology-related emergents that shape and host the dynamic processes of the city. Characteristics related to spatial distribution, land-use allocations, and mobility patterns define the behavior and performance of urban settlements. Key Categories arrange measurable aspects of urban morphological systems together to introduce individual models for different functional attributes. These models, supposedly, represents the following structural attributes:

- *Urban Porosity*: the spatial relationship between urban built-ups and voids
- *Proximity:* the structural relationships driven by the distances between basic land-uses
- *Diversity*: the structural relationship derived from the different typologies of land-uses
- *Accessibility*: the mobility patterns driven by dynamic characteristics of origins and destinations
- *Effectiveness*: the static effect of urban characteristics on the functioning order of mobility systems
- *Interface*: the characteristics of the street network that influence overall connectivity

- *Permeability*: the relationship between the street network and spatial components influencing overall connectivity

Here, it is worthy of mentioning that the Key Categories only illustrate the structural characteristic and not necessarily the performance. In IMM, like most of the scientific methodologies, the tools for performance evaluation are indicators. IMM examines scientific methods to find correlations between the structure and performance; hence, the Key Category models do not imply the performance on their own.

3.1.4 Proximity: How IMM defines Walkability

Tadi and Manesh used term proximity in IMM to describe the effect of closeness to certain types of uses on non-vehicular mobility (Manesh and Tadi 2011). In the earlier practices, the authors imagined proximity as the interaction of essential elements volume and function (Tadi et al. 2015; Shahrooz Vahabzadeh Manesh and Tadi 2013). The term function has changed into types of uses. However, no Key Categories represent the reciprocal relationship between the two elements (Arcidiacono et al. 2017).

According to IMM's definition, Proximity is the morphological quality that the urban context offers for walking through the arrangement of key types of uses. The key types of uses are vital urban services, which might differ from context to context. Concerning specific studies that measured the walking preference, the authors have chosen the convenient walking duration between five to ten minutes that roughly corresponds with 400 to 800 meters (Mohler et al. 2007; Levine and Norenzayan 1999).

In the early studies which used IMM methodology to measure proximity, this Key Category is represented qualitatively by maps and quantitatively by numbers. The walkable area around each of the selected types of uses formed a circle with a 400 to 800 meters radius. These areas collectively created a walkable pattern. The standard deviation of the number of types of use inside the circles was reported as the quantitative measure of proximity inside the selected boundary (Tadi et al. 2014) (figure 3.2).

This way of measuring walkability is innovative on so many levels; however, it is not free from trouble. On the one hand, it reveals a hidden pattern of the arrangement of the types of uses, which is quite noble. Although the functional distribution was a crucial concept in planning from the dawn of the urban design and planning, there were quite a few practices that delivered a structural measure out of it. Nevertheless, concerning many influential factors in non-motorized mobility, this measure does not seem to be accurate enough.

As the last chapters indicated, connectivity of street patterns plays the chief role in defining the quality of non-vehicular mobility in a given area. Although IMM measures connectivity by the axial analysis in a Key Category named *Interface*, the way that it explains the mutual relationship between these Key Categories was not clear at the time. This issue seems to be more of an evaluation problem rather than a conceptual one.

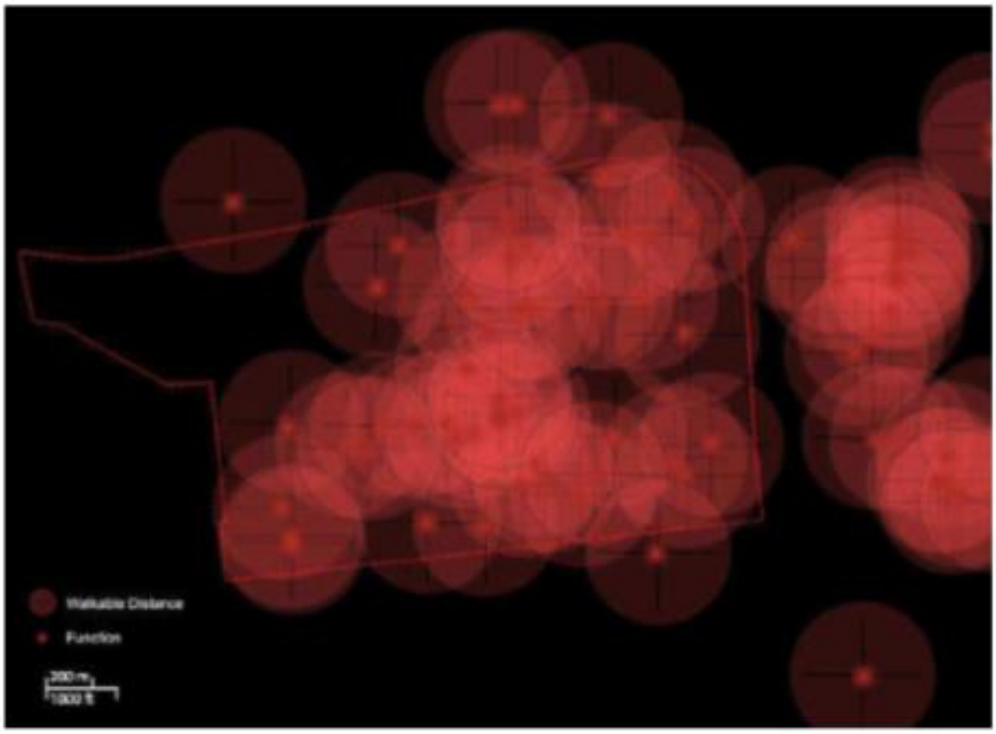

Figure 3.2 the map of IMM's Proximity of a neighborhood in Tehran (source: Tadi et al., Investigation of Urban Form and Environmental Performances via IMM methodology: The case of Tehran, Iran, 2014)

The way of considering the types of uses also raises some questions about the accuracy of measuring. While most of the experts agree that the existence of certain types of uses accounts highly in walkability, particular factors weight these types differently. The literature review concluded that the diversity of existing types and their location are two critical determinants in this regard. IMM measures diversity in another Key Category; hence, here too, the evaluation methodology can play an important role in relating walkability to the diversity of uses. Nonetheless, proximity has to address the factor of location.

According to the studies that the present thesis uses in the literature review, the distribution of specific urban uses in the street level, where much walking flow is expected to happen, is more effective concerning other forms of distribution. On this subject, the area of window-shops is a more precise value compared with the point position of the type in the plan.

The walking corridors illustrated in proximity maps are not accurate enough too. Although defining the buffer zones with the centrality of the type of use is correct for the origin/destination purpose of the types in proximity, the geometry of the circle does not seem to be realistic about the walking patterns. Walking and other modes of movement naturally take place on the paths. Moreover, there are many other physical obstacles like buildings on the street-levels that shapes the non-vehicular mobility. Therefore, the real walking corridors will not provide the freedom of circular shapes, and also, depended on the contextual directness, the buffer zones cover smaller boundaries than the radius.

Another critical aspect is the usage of one single value in measuring the proximity. The non-motorized traffic, according to the literature, is a function of many other variables. In addition to types of uses, population density, the street profile, mixed-use level, and human comforts are decisive parameters profoundly affecting non-motorized transport. The modeling of proximity should consider these factors both in numerical measurements and graphical representation.

This doctoral thesis uses the theoretical base of IMM but modifies its modeling following the mentioned parameters. The proximity modeling functions as a measurement base for this structural attribute, which in future research should correlate with performance evaluation for delivering an appropriate decision support tool.

3.1.5 Performance Evaluation in IMM

The Key Categories are only structural attributes. No values within them nor a single Key Category alone can offer enough information about the performance of the system. Key Categories only reveal how specific parameters arrange the system, and together, they show a much complete vision of the systemic structures. The performance of the system has the indicators of its own.

A multi-final system like the built environment, naturally, demands many indicators to cover different aspects of its performance. Cities are economic, social, and environmental systems with many associated subsystems. Each aspect of performance is also encompassing more other aspects. For evaluating the behavior of the urban systems, one needs accurate an accurate set of indicators.

For example, Non-motorized mobility, which IMM intends to address with Proximity, can associate with many performance aspects with coherent value loads. In general, the grade of a system in supporting non-vehicular modes of transportation can be shown by indicators like VDT (Vehicle Distance Traveled), public transportation boarding, and car ownership. The concentration of gasoline particles and its related pollution in the air can create environmental indicators for Proximity. For economic indicators, one might suggest the percentage of active sidewalk shops and their economic growth, the investments in non-vehicular mobility, or the economical production of public transportation. The diversity of social classes and health-related figures are also too essential bases for social indicators.

Accordingly, IMM offers an open list of indicators to approach the performance of the built environment from different angles. This list includes nearly 200 indicators today. Specific nested categories filter the indicators according to the discipline, sustainability pillars, or the SDGs with which they relate.

It is worthy of mentioning that this grouping does not contradict with the complexity of the built environment. On the contrary, the arrangement of indicators is a tool to recognize it. Individual Key Categories, in reality, affect more performance attributes than what one can imagine. Therefore, while one can search for immediate results of a particular structural arrangement in specific indicators, the totality of performance is readable with consideration of all Key Categories together. Everything in a complex adaptive system is related to everything else. Likewise, all the Key Categories are related to each other and all the indicators.

Here, there is a critical lesson for designers. The performance is the result of the structural arrangements, not the individual quality of components. Therefore, for improving the performance, the structure should change adequately and new design elements are merely the interpretation of such changes. For the complexity of the built environment, specific structural changes might produce contrasting effects on different aspects of performance. Thus, for optimum performance, the designer should make changes in any structural attribute considering its possible effects on the others.

In the future, if one gathers enough actual structural models of all Key Categories and enough performance indicators of the same contexts, the chance of accurately predicting the potential performance of given design scenarios concerning their structure will increase.

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CHAPTER 4

Discussion: The Totality of the Key Categories

4.1 Key Categories: The Functioning Mechanism of the Built Environment

4.1.1 A Review on the Structure of IMM's Key Categories

Although the city is a multi-final system with which a vast number of characteristics and purposes could be associated (Bai 2016), there is relatively little room for misunderstanding the morphological components as defined here. However, as was previously argued, the key to understanding the city as a Complex Adaptive System is not through its reduction to its parts, but the deep inquiry into the relationships between those parts. Now that the components are manifested, the question is how to study their fusing mechanism.

A range of scientifically-based methods exists to study the relationships between the urban primary layers. Nonetheless, this study holds its purpose to deliver a clearer understanding of the systemic behavior of the built environment. Thus, every concept defined herein has been visualized only as a tool to illustrate precise dimensions in which morphological arrangements influence operational behavior, and of course, does not necessarily defy other vantage points of the urban arrangement.

By introducing IMM to the scientific community, Tadi and V. Mansesh identified the term "Vertical Investigation," which is the main procedure for explaining the behavioral manner of the city (S. Vahabzadeh Manesh, Tadi, and Zanni 2011; Shahrooz Vahabzadeh Manesh and Tadi 2013). In Vertical Investigation, each of the four essential components has been asynchronously linked with the others and gave birth to several conceptual attributes named Key Categories. Key Categories, hence, are bi-cellular entities, of which each cell is one of the chief layers. There are seven Key Categories identified by IMM as Porosity, Proximity, Diversity, Permeability, Interface, Accessibility, and Effectiveness (formerly referred to as Efficiency).

The role of Key Categories is to decode the patterns of integration that the necessary subsystems make with each other and to define the working manner of the whole system. In IMM, they are the final explanation for the morphologically-propelled behavior of the spatial systems. Important operational traits such as spatial configurations, functional arrangements, travel behavior, and the quality of movement are justified.

IMM evaluates the performance of the system under the assumption that the Key Categories can represent the functioning manner. However, before investigating the transmission from analysis to evaluation, it seems fundamental to review the architecture of the Key Categories.

If the Key Categories are to be restructured, then the primary activity seems to be defining an inclusive fusing process producing functioning attributes by addressing more than only two layers. This new arrangement does not necessarily question the practical meanings of the Key Categories but offers a new way of conceptualizing them in a systemic perspective.

Here, it is worthy to point out that neither in the built environment nor in any other types of complex systems can the exact functioning mechanism of the system's components be understood and fully describe (Hayenga 2015; Rouse 2015). As the interconnection between its subsystems chiefly defines the functioning characteristics of any system, the persistent gap in understanding the functioning manners of complex systems is due to the inability to comprehend their fusing rules. Substantially, there is a profound oneness between integrity and purpose in complex systems: as if by functioning, the system is only unfolding its simultaneous multi-dimensional organic unity. The fusion is synchronous with performance as the system completely adapts to the new circumstances at any stage, resulting in a process that is utterly unique at any given point in time. That is in fundamental contradiction with human modeling logic, which, no matter how profound, is inevitably based on sequential procedures.

Thus, the practical attitude for approaching the complex system is to identify specific categories of outputs through which specific dimensions of the operational mechanism could be partially described. That is to say that the synthesis between parts can only manifest in forms of conceptual structures that are necessarily inspired by a specific range of outputs related to a particular area of the system's performance. The area of performance should reflect the problems that the ultimate model is going to address. Therefore, the abnormal situations must be identified, and the problem should be influenced in such a way that after forcing the intervention, those situations can be mitigated.

This research project mainly intends to study the various patterns in the spatial arrangements that could influence the performance of the built environment from the standpoint of environmental sustainability. The relevant outputs are those which affect mostly the environmental impacts, and more specifically, energy consumption.

Apart from a variation in energy demands for different types of uses, the ordinary procedures through which a city consumes, or leaks energy are the utilization of the existing buildings and infrastructure, mobility (flow of people, goods, and information), and construction of new buildings and infrastructure. Because the utilization of buildings is more of a corporate matter rather than systemic within the scope of this research, the optimization of energy consumption in buildings is a matter of retrofitting.

Accordingly, Key Categories are defined based on the morphological attributes that directly or indirectly influence specific patterns of energy consumption and are ultimately measured by indicators that address the figures of energy. Since there are a vast number of sustainable indicators verified by the literature on which this study relies, the main challenge of this research is to solidify a structure for understanding the morphological attributes through the Key Categories (essential tools) and proof of their relationship to the indicators as the evaluation tools.

By nature, the actual interactions between the components of the complex systems cannot be fully understood and modeled (Harel and Feldman 1987). The main obstacle is that the non-linear dynamics inherent in the functioning mechanisms of such systems (that is unusually explicit in biological systems), while even the most advanced simulation algorithms are based on hierarchical arrangements that prevent them from being simultaneous.

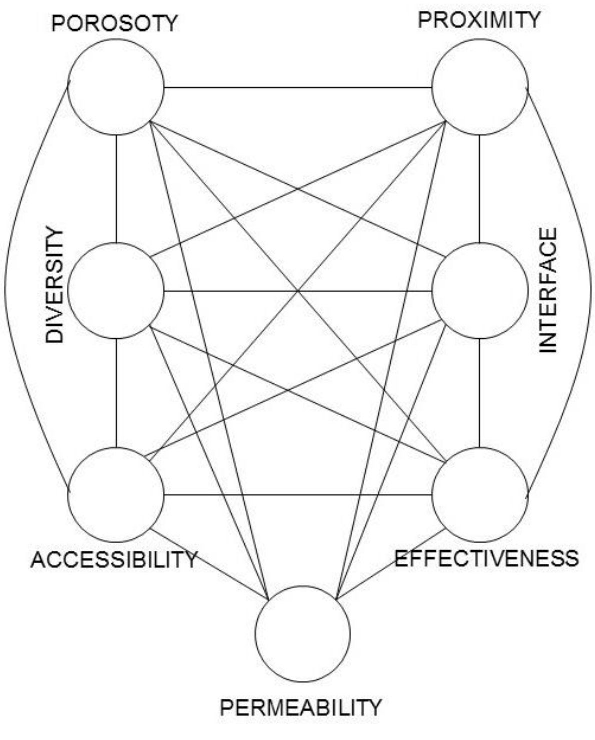

Figure 4.1 The mutual links between the IMM's Key Categories

Therefore, modeling the ways that the essential morphology generator elements of the built environment are fused and form the Key Categories is more a matter of coherency rather than accuracy. Now, the question remains as to where (or how) lies the coherency of the Key Categories?

Acknowledging that every model is an overall reduction of the modeled phenomenon, therefore, all models are wrong on many levels (Pike, Box, and Draper 1988). Thus, the study's purpose must shape the properties of the model. In this sense, two models of the same phenomenon with different purposes are naturally different from one other. As the purpose of the present study is an inquiry into the relationships between the structure and performance, the model should shape accordingly.

In a realistic view, all the Key Categories relate mutually to one another and affect each other simultaneously. There is a fundamental oneness in the structure which is reduced in structural attributes through the concept of Key Categories. In this view, the Key Categories form a closed network where each one of them relates to the others through a reciprocal link (figure 4.1).

Although the mentioned view is itself a reduced model, it is still too complicated. The constant multidirectional feedbacking that happens simultaneously between the elements produce more problems than solutions. Moreover, the closeness of this system makes the relation of the structure to the physical elements, one the one hand, and performance indicators, on the other hand, too much convoluted.

While the model of Key Categories should represent the complexity of the built environment, it must also be coherent enough to function as a model. It is also vital that this model addresses the relationships of the built environment morphology-related inputs (components) and the performance as the output (indicators). The ultimate target is that the Key Categories, as the structural attributes, connect the inputs to the outputs.

4.1.2 Key Categories and the Artificial Neural Network

It seems that the most appropriate modeling approach capable of maintaining the connection of the elements, structure, and performance is Artificial Neural Networks (ANNs). In computer science, ANNs might be used for predictive self-learning models (Hagan, Demuth, and Beale 1995). Neural Network is a framework for modeling which mimics the connections between biological neurons. Today it has a wide range of applications such as data mining, data processing, classification, function approximation, regression analysis, time series prediction models, studying non-linear systems, and more (Warwick 2011; Billings 2013).

The problem that this study is interested in is the relationship between urban physical arrangements and the performance of the built environment. IMM suggests a network of structural attributes that belongs in between them. Accordingly, the morphological elements are the physical features of the city that, whether in an actual situation or design, are measurable. As they are the parameters added or changed by the designer, they can form the input layer.

The performance indicators, on the other hand, are the results of the system functioning. They are measurable through the data, and in a simple approach, they are the output layer. Key Categories are the structural attributes that, according to the definition, receive inputs from the elements and produce the outputs. They can form one or multiple hidden layers (figure 4.2). In this view, the wights of the artificial neurons and the links between them depend on the individual modeling of the Key Categories and their related parameters. As the performance indicators form a complex network themselves, this modeling can expand enormously.

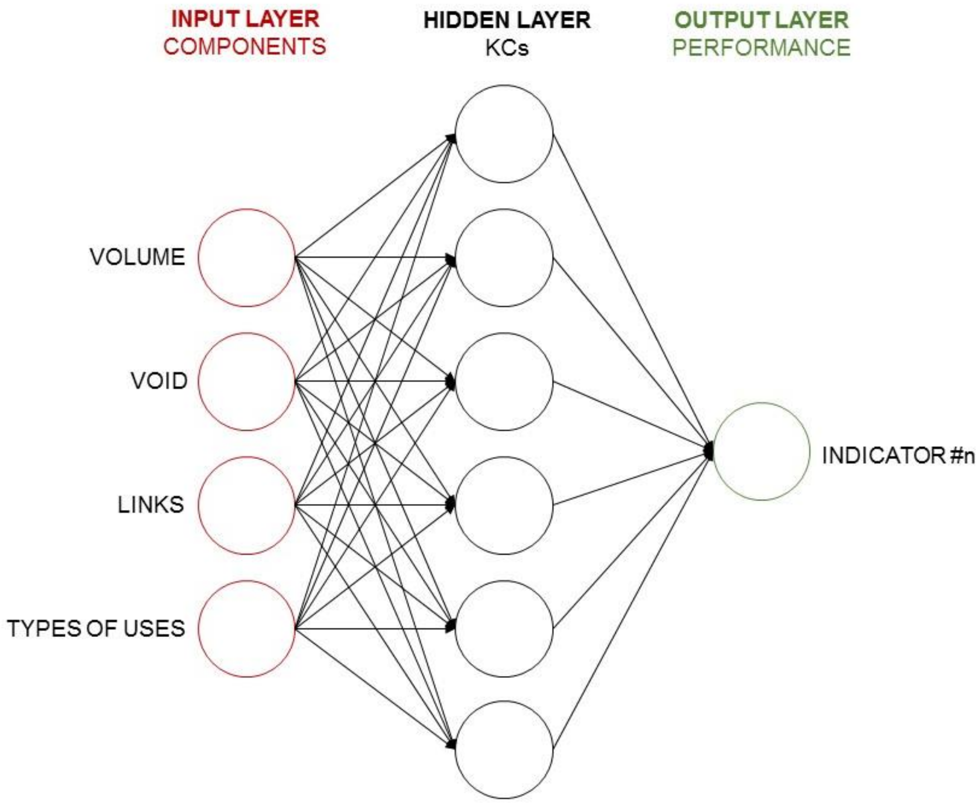

Figure 4.2 The connection of components, structure (IMM's Key Categories), and performance of the built environment in a simplified artificial neural network

It is crucial to mention that this modeling methodology is out of the expertise of the author and it is not in the context of this doctoral thesis. However, the reason for bringing it here is to stress out, again, the importance of considering the Key Categories in their totality. The suggestion of an Artificial Neural Networks modeling is a way of accepting that we deal with a complex system with non-linear dynamism in different scales.

There is no reason for our monumental failure in understanding the built environment except not having such a view towards it. We develop utopian theories, aim at high targets of sustainability, built high-tech devices, gather enormous sizes of data, and, still, modify the elements for good reasons and get surprised by the results and the side-effects. We neglect the structure and its complexness.

In a realistic view, the built environment is a complex system, and it is more comparable to biological networks than abstract intellectual ideals. Therefore, neural network modeling seems to be appropriate for approaching urban systems. However, there is long before us to be able to model cities like that without oversimplifying them. The first step is to understand the components of the model. There is a need for lunching inquiries about each artificial neuron and deliver quantifiable factors for measuring it and the relationship it makes with the others.

The present study aims at understanding Proximity as an element of this modeling framework. Based on the reviewed literature, this choice is justified, a framework for measuring it is suggested and tested on a study case in the following chapters.

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CHAPTER 5

Measuring IMM's Proximity

5.1 Contextual Parameters

5.1.1 The Components of the Proximity Model

The practical product of this dissertation is a framework for evaluating urban proximity, which is one of the seven Key Categories in the Integrated Modification Methodology (IMM). The goal is to identify measurable structural attributes profoundly influencing the performance of the built environment in this regard.

Proximity, referring to the proximity of different land-uses, is a concept with which IMM explains how land-use allocation might affect the choice of mobility in neighborhoods, and especially, encourage or discourage non-motived mobility.

This study is using proximity as an example to demonstrate that the structure attributes can quantifiably relate to the performing behavior in the city. The target is to devise a mathematical pattern from the structural elements and, in future research, correlate it directly with the performance indicators. As the previous chapters indicate, it is impossible to explain the functioning mechanisms of the city, as a complex adaptive system, in terms of hierarchical cause-and-effect orders. For that reason, to correlate structure with performance, one should hire a combination of supervised and unsupervised learning algorithms together with numerical methods.

Deep Learning and Artificial Neural Networks, in general, require enough data from all the categories desired to correlate (Francis 2014; Amari 2016). It means that for the case of proximity, we need to feed the algorithm with thousands of structural models and the performance indicators associated with them.

Such a process is out of the scope of this study for this doctoral research aims at delivering a basis for modeling the structural facets. Nevertheless, the case study adaptation involves testing and verification of this model for an actual urban context.

Conformingly, the model, should arrange, relate, and represent the morphology-related attributes influencing walking and cycling to deliver a comprehensive, measurable product.

The purpose of the model, as discussed in the last chapter, is to extract morphological values representing the quality of non-motorized flow in selected urban boundaries. The same approach is expected for the other IMM's Ky Categories in future research to form an integrated model for the structural attributes of the built environment. This structure will relate the inputs, which are the existing or design elements to the performance indicators as the outputs. The result would be a predictive model used as a decision support tool helping multiple parties of design and management.

Acknowledging the fundamental complexity of the built environment, the model should include all the essential parameters objectively. It should avoid any biased weighting and only provide flexibility for associating the parameters to the performance. Therefore, the model is expected to deliver numerical patterns of arrangement of morphological features.

According to the literature review presented in chapter two of this dissertation, the proximity model intends to include the influential morphology-related parameter in the following aspects:

1. Connectivity
2. Land-use mix
3. Human comfort

Although the model addresses certain quality of urban functioning, it is fundamental for it to be compatible and linked with the other functioning qualities presented by IMM's Key Categories. This approach provides systemic capacity and multi-scalar accuracy to the diagnosis. On this account, Interface, Accessibility, Permeability, Porosity, and Diversity address the systemic grades of connectivity and land-use mix in the intermediate and global scale. Porosity, on the other hand, reveals the local structural traits.

In making the proximity model, the goal is to deliver an equitable account of the involved elements. Furthermore, as any context is unique and genuinely comparable with itself, the parameters should address local measure, but, deliver a general proportional structure; hence, this doctoral thesis intends to construct unweighted dimensionless ratios out of the influential morphology related parameters.

For delivering a framework for an unbiased subjective model, this doctoral thesis suggests the following:

1. Selecting measurable features well representing the influential morphological parameters;

2. Producing dimensionless values out of these parameters and presenting them together.

The result would be a numerical pattern of a specific structural attribute, which can be used as a base for connecting the morphological elements and their arrangement to the performance scopes. In the future, with enough patterns collected from existing urban systems, together with their performance accounts, a deep learning algorithm in artificial neural networks can dig deeper in this regard.

It is worthy of mentioning that the reason for producing dimensionless values out of the morphological parameters is not to make them comparable whatsoever. These parameters are from widely different natures and represent different factors. However, as they influence a particular quality of urban dynamics together, dimensionless ratios make them readable on the same scale; hence they can form a clear numerical pattern.

5.1.2 Connectivity Parameters

Before anything else, the urban context should assure high grades of connectivity to support non-motorized mobility for transportation (Southworth 2005; Ilani Bilyamin and Hussaini Wahab, Mohammad, Kamarudin 2017; Nelessen 1994; Hillier and Iida 2005). As the previous chapters depicted, IMM measures the connectivity of streets with Interface. Interface quantifies the integrity of the street network, mainly through Axial Analysis, and delivers a systemic evaluation for the studied context.

In Proximity, however, the goal is to deliver a detailed perspective on the non-vehicular links. Therefore, as Interface analysis bears the integration score, connectivity parameters in Proximity focus the standards for non-vehicular links.

The first parameter in this regard measures the length of walkable/cyclable links compared to the total length of the streets in a given context (5.1). This parameter provides a proportional measure for the share of non-motorized links and their level of interruption compared to the rest of the street network. Higher values in this parameter indicate a more connected and continuous local network.

$$Lenght\ Share = \frac{Non\!-\!vehicular\ Links\ Lenght}{Total\ Street\ Network\ Lenght} \qquad (5.1)$$

According to literature, another path-related parameter profoundly influencing the non-motorized mobility for transport is the verge width. Similarly, the parameter measuring this attribute is the proportion of the non-motorized verge width to the total width of the streets (5.2). This parameter, too, measures the share of non-vehicular paths thought from users' preference viewpoint.

$$Width\ Share = \frac{Non-vehicular\ Links\ width}{Total\ Street\ width} \quad (5.2)$$

Higher values in this parameter represent safer and more preferable walkable/cyclable links.

5.1.3 Land-use Mix Parameters

Another category with a direct effect on non-motorized traffic is the land-use mix. According to the reviewed literature, the more mixed the land-use, the higher the chance of walking or cycling for transport reasons (Gehl 1987; Bradshaw 1988; Pikora et al. 2003). More diverse neighborhoods, because of natural shorter distances, are likely to host higher walking flow. This quality also makes them safer for walking and cycling because non-vehicular flow increases surveillance in the neighborhoods.

Literature bears that higher density is an essential prerequisite for having compact mixed-use developments (Saelens, Sallis, and Frank 2003; Newman and Kenworthy 1989; Hanson and Schwab 1987). Moreover, employment density independently depicts the number of employees for a particular area and diversifies the travel destinations and purposes.

While the Key Category Porosity measures the overall density distribution for global and intermediate scale, the ratio between employment density and total density gives a grade for the level of the land-use mix in a given area (5.3).

$$Mixed - ues\ Share = \frac{Employment\ Density}{Total\ Density} \quad (5.3)$$

It is important to note that higher values for this parameter do not necessarily associate with the more non-motorized flow, but, exhibits a more business-oriented land-use allocation — the lower the value, however, demonstrate residential uses which inevitably produce less transport-oriented walking and cycling.

Another land-use characteristic associated with non-vehicular traffic, mainly walking, is the existence of commercial activities at the street level (Campos 2012; Saelens, Sallis, and Frank 2003). Literature renders that street-level commercial activities attract the non-motorized flow and deliver surveillance. Accordingly, appropriate forms of a neighborhood, in this regard, are compact mixed-use development that host shops on the street level. A Parameter for measuring this quality would be the ratio between the surfaces with window-shops, and the total surface area on the street level (5.4).

$$Surface\ Share = \frac{Surface\ of\ Windowshops}{Total\ Street\ Level\ Surface} \qquad (5.4)$$

Higher values in this parameter indicate the existence of commercial bases, and if the other parameters agree, it can positively affect non-motorized traffic.

5.1.4 Human Comfort Parameters

The proposed model involves two parameters related to human comfort: 1. Street Slope, and 2. Temperature comfort zones.

There are studies about the range of street slopes comfortable for humans to climb (Sun et al. 1996; Hansen, Childress, and Miff 2004). This factor gains importance, especially when the inclusive design is the subject. An inclusive street design would intend to provide comfort for as many people as possible considering different age and handicap conditions. According to literature, this thesis considers the slope ranges fall behind seven percent as comfortable links (ten percent for cycling). However, the model has the flexibility to adjust to the local standards, which might vary from place to place.

The parameter measuring this aspect is the length of the street having a comfortable slope over the total length of the street network (5.5). More than comfort zones, this parameter exhibits a value for effective connectivity for the non-vehicular links.

$$Slope\ Ratio = \frac{Lenght\ of\ the\ Streets\ with\ Less\ than\ 7\%\ Slope}{Total\ Street\ Network\ Lenght} \qquad (5.5)$$

Naturally, the higher values in this parameter associated with level street networks are more convenient for walking and cycling.

Another factor considered in this doctoral thesis for measuring human comfort influencing the choice of transportation mode is the outdoor thermal comfort (Keller et al. 2005; Nikolopoulou and Steemers 2003; Nikolopoulou and Lykoudis 2006; Fallis 2013). Although the climate is the same in a given context, specific design solutions, and the right choices of available technology could help to mitigate. The constructed parameter for this aspect would be the proportion of the length of comfortable links, in specific periods of the year, over the total length of the street network (5.6).

$$Thermal\ Comfort\ Ratio = \frac{Lenght\ of\ the\ Comfortable\ Streets}{Total\ Street\ Network\ Lenght} \quad (5.6)$$

The higher values in these parameters show the comfort potential for the users to walk or cycle.

The next subchapter indicates considerations about the usage of these values and forming the IMM's Proximity model.

5.2 General Properties of IMM's Proximity Model

5.2.1 Modeling Considerations

With having all the values in hand, it is time to decide how they can form IMM's Proximity model. What are the properties of the dataset, data extraction, and processing in this model?

It is vital to express that the model, here, is a set of tools that facilitate the calculation of the numerical system formed from the Proximity values. Therefore, it might refer to one or multiple computer models and the resulting numerical model, in which the latter is created by measuring the parametric values.

The model should provide flexibility to relate to the morphological elements on the one hand numerically, and the performance indicators, on the other hand. For the former, the computer models of the urban area under study with accurate data must exist. For the latter, naturally, there should be enough data on the performance indicators.

The presence of computer modeling platforms with the ability of data processing, like Geographic Information Systems (GIS), is necessary. The final goal, for future research, is to have scientific inquiries into the numerical relations between the structural attributes in their totality with all performance indicators concerned with environmental sustainability. Therefore, the computer modeling system must support automation techniques for collecting enough numerical patterns for a future deep learning model. The computer model(s) must include the following data or their equivalents accurately:

- Location and dimension of the spatial elements
- Residential density
- Employment density
- Typology of streets (motorized, non-motorized, mixed)
- Typology of buildings (residential, services, mixed)
- The length and location of window-shops or the entrance of the commercial units
- The width of the paths
- The length of the paths
- The topography of the site
- Annual temperature data
- Shadow producer elements (buildings, bridges, trees or any other physical elements), their location and dimension
- Shadowed areas

The latter probably needs a third party solar model.

The performance evaluation requires a statistical dataset, including data on:

- Car ownership
- Vehicle Distance Travelled (VDT)
- Public transportation boarding
- Average (or annual) walked distances for transport reasons
- Average (or annual) cycled distances for transport reasons
- Local vehicle-induced air pollution statistics

There is an issue of availability for almost all the indicators mentioned above in many regions. This problem highlights the need for intelligent data-producing systems that are location sensitive. It is also crucial to point out that the purpose of the modeling and the structural properties must drive the data-producing standards, and not the vice versa.

It is crucial to mention that this model is not a closed system whatsoever. As any small modification is any functioning mechanism that can produce a never-ending chain reaction that affects the totality of the CAS, the arrangements of other Key Categories have concealed but influential effects on non-vehicular mobility. Proximity, too, affects the rest of the structure in the same way. Therefore, other Key Categories should be quantified with the same standard and one must relate the totality of structure with the totality of performance. Then, we will access to a powerful tool in which instead of interpreting through the dismantled elements, one might read the structure directly. This view would revolutionize design the same way. Designers would objectively design and modify the structure, and the urban elements would be only the physical manifestation of the process.

Modeling all the IMM's Key Category is a protracted inquiry which belongs to future research works. The next chapters include the application of the Proximity model on a case study to confirm the viability of the model. The case study adaptation would be the first step of an extended journey.

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CHAPTER 6

6.1 Informal Settlements: An Introduction

6.1.1 Why Informal Settlements

There is immense diversity in urban contexts all around the world. This diversity has various reasons such as culture, size, population, political situations, economy, existing infrastructure, climate, and developing features. However, one could roughly imagine two main categories that include all the urban areas: formal and informal.

Formal settlements contain almost all the areas formed by the established concepts and known boundaries of urban design and planning. These contexts are neighborhoods, zones, and sometimes whole towns in which groups of planers have decided about their complete existence and qualities ahead of their physical emergence. They are products of systematic development mechanisms that mostly formed around existing cores and segments.

Formal settlements are the stages of the theories, practices, movements, management paradigms and methodologies of urban studies. There are blueprints for their construction and standards for reading them, measuring their properties, and gathering data about them. Their formality comes from a collective acknowledgment of their whole lifecycle and also their role in the development course and the formal economy.

When it comes to the environmental issues of the built environment, usually, formal settlements are the subjects. Pieces of the built environment, whether sprawling or dense, come together in the analysis and plans while a rapidly growing portion of urban contexts is being neglected (Riley et al. 2007).

Informal settlements make the mentioned neglected part, which is typically absent in the predictions, calculations, and public plans. Today, nearly one billion of the world’s population live in informal settlements, which accounts for one in eight people worldwide (The World Bank 2018, 2017). Although particular attempts prevented partially prevented their formation and decreased their current share of the population by 9 percent, slums seem to grow immensely in the future (UN-HABITAT 2016; Pope 2015). Authorities expect that by 2050 around 70 percent of the whole urban population of the world will live different forms of shantytowns (United Nations 2018).

Informal settlements account for a considerable set of issues today, and the foreseen future and the predicted figures reveal the increasing severity of these problems for tomorrow. Thus, studying such contexts and gaining familiarity with the slum world should be a priority for the scientific community. Only with enough knowledge, the world can prevent the adverse consequences of slum growth and manage their associated problems.

Shantytowns, on the other hand, are peculiar urban systems having much to offer. Since they do not follow the strict regulations of urban design and do not pass long processes of planning, they are fundamentally different from the formal urban contexts in many ways. They are usually associated with very high density and low-cost constructions. For economic reasons, they hardly contain extra spaces or additional elements. Consequently, one might consider their morphologies and dynamism as organic-like systems arisen chiefly from the collective necessities.

Furthermore, compared to formal settlements, slums have much better environmental performances (Smedley 2013). Extreme population and minimum land and energy consumption, which are the bases of their existence, drive multiple factors through which informal settlements considerably rank higher than formal ones in environmental friendliness.

These features make the informal settlements to hold valuable lessons for the future development of the built environment. Today we are facing many conflicts regarding our development manners, and these conflicts are going to be much severe for tomorrow. So, we must embrace any lesson that can enlighten us even if these lessons come from seemingly unusual sources.

For these reasons, and some further discussed motivations, this doctoral dissertation selects Rocinha, the biggest single favela in Brazil, as its study case.

6.1.2 The general characteristics and challenges of the informal settlements

According to the official definition, slums are human communities dwelling in an urban area which lacks one or more of the following features (UN-HABITAT 2007):

- Durable housing that protects the inhabitants from local climate
- Enough space for people in leaving units
- Access to affordable and clean water
- Satisfactory access to health supports
- Security against forced eviction

Depended on the economy, culture, size, population, climate, geographical features, and the characteristics of the surrounding formal settlements, shantytowns might vary. The population inside them are also very diverse. However, most of the informal settlements share many of the following (Marx, Stoker, and Suri 2013; Seabrook 2008):

- Unplanned development
- Immense population densities
- Lack of necessary urban infrastructures
- Poorly engineered housing
- Lack of waste and water management
- Low incomes
- High crime rates
- Lack of sanitation and health services

The characteristics mentioned above usually form a system of problems that leads to inexplicable and high grades of physical, public, and authoritative miscommunications. While most of the slums are surrounded by the formal city, or at least see them in their vicinity, they consistently suffer from low levels of accessibility. Moreover, authorities mostly regard these contexts as a problem to be solved, even with harsh manners (Associated Press 2011; Egypt Today 2018). The citizens, too, regard the slum communities with hard misperceptions; hence there is a minimum social blending between the informal and the surrounding formal contexts. Such a situation is a complex issue with multiple reinforcing feedbacks that add to the level of miscommunication daily.

Informal settlements exist in both developed and developing countries. However, in reaction to the urbanization rate, they grow more rapidly in the developed ones. Given the official predictions about their unbalanced weight in the future of cities, science, too, cannot afford to neglect them. An objective understanding of the informal settlements can prevent many issues in cities and also inside the local boundaries of the slums which will host the majority of the urban population soon.

The next chapter, as the last chapter of the present doctoral dissertation, indicates a systemic study on Rocinha with the approach of the Integrated Modification Methodology that tests and verifies the IMM's Proximity model presented here.

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CHAPTER 7

Measurement and Evaluation: Case Study Adaptation

7.1 PolimiparaRocinha: An Introduction

7.1.1 Rocinha: A City within a City

Acknowledging the particularities in all aspects of its characteristic, there is no hesitation that Rocinha is an urban settlement far from being ordinary. Its placement in the heart of Rio, yet its practical isolation from it, the semi-independent functional distribution within its boundary, its durable community-oriented social fabric, its informal organic-like morphology that accommodates an astonishing population density and the bewildering energy consumption statistic associated with it draw a complex system of multidimensional urban organisms linked to each other in a profound and occasionally paradoxical style producing a wide variation of situations. Studying such a context demands a synthesis-based approach capable of addressing its profound systemic interconnectedness and occult qualities which are the source of both strengths and weaknesses in Rocinha's performance. The interdisciplinary framework of these projects, too, should be structured around an operative holistic methodology used as the departure and reference point for all the defined projects in different realms and areas.

In general, IMM consist of analysis, assumption, modification, and retrofitting phases forming an iterative nonlinear process to develop an urban/architectural project from an investigation in the actual situation and master planning to the prediction of the performances of the proposed design. The underlying theoretical assumption in IMM is the recognition of the built environment as a Complex Adaptive System (CAS). In that regard, the city is not a mere aggregation of buildings and roads but a convoluted organization of physical and functional features in which everything is profoundly related to everything else. Naturally, the collective behavior of a CAS is different from the sum of the individual elements making it. Any local alternation in one single element produces a chain reaction that involves many other parts and ultimately changes the global circumstances of the entire system in different periods. IMM uses this very quality of the complex systems to modify the behavior of the whole with local intervention scenarios. To be consistent with the nature of the CAS, IMM adopts holistic, multilayer, and multiscale manners of study as its main elements of the approach.

The goal of IMM is to enhance the performance of an urban system concerning the local situation. With this approach, each system, absolutely unique in its organization, is comparable only with itself and the systems within itself. Hence, the most fundamental prerequisite for working on a system is to gain a comprehensive understanding of its uniqueness in form and function. Accordingly, the central intention of IMM is to unfold the systemic arrangement of the built environment form, in which all the structural attributes, functional characteristics, and performing patterns are originated. Once such understanding is gained, the rest is just a matter of learning to play with the local system's rules. Based on morphological and functional arrangements, IMM schemes a local system mapping used both to investigate the actual base and predict future scenarios.

In PolimiparaRocinha, too, as an IMM-centric project, the mentioned system mapping is the ground for the analysis and scenario developments. Here, morphology is taken as the substructure that shapes the mobility and functional distribution and consequently influences the economy, social relations, and energy consumption patterns. Apart from morphology, PolimiparaRocinha encompasses various dimensions, each of them framing a broad work theme: Ecosystem services, waste management, food production, energy, and information technology. However, morphology is the standard hub through which each theme is related to the rest, and the aftermath of all interventions is measured regarding it. In other words, urban morphology is the root and the trunk of the tree, of which the other themes are the branches. A systemic transformation does not destroy the root and trunk but modifies but intends to offer limited custom-made modifications and leave the rest to the adaptation and evolution and mechanism.

Rocinha, being called sometimes "a city within a city," is a rather large system. A large-scale intervention inside it, not only being systemically wrong but is also not possible. IMM uses the chain-reaction quality of the complex systems to modify the global scale through limited local interventions. Therefore, the investigation and analysis have been carried out on a global scale, but with the selection of some smaller areas as the pilot projects, the central interventions were focused on smaller areas.

7.1.2 PolimiparaRocinha: Environmental Performances and Social Inclusion – a project for the Rocinha Favela

By the middle of the current century, the world's population is projected to grow exponentially, becoming one of the major concerns for the built environment all around the world, where the informal settlements are going to grow even faster. This growth will increase the demand for necessary infrastructure, which is lacking in such contexts. In developing countries, the promotion of urban technologies could contribute immensely to sustainable development and population wellbeing, besides creating attractive economic opportunities. Urban technologies could reduce the environmental impact of city development and urbanized slums renovation, creating employment opportunities for locals and economic opportunities of investment. However, deploying this in slums is a complex and challenging task. This text presents a project, based on a multidisciplinary and integrated design methodology for the sustainable regeneration of Rocinha, one of the largest favelas of Rio de Janeiro. The project adopts a systemic approach and fore-sees the deployment of an urban management system (UMS) able to manage and integrate several urban services including sanitation, energy, mobility, waste, food delivery, and growing and the flow of information connected to them, to reduce the environmental impact while improving the quality of life of citizens. Each of these areas required the development of a specific project, that, empowered by the UMS, will allow the circulation of information between citizens, fostering social inclusion and raising awareness on the topic of city's re-source management. This project is a demonstration of how minimal but calculated local modification can produce a considerable global reaction and ultimately change the whole system.

As the urban population of the world is increasing dramatically, it is predicted that by the year 2050, about 70 percent of this population will live in informal settlements. While this is an alarming matter for the policymakers and urban managers around the world to revise and re-plan the development manners, it highlights the importance of studying such organizations for the scientific communities too.

Depending on the local environment, cultural context, size, and contextual relations with the surrounding urban areas, the informal settlements could appear in different kinds. Nonetheless, there are structural features shared between them worldwide. There are innate characteristics like high population densities, inadequate infrastructures, and social segregation associated with them, which make them much challenging to manage, and at the same time, there are also surprising peculiarities, like certain environmental behaviors offered by them to learn from. Working on such human organization can provide valuable opportunities to examine the capacity of today's abilities for managing tomorrow's likely threats on the one hand and unveil the inherent capacities of these integral contexts for efficiency in energy consumption on the other hand.

This text summarizes the morphological studies of the project "PolimiparaRocinha," a 2016 Polisocial winner dedicated to the Favela Rocinha, which is the biggest single favela in Brazil. PolimiparaRocinha is an interdisciplinary project coordinated by DABC and partnered with DICA, DAStU, the Department of Energy, and several academic and non-academic partners outside Politecnico di Milano.

The core methodological tool for the investigation, evaluation, and project definition used in Polimipararocinha is *Integrated Modification Methodology* (IMM). IMM is a procedure encompassing a set of scientific techniques for understanding the systemic structure of the urban settlements and propose modification scenarios to enhance their socio-economic and environmental performances. It has been developed by the IMM Design Lab based in the Department of Architecture, Built Environment and Construction Engineering (DABC) of the Politecnico di Milano. Based on system thinking, the primary purpose of IMM is to introduce modification scenarios for morphologically transform the built environment -in different scales- into ecologically better-performing systems.

In Vertical Investigation, the attributes associated with these relationships are to be mentioned as Key Categories. For the performance of any system is resulted from the relationships between its elements, it is safe to state that Vertical Investigation is the methodological engine of IMM.

Six Key Categories have been investigated in Rocinha: Porosity, Proximity, Diversity, Effectiveness, Accessibility, and Interface.

Porosity: Normally, analyzing porosity in IMM encompasses a certain number of concepts like building coverage, density, and volume distribution concentration factor comparably. However, because the population density in Rocinha is dramatically high, it is almost impossible to carry on a comparative analysis there. Density is the only key player in Rocinha, and by no realistic modification scenario, it could be imagined that this boldness will be abated (Tadi et al. 2017).

Thus, the Porosity investigation in PolimiparaRocinha is a comprehensive study of built-up density, which with consideration of integrity in social characteristics in the whole favela, could be directly interpreted as Population Density too.

In this analysis, the buildings have been categorized concerning their heights. Considering the almost uniform size of the building footprints, the Porosity investigation here shows the distribution of density in an acceptably accurate way. Although there are limited numbers of buildings that are up to eight stories, the highest typical buildings are four-story buildings. This typology is taking peak mostly in the closeness of the western part (because of the metro station) and alongside the da Gávea street. The volume distribution in the rest of favela is following a quasi-random pattern.

Figure 7.1 Porosity Analysis in Rocinha

Proximity: Proximity is the quality of reaching to main urban types of uses employing non-motorized transportation (mainly waking). The central relationship here is the one between functions and volume/voids. Of course, the street network, too, is a key role player. For analyzing Proximity, according to its definition, it is fundamental to define the crucial urban function and to investigate the way that the functions influence non-motorized mobility (Tadi et al. 2015).

Considering the playful topography of Rocinha and the limited number of functions, the catchment areas have been considered as circles with a radius of 150 meters. However, these circles have been modified by the morphological limit. It means that they have been located on the functions, and the footprints of the buildings have been cut from them in a way that they are projected on the voids (obviously, because people cannot walk through the buildings). It is crucial to notice that the proximity analysis shows the actual/potential walking flow.

The proximity of Rocinha is regulated by the location of the metro and da Gávea street, where there are both relatively more functions and enough void spaces. Because of its adequate width and its physical relationship with da Gávea, the walking flow is continued to R. Nova at the center. Occasionally, there are some walkability spots at the southern part where the density is medium, and the spaces between buildings are enough to support local functions. These scattered patterns indicate a certain level of functional independence due to the long distance between these areas and the central kernel of proximity.

Diversity: As the conceptual linkage between open spaces and functions, Diversity is about the characteristics of voids influenced by different functions. In other words, Diversity is the quality of open spaces in giving access to different typologies of functions (Meurs 2007).

For evaluating the Diversity, IMM as a sustainable-oriented methodology targets at clustering the functions based on travel distances between the compatible typology of functions. In this regard, if an urban area offers an optimum functional diversity from a social point of view, there is a high chance that a significant level of daily needs is met in smaller distances, and that helps to avoid unnecessary urban travels.

From a social point of view, there are three categories of urban functions: 1. Necessary Activities; 2. Optional Activities; 3. Social Activities (Olwig, 2016).

Because it is impossible to pinpoint the social activities and for involving the time patterns in urban trips, IMM modifies the mentioned categories as 1. Necessary Regular Activities; 2. Necessary Occasional Activities; 3. Optional Activities.

As it is shown in the diversity analysis of Rocinha, the most diverse parts are again the area near the metro station and da Gávea street.

Figure 3 Diversity in Rocinha

Accessibility: Accessibility is the quality of reaching the main functions via the public transportation system in a certain amount of time. The functional and mobility layers are the boldest urban elements in this Key Category.

Sincerely, Accessibility map illustrates the coverage functions by the public transportation stop. The catchment areas are the same as mentioned in Effectiveness (Manesh and Tadi 2016).

Because of the Rocinha's simple pattern of functional development around the most accessible areas, it is not shocking that the Accessibility analysis is almost the same as the mobility in Horizontal Investigation.

Effectiveness: Mobility and build-ups are the two main building blocks of Effectiveness. As it is readable from its name, this Key Category is about the effectiveness of the public transportation system. Probably the most robust way to carry on such analysis is to study the relationship between population density and public transportation stops. That is to show the density that a stop/station can cover in its walkable catchment areas. According to literature, this catchment area is a circle (projected to open spaces) with a 400 meters radius for bus and tram stops and 800 meters for metro stations (Handy 2005).

Below is the Effectiveness analysis of Rocinha about different mobility modes existing in the favela.

Interface: In IMM, Interface is evaluated through Mean Depth calculation and the Axial Analysis provided by Space Syntax. The axial analysis is a simple iterative computation based on graph theory in which the number of the intersections to reach a particular link is being calculated from all parts of the street networks. In the end, the links that gain lower depth are the ones that are connected to the system with much higher integrity (Hillier and Iida 2005).

$$D = \frac{\sum d.n}{\mathrm{k} - 1}$$

D: Mean Depth; d: Depth; n: number of unit spaces at a specific depth; k: total unit spaces that comprise the system

The Interface analysis vividly illustrates that the street network of Rocinha is providing deficient connectivity and dictating a low quality of internal movement. That is not surprising that the urban flow is quickly interrupted everywhere inside it. Interestingly, the parts with low integrity are where it is preferred by criminal groups to arrange their activities. This situation is mainly due to the limitations caused by topography and the irregular pattern of buildings (which itself is an indirect consequence of topography.

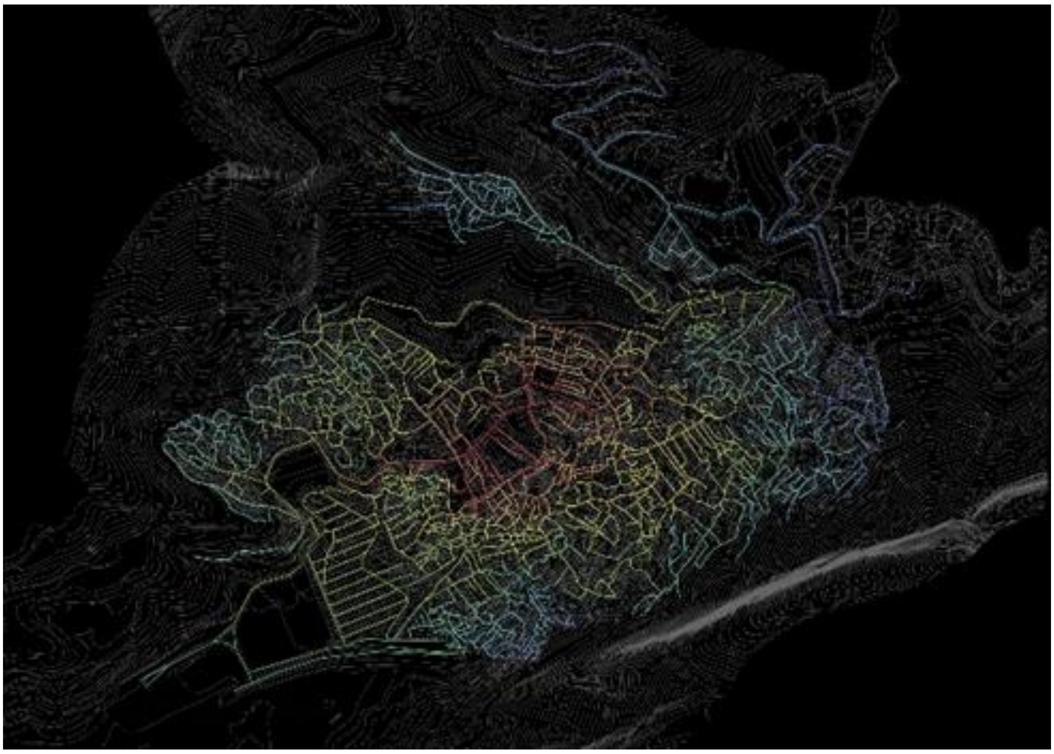

Figure 7.2 Interface Analysis in Rocinha

According to the investigation phase, it is evident that the malfunctioning urban element is the Void layer, and the most problematic Key Category is the Interface. Rocinha is suffering from not having enough empty spaces to provide enough flexibility for urban flow and practical support. On the other hand, the street network is a broken system unable to offer adequate connectivity for smooth movement. However, minor changes can be made to improve the situation and overall functioning manner of the system.

Accordingly, the initial concept is driven by the idea of providing more open spaces, hence, more integrity to the street networks by relocating a small number of low buildings where it is possible and beneficial. A very conceptual change in the Interface analysis supports this idea that with limited local modification, considerable global enhancement can be achieved.

Based on Interface analysis, 21 locations have been identified where the definition of new links resulted from a minimum relocation project could lead to massive global changes in system integration. Accordingly, a total number of 108 small buildings -which in comparison with the whole Rocinha size are safely negligible- were predicted to relocate on top of the nearest buildings possible. This decision was supported by the local partners of the project like Sorriso Dei Miei Bimbi, which is an educational institute inside Rocinha and is in close contact with the local community. However, due to some specific consideration regarding the social fabric of the different zones, it was suggested for the work to be initiated in six specific zones.

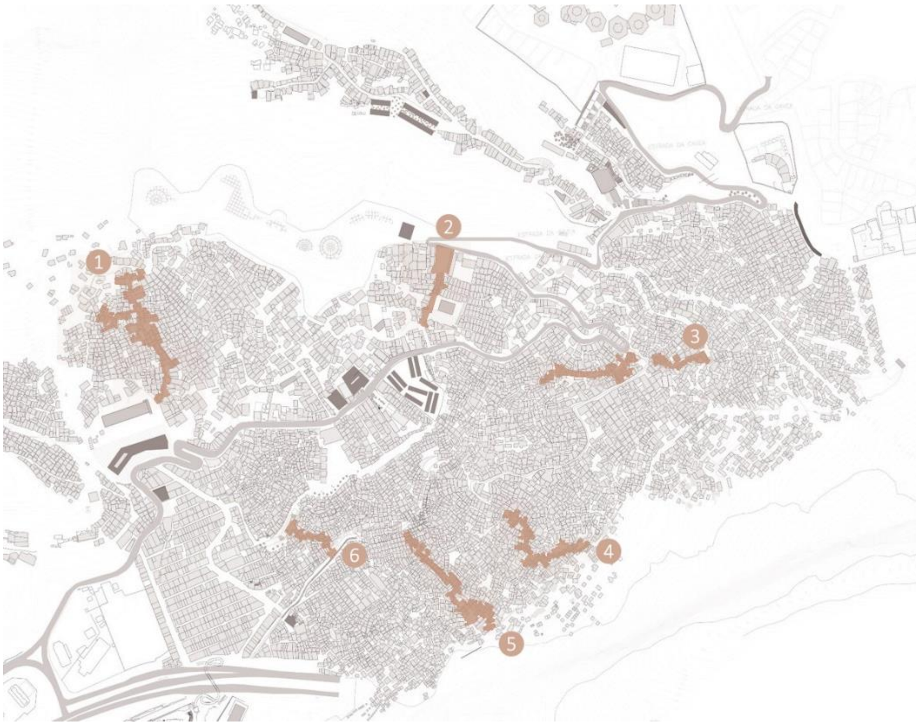

Figure 7.3 Intervention Zones in PolimiparaRocinha

This systemic modification creates optimum morphological flexibility in context for proceeding with the project themes. The immediate consequence is to have a better mobility flow that not only makes the area safer but also allowed to define a local-based bicycle network supported by bike-sharing systems that work in the compatibility of the existing public transportation system. In some of the new spaces defined by the relocation project community, gardening and aquaponic will be located to raise awareness on the value of the local food production. These projects are in integrity with the ecosystem service to ensure the management of runoff and water conservation and definition of a smart energy grid for harvesting and to manage the renewable sources for energy production and management. Local strategies to use organic waste for producing biogas are also considered, and new waste management plans compatible with local programs are proposed.

It is crucial to address the totality of the structure made by the local projects in the selected zones. These six zones are the locations that local strategies like the aquaponics, photovoltaic panels, community gardening, swage system are placed together and create an integrated system of prototype network in the whole Rocinha. This system has been designed in a way to ensure two levels of circularities in two different scales. They make a close system that their inflow is provided locally. The food production is using the local resources, the solar radiation is harvested on top of the local buildings, and the proposed functions are compatible with the local needs. However, they are linked together all over the favela with the smart grid-centered by an Urban Management System (UMS). As the proposed improvements require the development of a specific project, that, empowered by the UMS, it allows the circulation of information between citizens, that become the main actors of the whole system, promoting social inclusion and sustainable regeneration of the favela. The UMS as a system of computer-aided tools will monitor, control, and optimize the information flows coming from the different sectors improving services for citizens as street lighting, electrical local urban transportation, food delivery, waste management, goods delivery. In this way, the UMS can, for example, reduce traffic in congested areas, encourage the use of more efficient and ecological transport systems, prevent the frequent blackouts as well as establish citizens virtuous behavior in terms of waste collection, energy savings.

In the Rocinha scale, this system creates a balance between inflow and outflow by allocating the local resources to the overall outflow. Moreover, thanks to the prototypes, a new bicycle network has been designed and connect the intervention zones and other places (where the topography allows) physically. It means that local resources provide global energy storage, public lighting, and overall connectivity. This integrity in the prototype network allows moving from 21 critical locations to be improved to only six intervention zones without sacrificing the totality of the favela scale. Nevertheless, the prototype network provides the capacity of integration with more intervention zones applying the same strategies in the future.

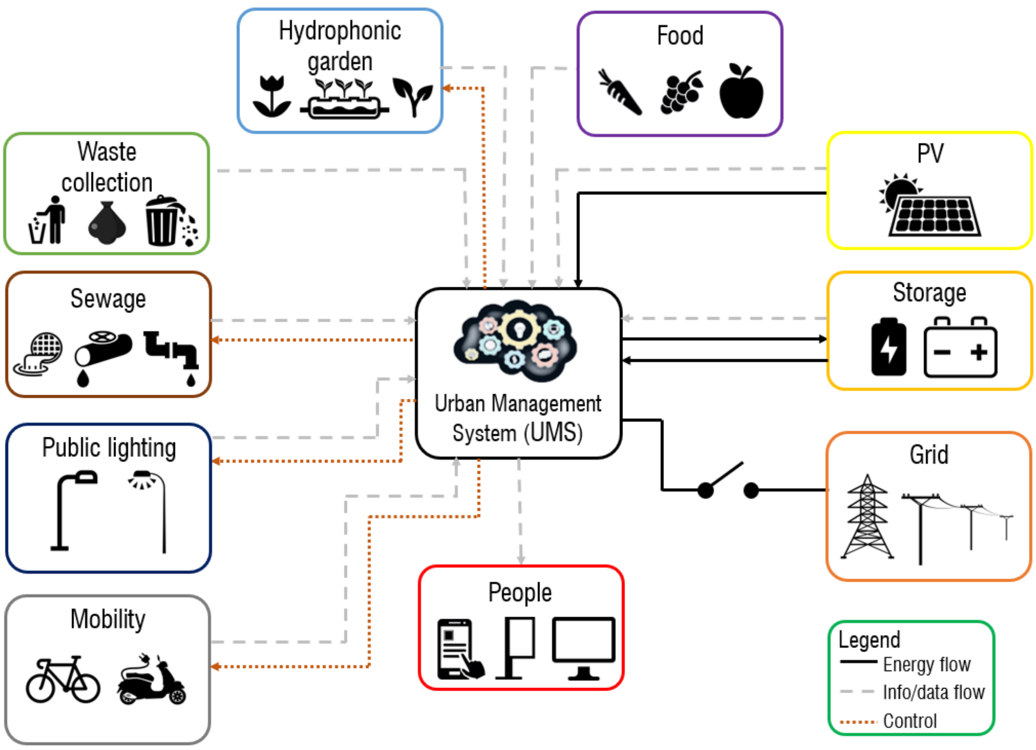

Figure 7.3 Urban Management system Proposed in PolimparaRocinha

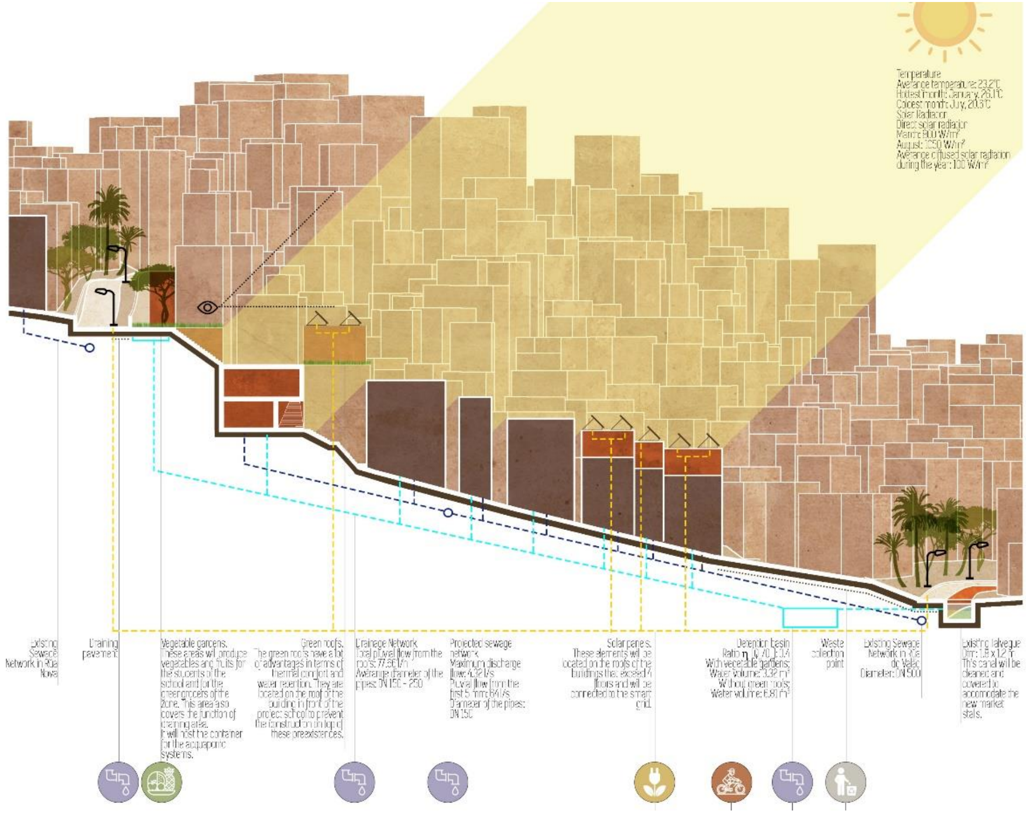

Figure 7.4 Local Intervention by PolimiParaRocinha

As it was explained before, the relocation project would enable the other sub-projects to proceed and create maximum unity between them in different scales. Besides creating new urban spaces and connections in local zones, which immediately leads to having a smoothen urban flow and more safety, it raises the ranks of other links all over the Rocinha more integrated. The retrofitting phase clearly showed advancement in numbers. The modification process in this project that size the urban mechanisms quantitatively contributed to revealing the hidden links between the structure and performance, which is naturally measured by different indicators. Such an approach not only helped in pinpointing the critical issues in Favela Rocinha and making appropriate decisions but also provided a new diagnosis system that is measurable, objective, and performance-oriented.

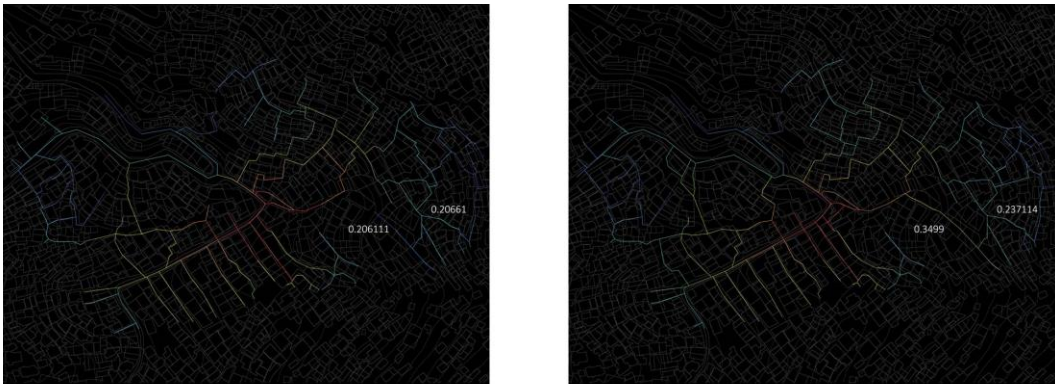

Figure 7.5 Local Interface of an Intervention Zone Before (left) and After (right) of the Morphological Modification

PolimiparaRocinha is a clear demonstration of how systemic local actions integrated with the whole can produce controlled chain reactions to modify the favela scale. The proposed sub-projects not only will powerfully change the different aspects of urban life in the intervention zone for the better but also makes tangible improvements in the performance of the whole Rocinha even where the project does not touch. The procedure of interventions proposed by PolimiparaRocinha can be easily replicated to the other parts of the Favela and create a high level of integrity, which advances the quality of life and the environmental performances (Arcidiacono et al. 2017).

The investigation phase highlights the structural blockage in urban flow due to the morphological pattern of Rocinha. Although there were 21 locations in which the morphological modification could create a systemic reaction in favela scale, an integrated prototype network allowed that the intervention is applied in only 6 location and activate the same systemic reaction. The UMS designed to control the flow of energy and information is locally based and can include future intervention in Rocinha and integrate them with the whole favela system.

Today, we are facing difficult unprecedented challenges like climate and socioeconomic inequity that puts our sustainable future in doubt. As most of the problems we are have their roots in cities, sustainability becomes a civil matter. While there should be a collective will to minimize the urban marginalization in future developments, the current problems of these areas should be addressed, and effective methods to improve the quality of life in them should be studied. There are indeed favorable traits in the structure of the informal settlements, especially inadequate energy consumption that could be learned from.

This project is not the first study proposed to deal with the favela Rocinha or, in general, the informal settlements. In most of them, the informal settlements are regarded as a problem to be solved, and the efforts were directed to formalize them or to eliminate them from the face of the cities. No surprise that they could not relate to the local communities and, in result, produced more conflicts and segregation. In Contrast, PolimiparaRocinha is regarding Rocinha as part of the city and a source of opportunity in which with local-based, minimal and systemic modifications, can perform better and make much integration with the rest of the city.

7.2.1 Proximity in Favela Rocinha

Although specific functions are always considered as essentials, there is no universal list for the vital urban functions. Concerning geographic situation, quality of life, local issues, cultural and economic aspects, size of the city, and many other factors essential functions differ city by city (or even neighborhood by neighborhood). Hence, in IMM, critical types of uses are considered as contextual elements.

Here in Rocinha, the key functions have been selected as:

- Police
- Banks/ATM Points
- Post Office
- Health Services (including pharmacies)
- Education Services
- Sport Services
- Waste Collection
- Shopping
- Food Markets
- Restaurants/Bars
- Parks

There are numerous researches on the ways that functional distribution determines non-motorized movements. Some studies suggest that relative to the number of functions in a specific area, people tend to walk within 100 to 400 meters (the more significant number of functions the higher radius of the walking distance). Of course, the waking catchment is also strongly related to the topography and the street network integrity too. Moreover, it is verified that people tend to walk more where the number of window-shops at the street level is higher than in other places.

Considering the playful topography of Rocinha and the limited number of functions, the catchment areas have been considered as circles with a radius of 150 meters. However, these circles have been modified by the morphological limit. It means that they have been located on the functions, and the footprints of the buildings have been cut from them in a way that they are projected on the voids (obviously, because people cannot walk through the buildings). It is vital to notice that the proximity analysis shows the actual/potential walking flow.

Not surprisingly, the proximity of Rocinha is regulated by the location of the metro and da Gávea street, where there are both relatively more functions and enough void spaces. Because of its adequate width and its physical relationship with da Gávea, the walking flow is continued to R. Nova at the center. Occasionally, there are some walkability spots at the southern part where the density is medium, and the spaces between buildings are enough to support local functions. These scattered patterns indicate a certain level of functional independence due to the long distance between these areas and the central kernel of proximity (figure 7.6).

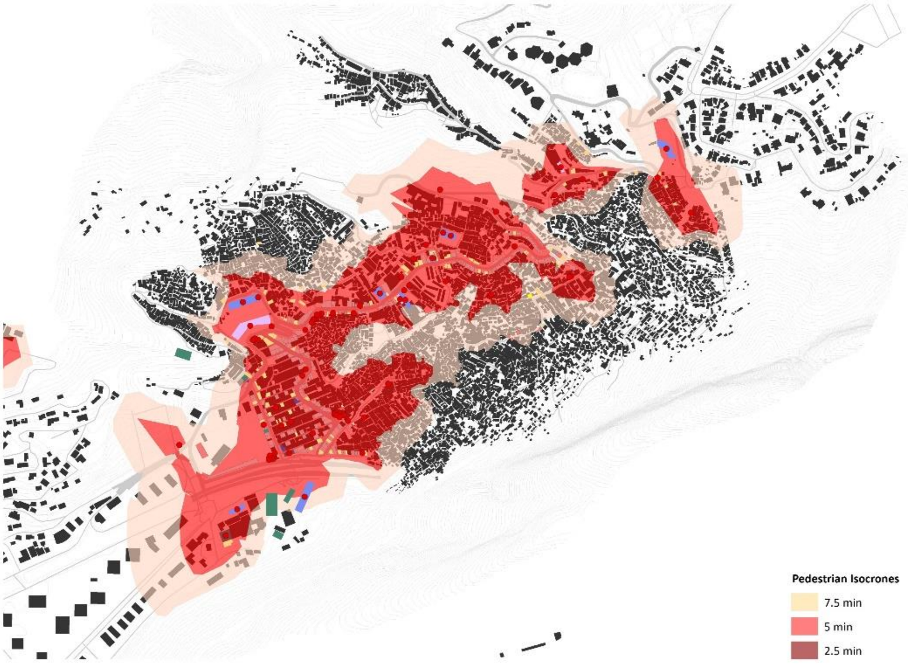

Figure 7.6 The Proximity Analysis in PolimiparaRocinha (source: PolimiparaRpcinha)

For measuring the proximity, in the structure of the model that this thesis proposes, the GIS model of the project PolimiparaRocinha has been used. For increasing the resolution and giving the sense of proximity in a neighborhood scale, which walking and cycling is more likelier to happen, three zones, out of the six of the project, has been selected. The primary criterion for selecting the zones was that they benefited from about the same score in the overall connectivity; hence, the central reference was the Interface analysis, and the zones 1, 2, and 6 have been selected.

The GIS models lack the accuracy of differentiating the functions from the street level from the other types of spatial allocation, therefore in the parameter Surface Share instead of the proportion of window-shop surfaces to the total surface, the total number of commercial uses over the total number of buildings in a zone has been considered. This parameter is named Functional Share here and is expected to correlate with the Surface Share.

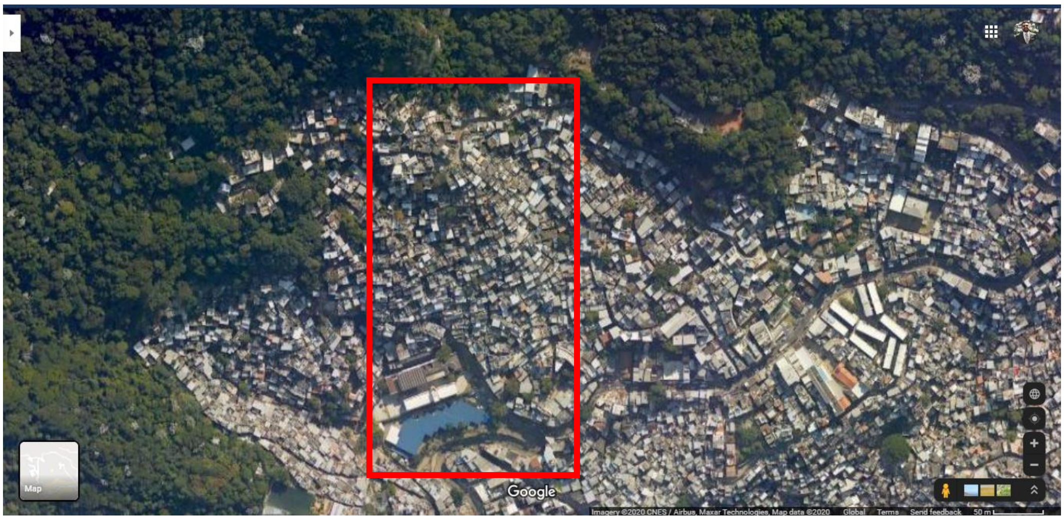

Figure 7.7 Sattelite view of Zone 1 of PolimiparaRocinha (GoogleMaps)

Figure 7.8 Zone 1 existing situation (source: PolimiparaRocina)

Figure 7.9 Sattelite view of Zone 2 of PolimiparaRocinha (GoogleMaps)

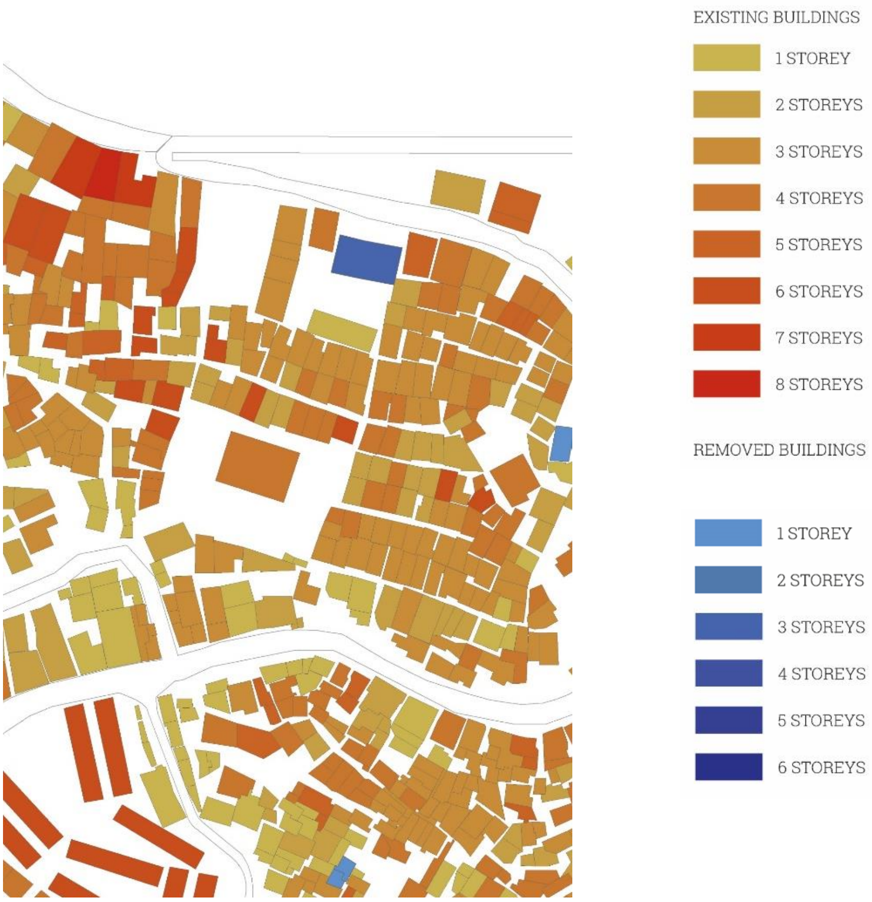

Figure 7.10 Zone 2 existing situation (source: PolimiparaRocina)

Figure 7.11 Sattelite view of Zone 6 of PolimiparaRocinha (GoogleMaps)

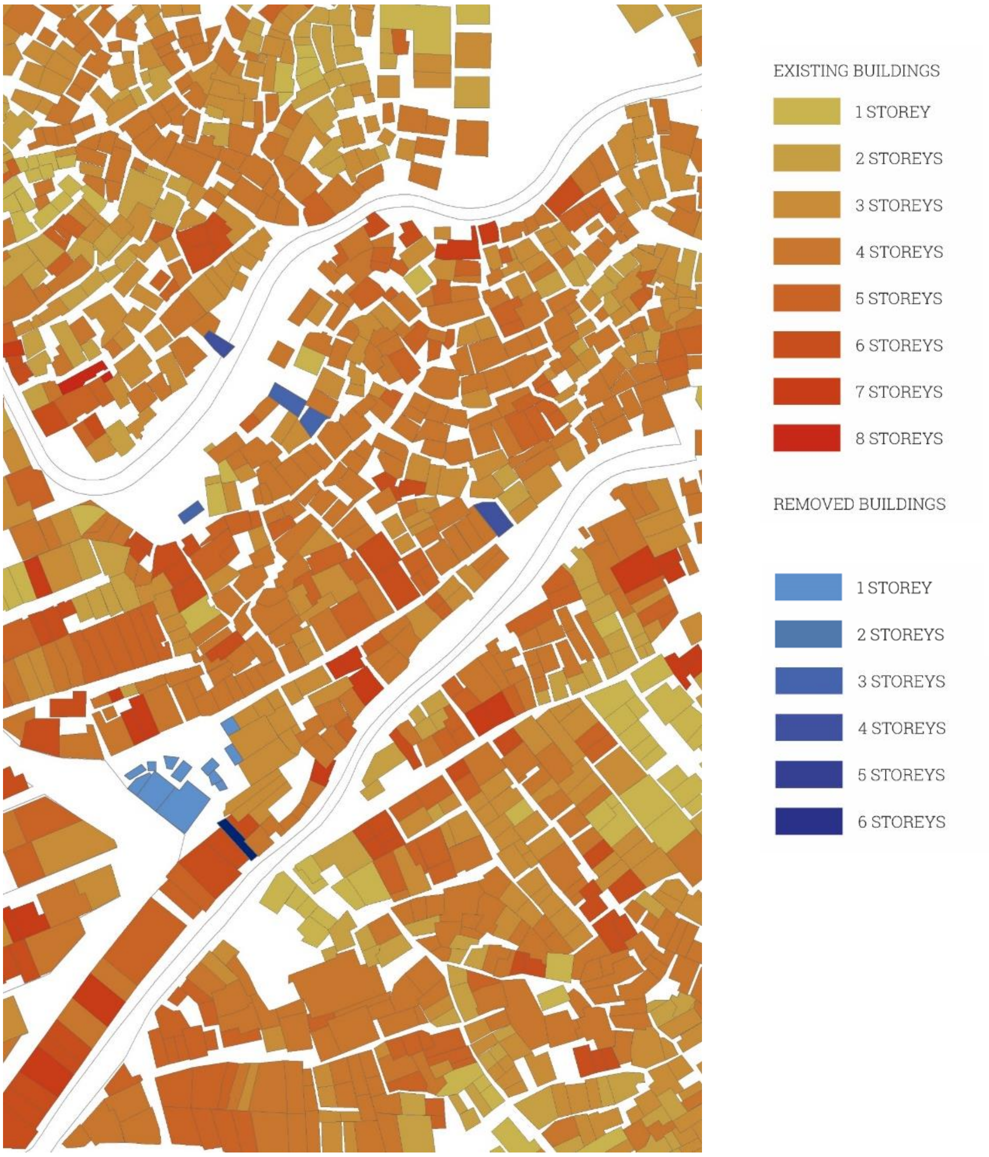

Figure 7.12 Zone 6 existing situation (source: PolimiparaRocina)

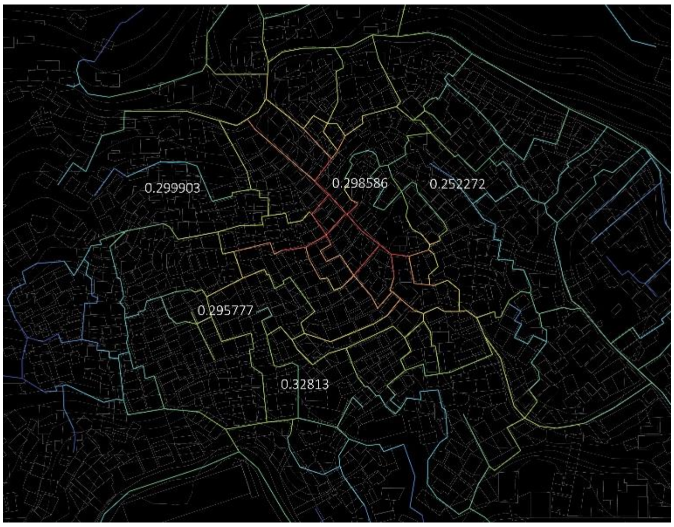

Figure 7.13 Interface Analysis of Zone 1, Average Value: 0.32 (source: PolimiparaRocinha)

Figure 7.14 Interface Analysis of Zone 2, Average Value: 0.58 (source: PolimiparaRocinha)

Figure 4 Interface Analysis of Zone 6, Average Value: 0.32 (source: PolimiparaRocinha)

Moreover, The GIS model does not endure the data separate the walkable paths from the motorized street (as in Rocinha, hardly these two are separated). Therefore, instead of the parameter With Share, the parameter Void Ratio has been used here, which is the ratio of the open areas to the total area.

For measuring the thermal comfort zones, a microclimate model for each zone has been built using the software Envi-met fed by the GIS model. Unfortunately, the scale allowed in the free version was too small to provide an accurate analysis. Moreover, the data on typology and location of trees, and the properties of path finishings, which is very influential in such analysis did not exist. Therefore, the value of the thermal comfort zone was omitted from the model.

The table below indicates the final measurements of the Proximity Model. Appendixes 1 to 4 bears datasets.

Table 7.1 The Values of The Proximity Model Before and After the Interventions by PolimiparaRocinha

	Actual State			PolimiparaRocinha		
	Zone 1	Zone 2	Zone 6	Zone 1	Zone 2	Zone 6
Length Share	0.75	1	0.74	0.82	1	0.84
Void Ratio	0.43	0.33	0.43	0.45	0.32	0.46
Mixed-use Share	0.1	0.09	0.11	0.09	0.12	0.28
Functional share	0.4	0.37	0.69	0.3	0.48	0.16
Slope Ratio	0.16	0.35	0.51	0.16	0.35	0.51

For regulating the proportions, the Mixed-use share and Functional Share has been calculated per ten inhabitants and ten buildings, respectively.

As the table and figure 7.16 indicate, all the zones have high values of length share. While zones 1 and 6 have rank almost equally, zone 2 benefits for its semi-greed arrangement from maximum grade in this regard. No street there prevents vehicular movement, and the interface analysis shows that the street network in this zone is more integrated concerning the other two. This zone, however, has the lowest rank of void ratio. Zone 6 seems to host more types of uses as it ranks very high in functional share, and its mixed-use share is also higher than zone 2. Zone 1, one the other hand, suffers from the lowest value in these regards. Its distance from Gavea, the artery of urban service around which the non-residential types of uses are distributed is a significant factor here. This zone is also the least comfortable in terms of topography. More than half of the paths in zone 6 are comfortable enough to climb and make this zone to have the best situation among the three.

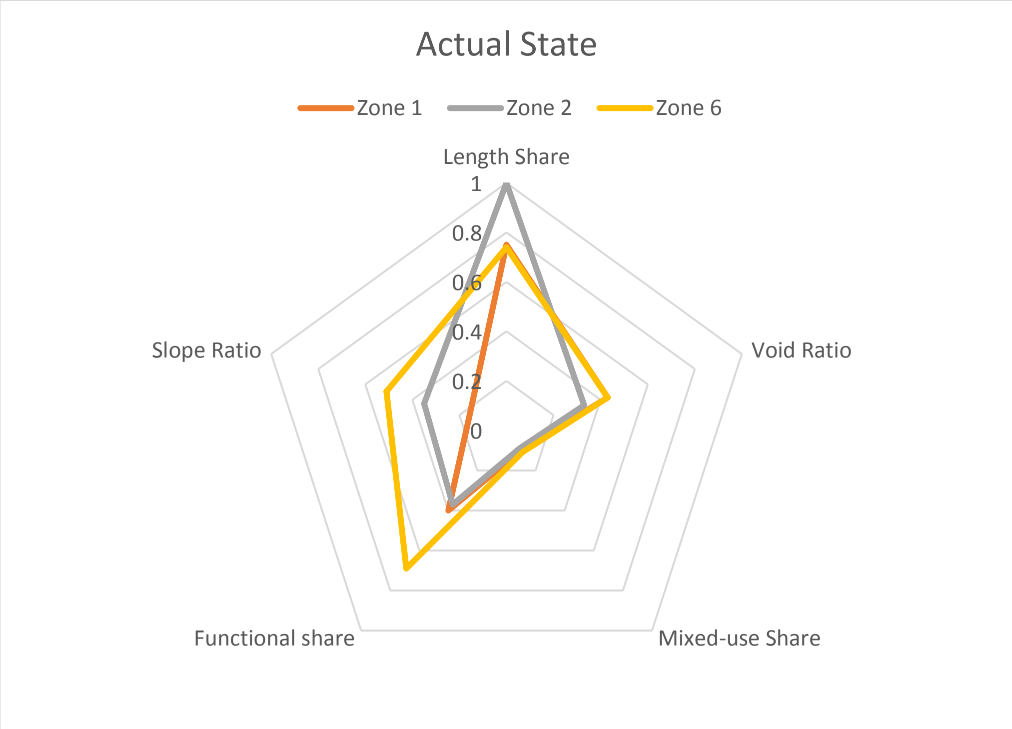

Figure 7.16 The Proximity Model for Zones 1, 2, and 3 in the Actual State

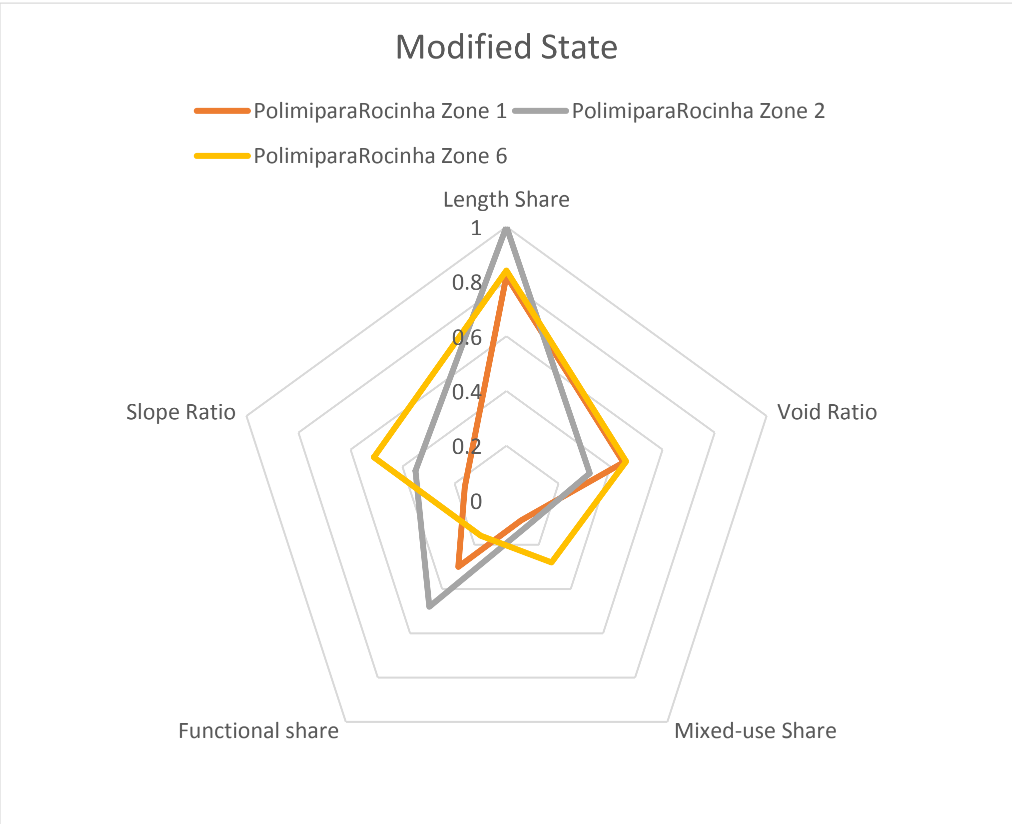

Figure 7.17 The Proximity Model for Zones 1, 2, and 3 in the Modified State

The master plans proposed by PolimiparaRocinha are based on the relocation of critical buildings (evident in figures 7.8, 7.10, and 7,12) for creating more connectivity in the street network. The produced spaces were also used to arrange functioning mechanisms and sometimes host some non-residential types of uses.

The main achievements in the states of the projects are increasing the length shares of the zones 1 and 6 and adding more services in zones 1 and 2. In this regard zone, two benefited more than zone one, naturally because of its higher capacity. The added types of uses in zone 6, seemingly, are not added to the GIS model, so the database shows a false decrease in functional share while its mixed-use level has increased.

Although the morphological capacity did not allow much intervention in voids, and the projects did not change the topography of the zones, the small changes introduced in PolimiparaRocinha slightly modified the structural pattern. Although predicting the performance of the project is not possible yet, the behavior of the actual situation is measurable, and the performance can be associated with the structural configurations.

7.2.2 Verification Methodology

The verification for the proximity model involves measuring the number of people walking in the zones as to associate each model to the performance. There are alternatives considered for verifying the model.

- Processing the telecommunications data
- Processing sensor data
- Manually counting

Also, there are four objectives for evaluating the best alternative:

- Availability
- Reliability
- Large data sizes
- Social acceptance

In this regard, the best possible alternative would be processing the telecommunications data. However, this data is not available for the author. The second option is ruled out because of its low score in social acceptance. Thus, manual counting is chosen as the verification methodology.

The criteria for conducting the verification processes is to select the street with the highest axial depth (hence higher integration and connectivity) for each zone and proceed with documenting the people walking and cycling in a specific time range and weather.

These paths are:

1. A nameless corridor parallel to Via Cachopa in zone one;
2. Travessa Galileia in zone two;
3. Continuation of R. Nova and in Zone 6

After the favorable streets have been selected, the local partner of the PolimiparaRocinha, who helped in manual counting, stated that due to criminal activities, these streets are not safe enough to collect the data. Therefore, alternative streets selected and filmed as the following (figure 7.18):

1. Rua Dioneia in Zone 1
2. Estrada da Gavea segment in Zone 2
3. Travessa Roma in Zone 6

Figure 7.18 The location of filming for verification (GoogleMaps)

Table 7.2 summarizes the data gathered in these videos. Full videos are available at the links that the appendix 5 contains.

Table 7.2 Verification data gathered by the videos

Zone	Date and Time	Video Lenght	Vehicle allowed	Pedestrian passed	Vehicle Passed	Pedestrian per min	Vehicle per min
1	13.12.19 11:38	8:15	yes	22	44	2.67	5.33
2	17.12.19 14:00	5:54	yes	61	161	10.34	27.29
6	14.12.19 14:25	5:07	filtered	59	2	11.52	0.39

The result shows that the zone 6 performs the best among the three as zone 1 ranks the lowest. The proximity model indicates that although area 6 does not have the highest length share, but has many other advantages like most comfortable paths, acceptable functional distribution, and mixed-density. Its filtered permeability that only allows motorcycles creates a pedestrian-friendly environment. Zone 1, on the other hand, lacks in mixed-use development and service support while its paths have the lowest grade of comfort. Therefore, it provides a vehicle-depended environment where no bikes and only a limited number of pedestrians, probably all residents, pass by. Zone 2 also holds an acceptable amount of pedestrian movement. As the verification takes place in Gavea, the beating heart of Rocinha, this result is not surprising. However, as Gavea is also open to vehicles, the result shows many more cars than pedestrians and bikers. Compared to Travessa Roma in zone 6 in which the shops are smaller and much less, still, Gavea performs in a lower rank. It is worthy of mentioning that Travessa Roma was filmed on a Saturday while the verification for the other two takes place on working days. Therefore, one might expect that zone 6 performs even better than the verification shows.

7.2.3 Conclusion

The case of Rocinha confirms that the functioning mechanism of a complex system like urban areas can be explained in terms of measurable structural attributes. Accurately selected parameters form different patterns that can make the system's functioning readable. Therefore, instead of studying the system through its elements, we can develop an accurate enough understanding of the relationships between the parts.

If we extend this view to all the known structural attributes and gather enough data on performance indicators, finally, we can associate the totality of structure to the entirety of the performance.

This notion can revolutionize our knowledge of the cities, both in building them and analyzing them. For the whole history, the components of this system were the only tools for design and study. Neglecting the complexity of the system, the human mind always modified the elements and was surprised by the result and side effects. The present study reveals that we can directly read the association of performance with the structure, and the elements can be considered only as of the physical manifestations of structure. In the presented view, items are the last pieces of the puzzle, not the firsts.

Today, we are in a mischievous state, which is an inevitable result of our misguided view towards the built environment and its development. We face alarming consequences of our actions as the performance of the built environment is one of the primary sources of environmental issues. All the experts agree upon the urgency of the situation, and it seems that we have no choice except to shift our paradigm.

Now we have the UN Agenda 2030 and the Sustainable Development Goals before us. Although these agendas direct out attention to the necessity of change, if we do not approach it holistically, we will naturally produce the same results. More than the goal itself, it is crucial how to address it.

The present dissertation took a specific quality of the urban systems, which the Agenda 2030 indicated in Goal 11, and showed that a systemic view could develop our understanding of the system that we want to change, hence, increase the probability of success. Such an approach can bridge between the targets and performance indicators of the SDGs and, in result, deliver valid methodological interpretations of the Agenda.

For stepping towards sustainability, we need more scientific works and financial investment in this regard. As Banki-Moon, the former secretary-general of the United Nations, stated once, “there is no plan B because there is no Planet B.”

This Ph.D. Thesis provided a systemic base for measuring walkability for transportation. Non-vehicular mobility is a structural configuration that -alongside other structural configuration- produces specific performing patterns. This work- at least in its aspirational layer- is the first step of our in our inevitable path towards reading the urban performance through the complexity of its structure. The logic behind the work was to pinpoint the structural attributes profoundly influencing the choice of non-vehicular transportation and correlate them directly to the performance indicators.

For the inescapable complexity of the urban systems, it will not be right to claim that attributes related to walkability only influence the performing measures related to their own nature. Therefore, for having a complete picture, other attributes should be identified and worked on in an integrated context.

As another future suggestion, it seems that we need to have an organized, comprehensive, and goal-oriented system of performance indicators. Most of the current indicators are the results of the sectorial approach to different issues. Hence, the indicator system that we deal with now is merely cut pieces of different scientific works glued together and form a Frankenstein-like list. A goal-oriented indicator system requires in-depth studies of the urban behavior in its totality and the systemic connection of the behavioral attributes. For reaching that, the data gathering and accessibility to data should be revolutionized too.

After having the structural and behavioral system ready, the main work would be to find the proper means to study their correlations. This dissertation suggested a Neural Network platform; however, other deep-learning computing methods might suit the purpose.

In the end, the author feels the moral obligation to state that although the scientific works might be the engines for changing tomorrow, they will lead nowhere if we continue the same economic and political paradigms that we practiced so far. What we need for a better future, is a firm and global will to reconsider our economic development methods and dedicated policies to support that. Only them, science will be a tool.

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Appendix 1

Datasheet of the building in Rocinha Zones 1, 2, and 6

FID	Number_Area	Floors	Area	Altezza	Volume
0	6	2 Floors (6m)	18.346567	6	110.079403
1	6	5 Floors (15m)	18.165756	15	272.486346
2	6	2 Floors (6m)	26.063003	6	156.378018
3	6	2 Floors (6m)	12.049049	6	72.294292
4	6	6 Floors (18m)	23.597315	18	424.751678
5	6	2 Floors (6m)	59.12251	6	354.735059
6	6	4 Floors (12m)	61.49516	12	737.941921
7	6	5 Floors (15m)	48.404776	15	726.071644
8	6	4 Floors (12m)	28.793359	12	345.520313
9	6	4 Floors (12m)	6.55843	12	78.70116
10	6	4 Floors (12m)	33.959102	12	407.509218
11	6	3 Foors (9m)	33.800595	9	304.205358
12	6	2 Floors (6m)	40.735281	6	244.411688
13	6	4 Floors (12m)	34.960522	12	419.526268
14	6	3 Foors (9m)	27.736391	9	249.627517
15	6	7 Floors(21m)	45.136311	21	947.862538
16	6	7 Floors(21m)	30.866144	21	648.189017
17	6	4 Floors (12m)	63.572039	12	762.864473
18	6	4 Floors (12m)	4.859414	12	58.312969
19	6	4 Floors (12m)	38.990001	12	467.880013
20	6	4 Floors (12m)	9.847782	12	118.173381
21	6	4 Floors (12m)	17.604724	12	211.256691
22	6	5 Floors (15m)	35.266285	15	528.994275
23	6	5 Floors (15m)	55.843825	15	837.657379
24	6	4 Floors (12m)	35.915769	12	430.989224
25	6	2 Floors (6m)	52.112951	6	312.677707
26	6	4 Floors (12m)	92.102978	12	1105.235731
27	6	3 Foors (9m)	34.401118	9	309.610059
28	6	2 Floors (6m)	24.876645	6	149.259872
29	6	4 Floors (12m)	20.913826	12	250.965907
30	6	4 Floors (12m)	36.94149	12	443.297878
31	6	4 Floors (12m)	27.419843	12	329.038111
32	6	4 Floors (12m)	68.379266	12	820.551194
33	6	5 Floors (15m)	34.67094	15	520.064097
34	6	6 Floors (18m)	76.164757	18	1370.965634
35	6	4 Floors (12m)	55.978453	12	671.74144
36	6	3 Foors (9m)	17.898599	9	161.087391
37	6	4 Floors (12m)	24.063871	12	288.766448
38	6	4 Floors (12m)	23.211225	12	278.534695
39	6	4 Floors (12m)	37.504736	12	450.056837
40	6	4 Floors (12m)	19.575485	12	234.90582
41	6	4 Floors (12m)	16.005573	12	192.066872
42	6	4 Floors (12m)	20.109066	12	241.308793
43	6	6 Floors (18m)	26.289336	18	473.208044
44	6	6 Floors (18m)	25.845301	18	465.215422
45	6	3 Foors (9m)	24.671589	9	222.044305
46	6	3 Foors (9m)	50.666304	9	455.996734
47	6	4 Floors (12m)	21.252188	12	255.026259
48	6	4 Floors (12m)	29.552104	12	354.62525
49	6	4 Floors (12m)	29.706546	12	356.478549
50	6	4 Floors (12m)	15.910864	12	190.930363
51	6	4 Floors (12m)	40.196754	12	482.361051
52	6	4 Floors (12m)	24.496852	12	293.962219
53	6	3 Foors (9m)	36.256772	9	326.310949

54	6	4 Floors (12m)	36.516208	12	438.194495
55	6	4 Floors (12m)	22.232163	12	266.785955
56	6	4 Floors (12m)	43.878929	12	526.547143
57	6	3 Foors (9m)	37.654845	9	338.893601
58	6	3 Foors (9m)	45.474243	9	409.268191
59	6	4 Floors (12m)	45.950373	12	551.404473
60	6	4 Floors (12m)	46.616	12	559.392
61	6	5 Floors (15m)	20.444393	15	306.665888
62	6	4 Floors (12m)	50.661636	12	607.939638
63	6	4 Floors (12m)	32.53045	12	390.365403
64	6	4 Floors (12m)	27.424046	12	329.088548
65	6	3 Foors (9m)	31.251344	9	281.262097
66	6	5 Floors (15m)	27.524292	15	412.864377
67	6	3 Foors (9m)	42.403514	9	381.631624
68	6	4 Floors (12m)	22.64956	12	271.794725
69	6	4 Floors (12m)	20.675453	12	248.105431
70	6	4 Floors (12m)	15.838776	12	190.065315
71	6	3 Foors (9m)	50.757311	9	456.815799
72	6	5 Floors (15m)	35.408556	15	531.128338
73	6	5 Floors (15m)	17.033443	15	255.501643
74	6	3 Foors (9m)	11.206148	9	100.855328
75	6	4 Floors (12m)	31.003072	12	372.036865
76	6	4 Floors (12m)	12.711621	12	152.539447
77	6	3 Foors (9m)	12.782638	9	115.043741
78	6	3 Foors (9m)	19.629674	9	176.667067
79	6	3 Foors (9m)	26.276816	9	236.491344
80	6	4 Floors (12m)	35.612765	12	427.353175
81	6	3 Foors (9m)	29.386474	9	264.478263
82	6	4 Floors (12m)	11.91848	12	143.021763
83	6	5 Floors (15m)	15.060964	15	225.914459
84	6	3 Foors (9m)	39.500114	9	355.501026
85	6	5 Floors (15m)	11.642321	15	174.634815
86	6	4 Floors (12m)	9.260739	12	111.128873
87	6	3 Foors (9m)	88.365524	9	795.289712
88	6	4 Floors (12m)	32.612084	12	391.345003
89	6	4 Floors (12m)	38.746906	12	464.962874
90	6	4 Floors (12m)	26.639386	12	319.672628
91	6	5 Floors (15m)	16.380687	15	245.710305
92	6	4 Floors (12m)	27.719956	12	332.639475
93	6	3 Foors (9m)	25.201441	9	226.81297
94	6	4 Floors (12m)	18.413716	12	220.964588
95	6	4 Floors (12m)	38.063767	12	456.765199
96	6	3 Foors (9m)	31.62496	9	284.624638
97	6	5 Floors (15m)	17.331337	15	259.97006
98	6	5 Floors (15m)	10.813309	15	162.19964
99	6	4 Floors (12m)	22.175759	12	266.109109
100	6	4 Floors (12m)	20.378044	12	244.536524
101	6	4 Floors (12m)	13.501464	12	162.017563
102	6	4 Floors (12m)	30.995679	12	371.948146
103	6	4 Floors (12m)	40.150686	12	481.808227
104	6	4 Floors (12m)	4.814034	12	57.768405
105	6	3 Foors (9m)	32.507855	9	292.570696
106	6	3 Foors (9m)	39.021932	9	351.197392
107	6	4 Floors (12m)	13.435823	12	161.229881
108	6	4 Floors (12m)	24.510788	12	294.129456

109	6	4 Floors (12m)	25.84357	12	310.122836
110	6	5 Floors (15m)	14.484998	15	217.274972
111	6	3 Foors (9m)	13.84168	9	124.575117
112	6	4 Floors (12m)	20.429064	12	245.148766
113	6	4 Floors (12m)	51.151587	12	613.819047
114	6	1 Floor (3m)	30.283646	3	90.850939
115	6	5 Floors (15m)	13.593288	15	203.899322
116	6	3 Foors (9m)	24.281745	9	218.535707
117	6	3 Foors (9m)	20.488298	9	184.394685
118	6	3 Foors (9m)	50.857193	9	457.714741
119	6	3 Foors (9m)	12.987829	9	116.890464
120	6	3 Foors (9m)	22.865939	9	205.793448
121	6	4 Floors (12m)	13.17381	12	158.085721
122	6	3 Foors (9m)	32.100974	9	288.908764
123	6	4 Floors (12m)	55.22624	12	662.714878
124	6	3 Foors (9m)	21.894752	9	197.052769
125	6	4 Floors (12m)	64.739909	12	776.878912
126	6	3 Foors (9m)	21.784453	9	196.060078
127	6	4 Floors (12m)	38.322857	12	459.874285
128	6	3 Foors (9m)	23.245009	9	209.20508
129	6	5 Floors (15m)	15.634059	15	234.510887
130	6	5 Floors (15m)	21.623649	15	324.354732
131	6	4 Floors (12m)	24.806459	12	297.677506
132	6	3 Foors (9m)	43.888963	9	395.000665
133	6	3 Foors (9m)	37.201728	9	334.815549
134	6	4 Floors (12m)	17.68378	12	212.205365
135	6	3 Foors (9m)	23.529321	9	211.76389
136	6	3 Foors (9m)	4.529994	9	40.76995
137	6	7 Floors(21m)	17.535988	21	368.255741
138	6	5 Floors (15m)	21.866039	15	327.990592
139	6	3 Foors (9m)	15.759085	9	141.831769
140	6	3 Foors (9m)	23.799301	9	214.193708
141	6	3 Foors (9m)	19.441621	9	174.974588
142	6	4 Floors (12m)	28.51359	12	342.163077
143	6	4 Floors (12m)	34.394803	12	412.737639
144	6	4 Floors (12m)	42.357208	12	508.286495
145	6	4 Floors (12m)	41.610949	12	499.331391
146	6	5 Floors (15m)	20.451672	15	306.775074
147	6	3 Foors (9m)	21.494584	9	193.451254
148	6	4 Floors (12m)	18.58137	12	222.976441
149	6	4 Floors (12m)	29.682724	12	356.192693
150	6	4 Floors (12m)	13.559271	12	162.711252
151	6	4 Floors (12m)	47.694402	12	572.332819
152	6	4 Floors (12m)	35.473809	12	425.685711
153	6	3 Foors (9m)	30.481182	9	274.330638
154	6	4 Floors (12m)	61.491565	12	737.898783
155	6	4 Floors (12m)	53.82094	12	645.851277
156	6	4 Floors (12m)	27.917436	12	335.009236
157	6	4 Floors (12m)	28.33005	12	339.960603
158	6	4 Floors (12m)	69.528562	12	834.34274
159	6	5 Floors (15m)	32.519681	15	487.795212
160	6	3 Foors (9m)	31.506093	9	283.55484
161	6	3 Foors (9m)	27.076292	9	243.686624
162	6	4 Floors (12m)	24.53	12	294.360004
163	6	4 Floors (12m)	31.521649	12	378.259789

164	6 4 Floors (12m)	49.095714	12	589.148572
165	6 4 Floors (12m)	34.058074	12	408.696893
166	6 5 Floors (15m)	17.926168	15	268.892521
167	6 5 Floors (15m)	36.924988	15	553.874817
168	6 5 Floors (15m)	26.037771	15	390.566558
169	6 5 Floors (15m)	8.728262	15	130.923925
170	6 4 Floors (12m)	18.047788	12	216.57345
171	6 4 Floors (12m)	42.332322	12	507.987866
172	6 5 Floors (15m)	21.426714	15	321.400706
173	6 6 Floors (18m)	26.054069	18	468.973245
174	6 4 Floors (12m)	26.599976	12	319.199714
175	6 5 Floors (15m)	25.449605	15	381.744082
176	6 4 Floors (12m)	18.746727	12	224.960727
177	6 4 Floors (12m)	25.056323	12	300.675874
178	6 3 Foors (9m)	42.610252	9	383.492267
179	6 4 Floors (12m)	23.582244	12	282.986931
180	6 3 Foors (9m)	22.745944	9	204.713492
181	6 5 Floors (15m)	29.000803	15	435.012045
182	6 4 Floors (12m)	27.836501	12	334.038007
183	6 4 Floors (12m)	37.995449	12	455.945391
184	6 4 Floors (12m)	49.561918	12	594.743011
185	6 4 Floors (12m)	25.656847	12	307.882169
186	6 5 Floors (15m)	11.65607	15	174.84105
187	6 4 Floors (12m)	19.093562	12	229.122749
188	6 4 Floors (12m)	27.965828	12	335.589931
189	6 4 Floors (12m)	31.679038	12	380.14846
190	6 4 Floors (12m)	14.477446	12	173.729353
191	6 7 Floors(21m)	26.782238	21	562.426994
192	6 7 Floors(21m)	50.028918	21	1050.607274
193	6 4 Floors (12m)	28.249554	12	338.994654
194	6 4 Floors (12m)	27.105083	12	325.260994
195	6 4 Floors (12m)	30.622277	12	367.46732
196	6 4 Floors (12m)	39.873321	12	478.479849
197	6 4 Floors (12m)	73.226927	12	878.723121
198	6 4 Floors (12m)	39.757293	12	477.087516
199	6 4 Floors (12m)	18.479512	12	221.754145
200	6 4 Floors (12m)	18.53445	12	222.413406
201	6 5 Floors (15m)	50.978831	15	764.682466
202	6 4 Floors (12m)	32.034852	12	384.41822
203	6 3 Foors (9m)	23.992292	9	215.930628
204	6 5 Floors (15m)	18.451816	15	276.777246
205	6 5 Floors (15m)	43.404579	15	651.068691
206	6 4 Floors (12m)	26.120652	12	313.447826
207	6 4 Floors (12m)	14.5242	12	174.290406
208	6 5 Floors (15m)	44.755625	15	671.334379
209	6 3 Foors (9m)	10.691379	9	96.222411
210	6 3 Foors (9m)	36.724798	9	330.523181
211	6 4 Floors (12m)	46.8231	12	561.877196
212	6 4 Floors (12m)	60.576397	12	726.916768
213	6 3 Foors (9m)	30.603484	9	275.431354
214	6 5 Floors (15m)	72.678006	15	1090.170095
215	6 5 Floors (15m)	32.137561	15	482.063409
216	6 6 Floors (18m)	17.315701	18	311.682609
217	6 3 Foors (9m)	28.407359	9	255.66623
218	6 4 Floors (12m)	40.256831	12	483.081978

219	6	4 Floors (12m)	11.142949	12	133.715384
220	6	5 Floors (15m)	22.230117	15	333.451748
221	6	7 Floors(21m)	28.979311	21	608.565525
222	6	4 Floors (12m)	30.153425	12	361.841103
223	6	6 Floors (18m)	25.290293	18	455.225272
224	6	7 Floors(21m)	58.198692	21	1222.172542
225	6	4 Floors (12m)	23.986162	12	287.833947
226	6	3 Foors (9m)	42.194126	9	379.747132
227	2	2 Floors (6m)	67.815239	6	406.891436
228	2	2 Floors (6m)	50.095804	6	300.574825
229	2	2 Floors (6m)	101.473817	6	608.842901
230	2	5 Floors (15m)	26.486987	15	397.304803
231	2	2 Floors (6m)	24.924	6	149.544
232	2	3 Foors (9m)	58.168808	9	523.51927
233	2	5 Floors (15m)	19.477679	15	292.165183
234	2	4 Floors (12m)	42.528072	12	510.336863
235	2	3 Foors (9m)	38.358161	9	345.223446
236	2	4 Floors (12m)	68.048149	12	816.577791
237	2	4 Floors (12m)	10.668308	12	128.01969
238	2	2 Floors (6m)	93.041115	6	558.246692
239	2	4 Floors (12m)	37.451278	12	449.415338
240	2	3 Foors (9m)	28.220816	9	253.987344
241	2	3 Foors (9m)	26.808272	9	241.27445
242	2	3 Foors (9m)	60.967741	9	548.709671
243	2	3 Foors (9m)	30.209917	9	271.889254
244	2	3 Foors (9m)	39.542292	9	355.880625
245	2	2 Floors (6m)	40.678606	6	244.071636
246	2	4 Floors (12m)	24.588649	12	295.063791
247	2	1 Floor (3m)	21.894462	3	65.683386
248	2	1 Floor (3m)	7.671843	3	23.01553
249	2	2 Floors (6m)	53.541029	6	321.246171
250	2	3 Foors (9m)	48.657306	9	437.91575
251	2	2 Floors (6m)	41.073315	6	246.439893
252	2	2 Floors (6m)	38.297259	6	229.783554
253	2	6 Floors (18m)	70.338797	18	1266.098351
254	2	3 Foors (9m)	25.079509	9	225.715579
255	2	2 Floors (6m)	66.874066	6	401.244394
256	2	6 Floors (18m)	41.968995	18	755.441918
257	2	5 Floors (15m)	89.83516	15	1347.527402
258	2	4 Floors (12m)	91.297429	12	1095.569144
259	2	6 Floors (18m)	80.209299	18	1443.767383
260	2	6 Floors (18m)	34.049341	18	612.888146
261	2	1 Floor (3m)	61.849245	3	185.547735
262	2	2 Floors (6m)	77.130523	6	462.783138
263	2	4 Floors (12m)	60.879452	12	730.553421
264	2	3 Foors (9m)	35.579994	9	320.219949
265	2	3 Foors (9m)	38.950013	9	350.550116
266	2	4 Floors (12m)	34.121324	12	409.455893
267	2	3 Foors (9m)	59.137732	9	532.239591
268	2	4 Floors (12m)	45.760248	12	549.122978
269	2	5 Floors (15m)	22.899924	15	343.498866
270	2	4 Floors (12m)	53.12335	12	637.480203
271	2	4 Floors (12m)	51.699172	12	620.390069
272	2	3 Foors (9m)	47.234292	9	425.108624
273	2	3 Foors (9m)	46.110688	9	414.996191

274	2	3 Foors (9m)	45.694161	9	411.247453
275	2	3 Foors (9m)	34.961598	9	314.65438
276	2	3 Foors (9m)	43.378521	9	390.406689
277	2	4 Floors (12m)	47.433775	12	569.205299
278	2	3 Foors (9m)	49.286859	9	443.58173
279	2	3 Foors (9m)	78.872121	9	709.849092
280	2	4 Floors (12m)	137.232292	12	1646.787507
281	2	4 Floors (12m)	39.507287	12	474.087442
282	2	5 Floors (15m)	38.76128	15	581.419197
283	2	3 Foors (9m)	60.892388	9	548.031495
284	2	5 Floors (15m)	112.363207	15	1685.448106
285	2	4 Floors (12m)	96.696576	12	1160.358917
286	2	3 Foors (9m)	27.471091	9	247.23982
287	2	3 Foors (9m)	28.883079	9	259.947713
288	2	3 Foors (9m)	39.873187	9	358.858682
289	2	4 Floors (12m)	32.909375	12	394.912503
290	2	3 Foors (9m)	38.412626	9	345.713637
291	2	3 Foors (9m)	55.540873	9	499.867858
292	2	3 Foors (9m)	74.733031	9	672.597276
293	2	3 Foors (9m)	41.742828	9	375.685451
294	2	3 Foors (9m)	50.269936	9	452.42942
295	2	3 Foors (9m)	55.035546	9	495.319913
296	2	3 Foors (9m)	63.189727	9	568.707543
297	2	3 Foors (9m)	52.109531	9	468.985783
298	2	3 Foors (9m)	54.385471	9	489.469242
299	2	3 Foors (9m)	51.13187	9	460.186831
300	2	3 Foors (9m)	44.050569	9	396.455123
301	2	3 Foors (9m)	31.936152	9	287.425372
302	2	6 Floors (18m)	46.626379	18	839.274828
303	2	6 Floors (18m)	14.744194	18	265.3955
304	2	2 Floors (6m)	28.239963	6	169.439776
305	2	3 Foors (9m)	41.612132	9	374.509187
306	2	3 Foors (9m)	42.889691	9	386.00722
307	2	2 Floors (6m)	55.514699	6	333.088195
308	2	2 Floors (6m)	42.876252	6	257.257514
309	2	3 Foors (9m)	59.173935	9	532.565411
310	2	3 Foors (9m)	69.41135	9	624.702148
311	2	2 Floors (6m)	41.649437	6	249.896624
312	2	3 Foors (9m)	40.85604	9	367.704364
313	2	2 Floors (6m)	37.983039	6	227.898236
314	2	4 Floors (12m)	31.37981	12	376.557722
315	2	2 Floors (6m)	38.83574	6	233.014441
316	2	4 Floors (12m)	18.576619	12	222.919428
317	2	3 Foors (9m)	48.644996	9	437.804964
318	2	4 Floors (12m)	28.930012	12	347.160141
319	2	6 Floors (18m)	43.147332	18	776.651978
320	2	4 Floors (12m)	50.242508	12	602.910097
321	2	2 Floors (6m)	51.370293	6	308.221761
322	2	2 Floors (6m)	45.44581	6	272.67486
323	2	3 Foors (9m)	46.301377	9	416.712389
324	2	3 Foors (9m)	39.944923	9	359.504307
325	2	2 Floors (6m)	45.806027	6	274.836165
326	2	3 Foors (9m)	42.947303	9	386.525728
327	2	3 Foors (9m)	39.103948	9	351.935529
328	2	2 Floors (6m)	32.201703	6	193.210215

329	2	6 Floors (18m)	50.349009	18	906.28216
330	2	2 Floors (6m)	37.73814	6	226.42884
331	2	4 Floors (12m)	37.489137	12	449.86964
332	2	3 Foors (9m)	36.108086	9	324.972774
333	2	4 Floors (12m)	43.448118	12	521.377411
334	2	2 Floors (6m)	34.99063	6	209.943778
335	2	1 Floor (3m)	34.266593	3	102.79978
336	2	3 Foors (9m)	55.687046	9	501.183412
337	2	4 Floors (12m)	55.849344	12	670.192133
338	2	1 Floor (3m)	32.202402	3	96.607206
339	2	3 Foors (9m)	31.792998	9	286.136983
340	2	3 Foors (9m)	26.215495	9	235.939456
341	2	2 Floors (6m)	31.936283	6	191.6177
342	2	3 Foors (9m)	44.00138	9	396.012422
343	2	2 Floors (6m)	29.871278	6	179.227666
344	2	3 Foors (9m)	28.099226	9	252.89303
345	2	4 Floors (12m)	50.628197	12	607.53837
346	2	3 Foors (9m)	45.003611	9	405.032499
347	2	3 Foors (9m)	42.341442	9	381.072976
348	2	3 Foors (9m)	42.051122	9	378.460097
349	2	3 Foors (9m)	46.55053	9	418.954772
350	2	3 Foors (9m)	49.918573	9	449.267155
351	2	3 Foors (9m)	25.084751	9	225.762759
352	2	6 Floors (18m)	50.797626	18	914.357268
353	2	4 Floors (12m)	39.684788	12	476.217459
354	2	4 Floors (12m)	50.178377	12	602.140524
355	2	4 Floors (12m)	52.676082	12	632.11298
356	2	4 Floors (12m)	44.643995	12	535.727944
357	2	3 Foors (9m)	33.319911	9	299.879198
358	2	2 Floors (6m)	42.196232	6	253.17739
359	2	2 Floors (6m)	49.4255	6	296.553003
360	2	3 Foors (9m)	47.953794	9	431.584143
361	2	4 Floors (12m)	41.080631	12	492.967569
362	2	3 Foors (9m)	42.548878	9	382.9399
363	2	3 Foors (9m)	45.80347	9	412.231232
364	2	4 Floors (12m)	46.442174	12	557.30609
365	2	4 Floors (12m)	54.650508	12	655.8061
366	2	2 Floors (6m)	48.638829	6	291.832971
367	2	4 Floors (12m)	54.782531	12	657.390375
368	2	2 Floors (6m)	50.148944	6	300.893663
369	2	6 Floors (18m)	57.58274	18	1036.489326
370	2	3 Foors (9m)	59.896475	9	539.068278
371	2	3 Foors (9m)	41.677817	9	375.100357
372	2	2 Floors (6m)	37.703589	6	226.221534
373	2	4 Floors (12m)	41.095874	12	493.150485
374	2	3 Foors (9m)	49.992953	9	449.936579
375	2	4 Floors (12m)	43.501167	12	522.014009
376	2	4 Floors (12m)	51.491887	12	617.902643
377	2	4 Floors (12m)	42.504252	12	510.05102
378	2	3 Foors (9m)	51.41873	9	462.768573
379	2	3 Foors (9m)	39.341067	9	354.069606
380	2	3 Foors (9m)	58.655169	9	527.896524
381	2	3 Foors (9m)	58.867569	9	529.808123
382	2	3 Foors (9m)	61.719295	9	555.473659
383	2	2 Floors (6m)	44.744429	6	268.466574

384	2	2 Floors (6m)	37.049028	6	222.294166
385	2	2 Floors (6m)	39.488434	6	236.930602
386	2	3 Foors (9m)	62.939771	9	566.457939
387	2	3 Foors (9m)	82.644425	9	743.799827
388	2	3 Foors (9m)	59.147209	9	532.324882
389	2	1 Floor (3m)	64.146279	3	192.438836
390	2	3 Foors (9m)	45.428163	9	408.853466
391	2	3 Foors (9m)	30.231614	9	272.08453
392	2	1 Floor (3m)	77.033629	3	231.100886
393	2	1 Floor (3m)	58.602587	3	175.80776
394	2	2 Floors (6m)	80.779208	6	484.675247
395	2	3 Foors (9m)	71.366495	9	642.298455
396	2	3 Foors (9m)	69.205468	9	622.849215
397	2	1 Floor (3m)	8.982772	3	26.948315
398	2	3 Foors (9m)	41.64678	9	374.821018
399	2	3 Foors (9m)	63.289409	9	569.604677
400	2	3 Foors (9m)	47.413066	9	426.717598
401	2	4 Floors (12m)	69.812382	12	837.74859
402	2	5 Floors (15m)	61.146807	15	917.202103
403	2	1 Floor (3m)	40.648172	3	121.944516
404	2	5 Floors (15m)	36.346086	15	545.19129
405	2	4 Floors (12m)	39.103933	12	469.247196
406	2	3 Foors (9m)	42.232935	9	380.096418
407	2	6 Floors (18m)	53.9396	18	970.912807
408	2	3 Foors (9m)	49.241538	9	443.173841
409	2	6 Floors (18m)	56.337022	18	1014.066393
410	2	4 Floors (12m)	44.458247	12	533.498959
411	2	4 Floors (12m)	56.926537	12	683.118443
412	2	3 Foors (9m)	53.028577	9	477.257195
413	2	1 Floor (3m)	42.081794	3	126.245381
414	2	3 Foors (9m)	67.590858	9	608.317721
415	2	6 Floors (18m)	66.998337	18	1205.970064
416	2	2 Floors (6m)	58.964694	6	353.788162
417	2	5 Floors (15m)	20.873075	15	313.096127
418	1	3 Foors (9m)	26.863324	9	241.76992
419	1	3 Foors (9m)	49.339952	9	444.059567
420	1	3 Foors (9m)	38.164268	9	343.47841
421	1	3 Foors (9m)	22.703759	9	204.333828
422	1	5 Floors (15m)	34.824684	15	522.37026
423	1	2 Floors (6m)	32.403121	6	194.418728
424	1	3 Foors (9m)	33.964933	9	305.684394
425	1	3 Foors (9m)	34.749837	9	312.748534
426	1	3 Foors (9m)	66.595387	9	599.35848
427	1	4 Floors (12m)	28.56308	12	342.756966
428	1	6 Floors (18m)	151.092702	18	2719.668643
429	1	6 Floors (18m)	105.298055	18	1895.364981
430	1	6 Floors (18m)	52.183273	18	939.298912
431	1	6 Floors (18m)	16.094409	18	289.699368
432	1	5 Floors (15m)	15.16735	15	227.510255
433	1	4 Floors (12m)	61.145157	12	733.741882
434	1	7 Floors(21m)	82.087877	21	1723.845409
435	1	6 Floors (18m)	84.647513	18	1523.65523
436	1	5 Floors (15m)	42.159786	15	632.396785
437	1	5 Floors (15m)	68.256004	15	1023.84006
438	1	6 Floors (18m)	70.174046	18	1263.132823

439	1	5 Floors (15m)	52.353887	15	785.308305
440	1	6 Floors (18m)	88.363841	18	1590.549133
441	1	6 Floors (18m)	15.95086	18	287.115481
442	1	4 Floors (12m)	11.108312	12	133.299741
443	1	4 Floors (12m)	61.134603	12	733.615238
444	1	3 Foors (9m)	29.814783	9	268.333048
445	1	3 Foors (9m)	45.380934	9	408.428407
446	1	3 Foors (9m)	38.770888	9	348.93799
447	1	3 Foors (9m)	93.095485	9	837.859361
448	1	1 Floor (3m)	32.597407	3	97.79222
449	1	1 Floor (3m)	33.930816	3	101.792448
450	1	4 Floors (12m)	48.992768	12	587.913218
451	1	3 Foors (9m)	46.339359	9	417.054235
452	1	4 Floors (12m)	39.162769	12	469.953231
453	1	4 Floors (12m)	60.813453	12	729.761431
454	1	3 Foors (9m)	98.658536	9	887.926824
455	1	5 Floors (15m)	76.612621	15	1149.189316
456	1	4 Floors (12m)	27.956379	12	335.476542
457	1	2 Floors (6m)	88.617827	6	531.706959
458	1	6 Floors (18m)	37.053274	18	666.958925
459	1	5 Floors (15m)	21.351398	15	320.270967
460	1	5 Floors (15m)	39.150909	15	587.263632
461	1	5 Floors (15m)	37.419732	15	561.295986
462	1	5 Floors (15m)	55.407558	15	831.113377
463	1	4 Floors (12m)	33.455748	12	401.468979
464	1	3 Foors (9m)	32.454115	9	292.087031
465	1	2 Floors (6m)	8.526647	6	51.159879
466	1	6 Floors (18m)	66.26866	18	1192.835873
467	1	3 Foors (9m)	45.502933	9	409.526399
468	1	1 Floor (3m)	22.532442	3	67.597326
469	1	2 Floors (6m)	39.063032	6	234.378192
470	1	3 Foors (9m)	37.406988	9	336.662888
471	1	2 Floors (6m)	41.659917	6	249.959501
472	1	3 Foors (9m)	18.894745	9	170.052705
473	1	3 Foors (9m)	52.485066	9	472.365591
474	1	3 Foors (9m)	40.781509	9	367.033585
475	1	2 Floors (6m)	32.472618	6	194.835706
476	1	1 Floor (3m)	58.164195	3	174.492584
477	1	1 Floor (3m)	39.551765	3	118.655296
478	1	1 Floor (3m)	37.69585	3	113.087551
479	1	1 Floor (3m)	55.294673	3	165.88402
480	1	3 Foors (9m)	23.893977	9	215.045793
481	1	2 Floors (6m)	34.884385	6	209.306311
482	1	2 Floors (6m)	18.910714	6	113.464281
483	1	2 Floors (6m)	31.855994	6	191.135961
484	1	1 Floor (3m)	35.932116	3	107.796349
485	1	1 Floor (3m)	106.868196	3	320.604588
486	1	3 Foors (9m)	49.145811	9	442.312295
487	1	2 Floors (6m)	43.394623	6	260.367739
488	1	2 Floors (6m)	72.107667	6	432.645999
489	1	6 Floors (18m)	46.96996	18	845.459275
490	1	3 Foors (9m)	104.230909	9	938.078178
491	1	1 Floor (3m)	30.127093	3	90.381279
492	1	1 Floor (3m)	34.005618	3	102.016855
493	1	1 Floor (3m)	52.777343	3	158.332029

494	1	1 Floor (3m)	33.359733	3	100.079199
495	1	1 Floor (3m)	57.100638	3	171.301915
496	1	1 Floor (3m)	37.674314	3	113.022943
497	1	2 Floors (6m)	44.182193	6	265.09316
498	1	2 Floors (6m)	57.347145	6	344.082868
499	1	2 Floors (6m)	26.53728	6	159.223683
500	1	2 Floors (6m)	24.828076	6	148.968456
501	1	1 Floor (3m)	88.573503	3	265.720509
502	1	1 Floor (3m)	29.757517	3	89.272551
503	1	3 Foors (9m)	56.699253	9	510.293274
504	1	1 Floor (3m)	21.827852	3	65.483556
505	1	1 Floor (3m)	40.380957	3	121.14287
506	1	1 Floor (3m)	26.937158	3	80.811473
507	1	1 Floor (3m)	105.162955	3	315.488866
508	1	3 Foors (9m)	27.910007	9	251.190063
509	1	1 Floor (3m)	24.2949	3	72.8847
510	1	2 Floors (6m)	54.16259	6	324.975537
511	1	1 Floor (3m)	25.914093	3	77.74228
512	1	1 Floor (3m)	26.783408	3	80.350223
513	1	3 Foors (9m)	30.562325	9	275.060924
514	1	3 Foors (9m)	25.284925	9	227.564323
515	1	3 Foors (9m)	39.886818	9	358.981361
516	1	2 Floors (6m)	37.837571	6	227.025425
517	1	2 Floors (6m)	44.05108	6	264.306483
518	1	1 Floor (3m)	43.874511	3	131.623532
519	1	3 Foors (9m)	38.824966	9	349.424698
520	1	5 Floors (15m)	30.493561	15	457.403408
521	1	1 Floor (3m)	47.545232	3	142.635696
522	1	1 Floor (3m)	51.581724	3	154.745172
523	1	1 Floor (3m)	27.008785	3	81.026356
524	1	1 Floor (3m)	36.11843	3	108.355289
525	1	1 Floor (3m)	31.533829	3	94.601486
526	1	2 Floors (6m)	20.600784	6	123.604707
527	1	1 Floor (3m)	43.209243	3	129.627729
528	1	1 Floor (3m)	48.745613	3	146.236838
529	1	1 Floor (3m)	41.177855	3	123.533566
530	1	3 Foors (9m)	21.192991	9	190.736923
531	1	3 Foors (9m)	39.086303	9	351.776727
532	1	1 Floor (3m)	93.18838	3	279.565141
533	1	3 Foors (9m)	50.759214	9	456.83293
534	1	3 Foors (9m)	86.946295	9	782.516654
535	1	3 Foors (9m)	65.915244	9	593.237199
536	1	3 Foors (9m)	93.712696	9	843.414265
537	1	1 Floor (3m)	38.557705	3	115.673114
538	1	3 Foors (9m)	35.122953	9	316.106581
539	1	2 Floors (6m)	56.622328	6	339.733966
540	1	2 Floors (6m)	68.146577	6	408.879465
541	1	4 Floors (12m)	105.456955	12	1265.483458
542	1	3 Foors (9m)	45.820167	9	412.381506
543	1	3 Foors (9m)	48.217165	9	433.954486
544	1	3 Foors (9m)	47.292108	9	425.628968
545	1	3 Foors (9m)	21.638175	9	194.743575
546	1	2 Floors (6m)	3.018344	6	18.110063
547	1	4 Floors (12m)	59.358854	12	712.306247
548	1	7 Floors(21m)	62.572759	21	1314.027939

549	1	4 Floors (12m)	50.825944	12	609.911326
550	1	4 Floors (12m)	23.161984	12	277.94381
551	1	2 Floors (6m)	59.696176	6	358.177054
552	1	7 Floors(21m)	47.954813	21	1007.051075
553	1	4 Floors (12m)	52.988119	12	635.857428
554	1	3 Foors (9m)	31.643737	9	284.793637
555	1	2 Floors (6m)	96.982797	6	581.896784
556	1	5 Floors (15m)	45.204091	15	678.061369
557	1	5 Floors (15m)	35.315621	15	529.734315
558	1	1 Floor (3m)	166.161843	3	498.485528
559	1	2 Floors (6m)	31.526873	6	189.161236
560	1	2 Floors (6m)	115.857831	6	695.146984
561	1	7 Floors(21m)	61.814893	21	1298.112743
562	1	7 Floors(21m)	61.694515	21	1295.58482
563	1	2 Floors (6m)	35.795197	6	214.771181
564	1	4 Floors (12m)	114.146603	12	1369.759239
565	1	7 Floors(21m)	125.256195	21	2630.38009
566	1	7 Floors(21m)	23.766679	21	499.100263
567	1	6 Floors (18m)	22.900697	18	412.21255
568	1	6 Floors (18m)	22.498421	18	404.971582
569	1	3 Foors (9m)	31.394573	9	282.551155
570	1	7 Floors(21m)	125.739811	21	2640.536021
571	1	5 Floors (15m)	44.712885	15	670.693271
572	1	3 Foors (9m)	55.447338	9	499.026043
573	1	7 Floors(21m)	43.004196	21	903.088115
574	1	1 Floor (3m)	49.959484	3	149.878452
575	1	3 Foors (9m)	33.497011	9	301.4731
576	1	3 Foors (9m)	24.038095	9	216.342852
577	1	3 Foors (9m)	37.161991	9	334.457916
578	1	4 Floors (12m)	40.693738	12	488.324855
579	1	3 Foors (9m)	51.498692	9	463.48823
580	1	4 Floors (12m)	54.509558	12	654.114691
581	1	4 Floors (12m)	38.313321	12	459.759849
582	1	2 Floors (6m)	64.440209	6	386.641254
583	1	3 Foors (9m)	35.046287	9	315.416584
584	1	5 Floors (15m)	36.658666	15	549.87999
585	1	3 Foors (9m)	49.023362	9	441.21026
586	1	2 Floors (6m)	55.668582	6	334.011492
587	1	2 Floors (6m)	27.587803	6	165.526816
588	1	4 Floors (12m)	71.001942	12	852.023308
589	1	3 Foors (9m)	59.94782	9	539.530384
590	1	4 Floors (12m)	57.221871	12	686.662453
591	1	4 Floors (12m)	51.13523	12	613.622755
592	1	4 Floors (12m)	79.438507	12	953.262081
593	1	3 Foors (9m)	26.085578	9	234.7702
594	1	5 Floors (15m)	21.613196	15	324.197935
595	1	6 Floors (18m)	50.306589	18	905.518604
596	1	6 Floors (18m)	56.717196	18	1020.909521
597	1	5 Floors (15m)	42.79395	15	641.909244
598	1	6 Floors (18m)	66.71536	18	1200.876478
599	1	4 Floors (12m)	69.826472	12	837.917667
600	1	7 Floors(21m)	36.203455	21	760.272562
601	1	5 Floors (15m)	67.512164	15	1012.682467
602	1	3 Foors (9m)	46.533176	9	418.798583
603	1	3 Foors (9m)	40.46947	9	364.225232

604	1	4 Floors (12m)	43.699929	12	524.399146
605	1	3 Foors (9m)	64.842117	9	583.579053
606	1	4 Floors (12m)	46.172914	12	554.074964
607	1	3 Foors (9m)	74.675217	9	672.076956
608	1	3 Foors (9m)	113.9863	9	1025.876701
609	1	2 Floors (6m)	71.290006	6	427.740036
610	1	5 Floors (15m)	138.331405	15	2074.971079
611	1	4 Floors (12m)	30.856503	12	370.278037
612	1	7 Floors(21m)	76.753177	21	1611.816711
613	1	7 Floors(21m)	49.793283	21	1045.658951
614	1	3 Foors (9m)	53.076914	9	477.692224
615	1	3 Foors (9m)	38.676305	9	348.086741
616	1	2 Floors (6m)	41.143474	6	246.860846
617	1	2 Floors (6m)	39.377671	6	236.266025
618	1	3 Foors (9m)	68.133791	9	613.204122
619	1	4 Floors (12m)	43.813349	12	525.76019
620	1	5 Floors (15m)	11.531789	15	172.976835
621	2	4 Floors (12m)	370.219471	12	4442.633654
622	2	3 Foors (9m)	53.608713	9	482.478419
623	2	3 Foors (9m)	56.140311	9	505.262802
624	6	3 Foors (9m)	56.857875	9	511.720875
625	6	3 Foors (9m)	18.329742	9	164.967676
626	6	3 Foors (9m)	19.092042	9	171.828378
627	6	4 Floors (12m)	17.258901	12	207.106812
628	6	3 Foors (9m)	23.810251	9	214.292261
629	6	4 Floors (12m)	50.490662	12	605.887939
630	6	4 Floors (12m)	34.173522	12	410.082266
631	6	4 Floors (12m)	32.583507	12	391.002081
632	6	5 Floors (15m)	13.9368	15	209.051997
633	6	4 Floors (12m)	22.558756	12	270.705072
634	6	3 Foors (9m)	24.913302	9	224.219719
635	6	2 Floors (6m)	36.215507	6	217.293043
636	6	3 Foors (9m)	37.856229	9	340.706061
637	6	4 Floors (12m)	46.607116	12	559.285391
638	6	4 Floors (12m)	20.321348	12	243.856178
639	6	4 Floors (12m)	36.974791	12	443.697494
640	6	3 Foors (9m)	14.249085	9	128.241763
641	6	5 Floors (15m)	29.397696	15	440.965438
642	6	5 Floors (15m)	49.993253	15	749.898788
643	6	5 Floors (15m)	79.867584	15	1198.01376
644	1	4 Floors (12m)	1228.561424	12	14742.73708
645	6	5 Floors (15m)	63.552311	15	953.28467
646	6	4 Floors (12m)	68.175986	12	818.111834
647	6	4 Floors (12m)	22.546939	12	270.563268
648	6	5 Floors (15m)	33.499254	15	502.488817
649	2	2 Floors (6m)	113.316445	6	679.898668
650	2	1 Floor (3m)	68.996532	3	206.989596
651	2	4 Floors (12m)	16.359159	12	196.309908
652	2	4 Floors (12m)	26.489582	12	317.874979
653	6	4 Floors (12m)	72.15945	12	865.913404
654	6	4 Floors (12m)	26.637384	12	319.648613
655	6	3 Foors (9m)	70.051911	9	630.467202
656	6	3 Foors (9m)	28.397456	9	255.577105
657	6	3 Foors (9m)	20.942352	9	188.481164
658	6	5 Floors (15m)	13.869166	15	208.037488

659	6	5 Floors (15m)	12.540482	15	188.107231
660	6	3 Foors (9m)	34.84726	9	313.625339
661	6	3 Foors (9m)	19.883961	9	178.955653
662	6	4 Floors (12m)	18.311534	12	219.738411
663	6	4 Floors (12m)	28.214683	12	338.576202
664	6	4 Floors (12m)	34.663938	12	415.967251
665	6	4 Floors (12m)	31.465295	12	377.583538
666	6	3 Foors (9m)	40.901387	9	368.112486
667	6	3 Foors (9m)	78.899044	9	710.091394
668	6	6 Floors (18m)	27.562875	18	496.131742
669	6	6 Floors (18m)	55.827877	18	1004.901789
670	6	4 Floors (12m)	42.919657	12	515.035882
671	1	4 Floors (12m)	50.308194	12	603.698333
672	1	7 Floors(21m)	107.800406	21	2263.808531
673	1	5 Floors (15m)	40.192728	15	602.890927
674	1	2 Floors (6m)	40.094	6	240.563997
675	2	1 Floor (3m)	15.695199	3	47.085598
676	2	1 Floor (3m)	16.592635	3	49.777906
677	6	4 Floors (12m)	20.240944	12	242.891327
678	6	4 Floors (12m)	26.596717	12	319.160608
679	1	3 Foors (9m)	14.953411	9	134.580696
680	1	3 Foors (9m)	115.073639	9	1035.66275
681	1	3 Foors (9m)	54.76685	9	492.901652
682	1	3 Foors (9m)	46.087456	9	414.787107
683	1	3 Foors (9m)	28.027844	9	252.250598
684	1	3 Foors (9m)	50.598884	9	455.389954
685	1	2 Floors (6m)	42.87065	6	257.223897
686	1	5 Floors (15m)	54.415964	15	816.239466
687	1	1 Floor (3m)	49.607296	3	148.821888
688	1	4 Floors (12m)	66.887194	12	802.646326
689	2	1 Floor (3m)	13.317833	3	39.9535
690	2	4 Floors (12m)	24.295428	12	291.54514
691	2	4 Floors (12m)	32.191085	12	386.293017
692	2	3 Foors (9m)	103.443891	9	930.995016
693	2	3 Foors (9m)	112.893394	9	1016.040545
694	2	3 Foors (9m)	64.422351	9	579.801161
695	2	3 Foors (9m)	38.250545	9	344.254904
696	2	3 Foors (9m)	142.900061	9	1286.100552
697	2	3 Foors (9m)	99.43088	9	894.877918
698	2	3 Foors (9m)	46.283239	9	416.549149
699	2	3 Foors (9m)	68.204021	9	613.836192
700	2	3 Foors (9m)	109.678434	9	987.105907
701	2	3 Foors (9m)	19.149737	9	172.347636
702	2	2 Floors (6m)	75.413166	6	452.478994
703	2	1 Floor (3m)	13.065303	3	39.195909
704	2	1 Floor (3m)	52.727704	3	158.183111
705	2	1 Floor (3m)	38.6177	3	115.853101
706	2	3 Foors (9m)	32.707965	9	294.371689
707	2	4 Floors (12m)	144.839674	12	1738.076083
708	2	4 Floors (12m)	47.686751	12	572.241008
709	2	4 Floors (12m)	50.634869	12	607.61843
710	2	4 Floors (12m)	49.446021	12	593.35225
711	2	4 Floors (12m)	137.344783	12	1648.137396
712	2	4 Floors (12m)	41.070446	12	492.845351
713	2	4 Floors (12m)	58.797279	12	705.567342

714	2	4 Floors (12m)	76.680901	12	920.170813
715	2	4 Floors (12m)	43.684195	12	524.210337
716	2	4 Floors (12m)	101.400662	12	1216.807945
717	2	4 Floors (12m)	70.120455	12	841.445455
718	2	4 Floors (12m)	49.414837	12	592.978048
719	2	4 Floors (12m)	82.083833	12	985.005997
720	2	5 Floors (15m)	88.926739	15	1333.901089
721	2	5 Floors (15m)	33.583245	15	503.748668
722	2	5 Floors (15m)	37.11147	15	556.672046
723	2	5 Floors (15m)	31.693098	15	475.396469
724	2	6 Floors (18m)	146.327391	18	2633.893047
725	2	6 Floors (18m)	143.174559	18	2577.14207
726	2	6 Floors (18m)	26.16577	18	470.983856
727	2	7 Floors(21m)	168.692547	21	3542.543495
728	2	7 Floors(21m)	144.283062	21	3029.944308
729	2	8 Floors (24m)	130.587115	24	3134.090771
730	2	2 Floors (6m)	55.803791	6	334.822746
731	2	2 Floors (6m)	35.249866	6	211.499199
732	2	3 Foors (9m)	53.462844	9	481.1656
733	2	1 Floor (3m)	158.431637	3	475.294912
734	6	4 Floors (12m)	51.228819	12	614.745824
735	6	3 Foors (9m)	26.918441	9	242.26597
736	6	1 Floor (3m)	36.954566	3	110.863699
737	6	4 Floors (12m)	37.087527	12	445.050323
738	6	3 Foors (9m)	17.798496	9	160.186463
739	6	4 Floors (12m)	17.183316	12	206.19979
740	6	1 Floor (3m)	19.424701	3	58.274104
741	6	2 Floors (6m)	8.199288	6	49.19573
742	6	2 Floors (6m)	4.001509	6	24.009052
743	6	4 Floors (12m)	23.284429	12	279.41315
744	6	1 Floor (3m)	37.794679	3	113.384038
745	6	4 Floors (12m)	28.005238	12	336.06285
746	6	3 Foors (9m)	27.027296	9	243.24566
747	6	4 Floors (12m)	34.631478	12	415.577731
748	6	6 Floors (18m)	70.002073	18	1260.037309
749	6	4 Floors (12m)	29.287925	12	351.455106
750	6	3 Foors (9m)	37.352557	9	336.173017
751	1	1 Floor (3m)	30.207843	3	90.62353
752	1	2 Floors (6m)	43.695972	6	262.175829
753	1	2 Floors (6m)	26.989531	6	161.937186
754	1	2 Floors (6m)	33.519675	6	201.11805
755	1	1 Floor (3m)	34.289399	3	102.868197
756	1	2 Floors (6m)	104.854157	6	629.12494
757	1	2 Floors (6m)	65.801303	6	394.80782
758	1	2 Floors (6m)	29.479114	6	176.874683
759	1	2 Floors (6m)	30.271056	6	181.626337
760	1	2 Floors (6m)	36.085439	6	216.512632
761	1	2 Floors (6m)	71.873211	6	431.239265
762	1	2 Floors (6m)	52.08158	6	312.489478
763	1	2 Floors (6m)	30.993883	6	185.963295
764	1	1 Floor (3m)	22.589752	3	67.769257
765	1	1 Floor (3m)	12.515717	3	37.54715
766	1	1 Floor (3m)	49.206589	3	147.619766
767	1	1 Floor (3m)	54.602667	3	163.808001
768	1	2 Floors (6m)	59.456756	6	356.740535

769	1	1 Floor (3m)	55.118069	3	165.354207
770	1	1 Floor (3m)	37.480404	3	112.441211
771	1	3 Foors (9m)	57.644264	9	518.798377
772	1	4 Floors (12m)	19.92037	12	239.044435
773	1	4 Floors (12m)	25.070333	12	300.84399
774	1	4 Floors (12m)	82.127682	12	985.532181
775	1	1 Floor (3m)	6.147764	3	18.443292
776	1	6 Floors (18m)	70.942625	18	1276.967247
777	1	1 Floor (3m)	34.50561	3	103.516829
778	1	3 Foors (9m)	36.107484	9	324.967358
779	1	3 Foors (9m)	1849.460739	9	16645.14665
780	1	4 Floors (12m)	16.984893	12	203.818715
781	2	3 Foors (9m)	239.213554	9	2152.921987
782	6	1 Floor (3m)	10.434008	3	31.302024
783	6	1 Floor (3m)	7.775042	3	23.325126
784	6	1 Floor (3m)	5.063917	3	15.19175
785	6	1 Floor (3m)	14.432196	3	43.296588
786	6	1 Floor (3m)	8.75882	3	26.27646
787	6	1 Floor (3m)	5.150073	3	15.450219
788	6	1 Floor (3m)	9.423644	3	28.270932
789	6	1 Floor (3m)	15.4927	3	46.478101
790	6	1 Floor (3m)	53.122472	3	159.367417
791	6	1 Floor (3m)	99.518337	3	298.55501
792	6	1 Floor (3m)	12.822528	3	38.467583
793	6	1 Floor (3m)	14.197026	3	42.591077
794	6	4 Floors (12m)	25.317631	12	303.811568
795	6	6 Floors (18m)	120.36429	18	2166.557219
796	6	3 Foors (9m)	18.514196	9	166.627768
797	6	3 Foors (9m)	29.630974	9	266.678764
798	6	7 Floors(21m)	31.856794	21	668.992672

Appendix 2

Datasheet of the building modified by the project PolimiparaRocinha Zones 1, 2, and 6

FID	Number_A	Layer	Color	RefName	Area	Altezza	Volume
0	3	2 Floors (6m)	50		18.346567	6	110.079403
1	3	5 Floors (15m)	30		18.165756	15	272.486346
2	3	2 Floors (6m)	50		26.063003	6	156.378018
3	3	2 Floors (6m)	50		12.049049	6	72.294292
4	3	6 Floors (18m)	222		23.597315	18	424.751678
5	3	2 Floors (6m)	50		59.12251	6	354.735059
6	3	4 Floors (12m)	161		61.49516	12	737.941921
7	3	5 Floors (15m)	30		48.404776	15	726.071644
8	3	4 Floors (12m)	161		28.793359	12	345.520313
9	3	4 Floors (12m)	161		6.55843	12	78.70116
10	3	4 Floors (12m)	161		33.959102	12	407.509218
11	3	3 Foors (9m)	90		33.800595	9	304.205358
12	3	2 Floors (6m)	50		40.735281	6	244.411688
13	3	4 Floors (12m)	161		34.960522	12	419.526268
14	3	3 Foors (9m)	90		27.736391	9	249.627517
15	3	7 Floors(21m)	192		45.136311	21	947.862538
16	3	7 Floors(21m)	192		30.866144	21	648.189017
17	3	4 Floors (12m)	161		63.572039	12	762.864473
18	3	4 Floors (12m)	161		4.859414	12	58.312969
19	3	4 Floors (12m)	161	Market	38.990001	12	467.880013
20	3	4 Floors (12m)	161		9.847782	12	118.173381
21	3	4 Floors (12m)	161		17.604724	12	211.256691
22	3	5 Floors (15m)	30		35.266285	15	528.994275
23	3	5 Floors (15m)	30		55.843825	15	837.657379
24	3	4 Floors (12m)	161		35.915769	12	430.989224
25	3	2 Floors (6m)	50		52.112951	6	312.677707
26	3	4 Floors (12m)	161		92.102978	12	1105.235731
27	3	3 Foors (9m)	90		34.401118	9	309.610059
28	3	2 Floors (6m)	50		24.876645	6	149.259872
29	3	4 Floors (12m)	161		20.913826	12	250.965907
30	3	4 Floors (12m)	161		36.94149	12	443.297878
31	3	4 Floors (12m)	161		27.419843	12	329.038111
32	3	4 Floors (12m)	161		68.379266	12	820.551194
33	3	5 Floors (15m)	30		34.67094	15	520.064097
34	3	6 Floors (18m)	222		76.164757	18	1370.965634
35	3	4 Floors (12m)	161		55.978453	12	671.74144
36	3	3 Foors (9m)	90		17.898599	9	161.087391
37	3	4 Floors (12m)	161		24.063871	12	288.766448
38	3	4 Floors (12m)	161		23.211225	12	278.534695
39	3	4 Floors (12m)	161		37.504736	12	450.056837
40	3	4 Floors (12m)	161		19.575485	12	234.90582
41	3	4 Floors (12m)	161		16.005573	12	192.066872
42	3	4 Floors (12m)	161		20.109066	12	241.308793
43	3	6 Floors (18m)	222		26.289336	18	473.208044
44	3	6 Floors (18m)	222		25.845301	18	465.215422
45	3	3 Foors (9m)	90		24.671589	9	222.044305
46	3	3 Foors (9m)	90		50.666304	9	455.996734
47	3	4 Floors (12m)	161		21.252188	12	255.026259
48	3	4 Floors (12m)	161		29.552104	12	354.62525
49	3	4 Floors (12m)	161		29.706546	12	356.478549
50	3	4 Floors (12m)	161		15.910864	12	190.930363
51	3	4 Floors (12m)	161		40.196754	12	482.361051
52	3	4 Floors (12m)	161		24.496852	12	293.962219
53	3	3 Foors (9m)	90		36.256772	9	326.310949

54	3	4 Floors (12m)	161		36.516208	12	438.194495
55	3	4 Floors (12m)	161		22.232163	12	266.785955
56	3	4 Floors (12m)	161		43.878929	12	526.547143
57	3	3 Foors (9m)	90		37.654845	9	338.893601
58	3	3 Foors (9m)	90		45.474243	9	409.268191
59	3	4 Floors (12m)	161		46.616	12	559.392
60	3	5 Floors (15m)	30		20.444393	15	306.665888
61	3	4 Floors (12m)	161		50.661636	12	607.939638
62	3	4 Floors (12m)	161		32.53045	12	390.365403
63	3	4 Floors (12m)	161		27.424046	12	329.088548
64	3	3 Foors (9m)	90		31.251344	9	281.262097
65	3	5 Floors (15m)	30		27.524292	15	412.864377
66	3	3 Foors (9m)	90		42.403514	9	381.631624
67	3	4 Floors (12m)	161		22.64956	12	271.794725
68	3	4 Floors (12m)	161		20.675453	12	248.105431
69	3	4 Floors (12m)	161		15.838776	12	190.065315
70	3	3 Foors (9m)	90		50.757311	9	456.815799
71	3	5 Floors (15m)	30		35.408556	15	531.128338
72	3	5 Floors (15m)	30		17.033443	15	255.501643
73	3	3 Foors (9m)	90		11.206148	9	100.855328
74	3	4 Floors (12m)	161		31.003072	12	372.036865
75	3	4 Floors (12m)	161		12.711621	12	152.539447
76	3	3 Foors (9m)	90		12.782638	9	115.043741
77	3	3 Foors (9m)	90		19.629674	9	176.667067
78	3	3 Foors (9m)	90		26.276816	9	236.491344
79	3	3 Foors (9m)	90	Education	35.612765	9	320.514881
80	3	3 Foors (9m)	90		29.386474	9	264.478263
81	3	4 Floors (12m)	161		11.91848	12	143.021763
82	3	5 Floors (15m)	30		15.060964	15	225.914459
83	3	3 Foors (9m)	90		39.500114	9	355.501026
84	3	5 Floors (15m)	30		11.642321	15	174.634815
85	3	4 Floors (12m)	161		13.666841	12	164.002096
86	3	4 Floors (12m)	161		9.260739	12	111.128873
87	3	3 Foors (9m)	90		88.365524	9	795.289712
88	3	4 Floors (12m)	161		32.612084	12	391.345003
89	3	4 Floors (12m)	161		38.746906	12	464.962874
90	3	4 Floors (12m)	161		26.639386	12	319.672628
91	3	5 Floors (15m)	30		16.380687	15	245.710305
92	3	4 Floors (12m)	161		27.719956	12	332.639475
93	3	3 Foors (9m)	90		25.201441	9	226.81297
94	3	4 Floors (12m)	161		18.413716	12	220.964588
95	3	4 Floors (12m)	161		38.063767	12	456.765199
96	3	3 Foors (9m)	90		31.62496	9	284.624638
97	3	5 Floors (15m)	30		17.331337	15	259.97006
98	3	5 Floors (15m)	30		10.813309	15	162.19964
99	3	4 Floors (12m)	161		22.175759	12	266.109109
100	3	4 Floors (12m)	161		20.378044	12	244.536524
101	3	4 Floors (12m)	161		13.501464	12	162.017563
102	3	4 Floors (12m)	161		30.995679	12	371.948146
103	3	4 Floors (12m)	161		40.150686	12	481.808227
104	3	4 Floors (12m)	161		4.814034	12	57.768405
105	3	3 Foors (9m)	90		32.507855	9	292.570696
106	3	3 Foors (9m)	90	Education	39.021932	9	351.197392
107	3	4 Floors (12m)	161		13.435823	12	161.229881
108	3	4 Floors (12m)	161		24.510788	12	294.129456

109	3	4 Floors (12m)	161	25.84357	12	310.122836
110	3	5 Floors (15m)	30	14.484998	15	217.274972
111	3	3 Foors (9m)	90	13.84168	9	124.575117
112	3	4 Floors (12m)	161	20.429064	12	245.148766
113	3	4 Floors (12m)	161	51.151587	12	613.819047
114	3	1 Floor (3m)	210	30.283646	3	90.850939
115	3	5 Floors (15m)	30	13.593288	15	203.899322
116	3	3 Foors (9m)	90	24.281745	9	218.535707
117	3	3 Foors (9m)	90	20.488298	9	184.394685
118	3	3 Foors (9m)	90	50.857193	9	457.714741
119	3	3 Foors (9m)	90	12.987829	9	116.890464
120	3	3 Foors (9m)	90	22.865939	9	205.793448
121	3	4 Floors (12m)	161	13.17381	12	158.085721
122	3	3 Foors (9m)	90	32.100974	9	288.908764
123	3	4 Floors (12m)	161	55.22624	12	662.714878
124	3	3 Foors (9m)	90	21.894752	9	197.052769
125	3	4 Floors (12m)	161	64.739909	12	776.878912
126	3	3 Foors (9m)	90	21.784453	9	196.060078
127	3	4 Floors (12m)	161	38.322857	12	459.874285
128	3	3 Foors (9m)	90	23.245009	9	209.20508
129	3	5 Floors (15m)	30	15.634059	15	234.510887
130	3	5 Floors (15m)	30	21.623649	15	324.354732
131	3	4 Floors (12m)	161	24.806459	12	297.677506
132	3	3 Foors (9m)	90	43.888963	9	395.000665
133	3	3 Foors (9m)	90	37.201728	9	334.815549
134	3	4 Floors (12m)	161	17.68378	12	212.205365
135	3	3 Foors (9m)	90	23.529321	9	211.76389
136	3	3 Foors (9m)	90	4.529994	9	40.76995
137	3	7 Floors(21m)	192	17.535988	21	368.255741
138	3	5 Floors (15m)	30	21.866039	15	327.990592
139	3	3 Foors (9m)	90	15.759085	9	141.831769
140	3	3 Foors (9m)	90	23.799301	9	214.193708
141	3	3 Foors (9m)	90	19.441621	9	174.974588
142	3	4 Floors (12m)	161	28.51359	12	342.163077
143	3	4 Floors (12m)	161	34.394803	12	412.737639
144	3	4 Floors (12m)	161	42.357208	12	508.286496
145	3	4 Floors (12m)	161	41.610949	12	499.331391
146	3	5 Floors (15m)	30	20.451672	15	306.775074
147	3	3 Foors (9m)	90	21.494584	9	193.451254
148	3	4 Floors (12m)	161	18.58137	12	222.976441
149	3	4 Floors (12m)	161	29.682724	12	356.192693
150	3	4 Floors (12m)	161	13.559271	12	162.711252
151	3	4 Floors (12m)	161	47.694402	12	572.332819
152	3	4 Floors (12m)	161	35.473809	12	425.685711
153	3	3 Foors (9m)	90	30.481182	9	274.330638
154	3	4 Floors (12m)	161	61.491565	12	737.898783
155	3	4 Floors (12m)	161	53.82094	12	645.851277
156	3	4 Floors (12m)	161	27.917436	12	335.009236
157	3	4 Floors (12m)	161	28.33005	12	339.960603
158	3	4 Floors (12m)	161	69.528562	12	834.34274
159	3	5 Floors (15m)	30	32.519681	15	487.795212
160	3	3 Foors (9m)	90	31.506093	9	283.55484
161	3	3 Foors (9m)	90	27.076292	9	243.686624
162	3	4 Floors (12m)	161	24.53	12	294.360004
163	3	4 Floors (12m)	161	31.521649	12	378.259789

164	3	4 Floors (12m)	161		49.095714	12	589.148572
165	3	4 Floors (12m)	161		34.058074	12	408.696893
166	3	5 Floors (15m)	30		17.926168	15	268.892521
167	3	5 Floors (15m)	30		36.924988	15	553.874817
168	3	5 Floors (15m)	30		26.037771	15	390.566558
169	3	5 Floors (15m)	30		8.728262	15	130.923925
170	3	4 Floors (12m)	161		18.047788	12	216.57345
171	3	4 Floors (12m)	161		42.332322	12	507.987866
172	3	5 Floors (15m)	30		21.426714	15	321.400706
173	3	6 Floors (18m)	222		26.054069	18	468.973245
174	3	4 Floors (12m)	161		26.599976	12	319.199714
175	3	5 Floors (15m)	30		25.449605	15	381.744082
176	3	4 Floors (12m)	161		18.746727	12	224.960727
177	3	4 Floors (12m)	161		25.056323	12	300.675874
178	3	3 Foors (9m)	90		42.610252	9	383.492267
179	3	4 Floors (12m)	161		23.582244	12	282.986931
180	3	3 Foors (9m)	90		22.745944	9	204.713492
181	3	5 Floors (15m)	30		29.000803	15	435.012045
182	3	4 Floors (12m)	161		27.836501	12	334.038007
183	3	4 Floors (12m)	161		37.995449	12	455.945391
184	3	4 Floors (12m)	161		49.561918	12	594.743011
185	3	4 Floors (12m)	161		25.656847	12	307.882169
186	3	5 Floors (15m)	30		11.65607	15	174.84105
187	3	4 Floors (12m)	161		19.093562	12	229.122749
188	3	4 Floors (12m)	161		27.965828	12	335.589931
189	3	4 Floors (12m)	161	Market	31.679038	12	380.14846
190	3	4 Floors (12m)	161		14.477446	12	173.729353
191	3	7 Floors(21m)	192		26.782238	21	562.426994
192	3	7 Floors(21m)	192		50.028918	21	1050.607274
193	3	4 Floors (12m)	161		28.249554	12	338.994654
194	3	4 Floors (12m)	161		27.105083	12	325.260994
195	3	4 Floors (12m)	161		30.622277	12	367.46732
196	3	4 Floors (12m)	161		39.873321	12	478.479849
197	3	4 Floors (12m)	161		73.226927	12	878.723121
198	3	4 Floors (12m)	161		39.757293	12	477.087516
199	3	4 Floors (12m)	161		18.479512	12	221.754145
200	3	4 Floors (12m)	161		18.53445	12	222.413406
201	3	5 Floors (15m)	30		50.978831	15	764.682466
202	3	4 Floors (12m)	161		32.034852	12	384.41822
203	3	3 Foors (9m)	90		23.992292	9	215.930628
204	3	5 Floors (15m)	30		18.451816	15	276.777246
205	3	5 Floors (15m)	30		43.404579	15	651.068691
206	3	4 Floors (12m)	161		26.120652	12	313.447826
207	3	4 Floors (12m)	161		14.5242	12	174.290406
208	3	5 Floors (15m)	30		44.755625	15	671.334379
209	3	3 Foors (9m)	90		10.691379	9	96.222411
210	3	3 Foors (9m)	90		36.724798	9	330.523181
211	3	4 Floors (12m)	161		46.8231	12	561.877196
212	3	4 Floors (12m)	161		60.576397	12	726.916768
213	3	3 Foors (9m)	90		30.603484	9	275.431354
214	3	5 Floors (15m)	30		72.678006	15	1090.170095
215	3	5 Floors (15m)	30		32.137561	15	482.063409
216	3	6 Floors (18m)	222		17.315701	18	311.682609
217	3	3 Foors (9m)	90		28.407359	9	255.66623
218	3	4 Floors (12m)	161		40.256831	12	483.081978

219	3	4 Floors (12m)	161	11.142949	12	133.715384
220	3	5 Floors (15m)	30	22.230117	15	333.451748
221	3	7 Floors(21m)	192	28.979311	21	608.565525
222	3	4 Floors (12m)	161	30.153425	12	361.841103
223	3	6 Floors (18m)	222	25.290293	18	455.225272
224	3	7 Floors(21m)	192	58.198692	21	1222.172542
225	3	4 Floors (12m)	161	23.986162	12	287.833947
226	3	3 Foors (9m)	90	42.194126	9	379.747132
227	2	2 Floors (6m)	50	67.815239	6	406.891436
228	2	2 Floors (6m)	50	50.095804	6	300.574825
229	2	2 Floors (6m)	50	101.473817	6	608.842901
230	2	5 Floors (15m)	30	26.486987	15	397.304803
231	2	2 Floors (6m)	50	24.924	6	149.544
232	2	3 Foors (9m)	90	58.168808	9	523.51927
233	2	5 Floors (15m)	30	19.477679	15	292.165183
234	2	4 Floors (12m)	161	42.528072	12	510.336863
235	2	3 Foors (9m)	90	38.358161	9	345.223446
236	2	4 Floors (12m)	161	68.048149	12	816.577791
237	2	4 Floors (12m)	161	10.668308	12	128.01969
238	2	2 Floors (6m)	50	93.041115	6	558.246692
239	2	4 Floors (12m)	161	37.451278	12	449.415338
240	2	3 Foors (9m)	90	28.220816	9	253.987344
241	2	3 Foors (9m)	90	26.808272	9	241.27445
242	2	3 Foors (9m)	90	60.967741	9	548.709671
243	2	3 Foors (9m)	90	30.209917	9	271.889254
244	2	3 Foors (9m)	90	39.542292	9	355.880624
245	2	2 Floors (6m)	50	40.678606	6	244.071635
246	2	4 Floors (12m)	161	24.588649	12	295.063791
247	2	1 Floor (3m)	210	21.894462	3	65.683386
248	2	1 Floor (3m)	210	7.671843	3	23.01553
249	2	2 Floors (6m)	50	53.541029	6	321.246171
250	2	3 Foors (9m)	90	48.657306	9	437.91575
251	2	2 Floors (6m)	50	41.073315	6	246.439893
252	2	2 Floors (6m)	50	38.297259	6	229.783554
253	2	6 Floors (18m)	222	70.338797	18	1266.098351
254	2	3 Foors (9m)	90	25.079509	9	225.715579
255	2	2 Floors (6m)	50	66.874066	6	401.244394
256	2	6 Floors (18m)	222	41.968995	18	755.441918
257	2	5 Floors (15m)	30	89.83516	15	1347.527402
258	2	4 Floors (12m)	161	91.297429	12	1095.569144
259	2	6 Floors (18m)	222	80.209299	18	1443.767383
260	2	6 Floors (18m)	222	34.049341	18	612.888146
261	2	1 Floor (3m)	210	61.849245	3	185.547735
262	2	2 Floors (6m)	50	77.130523	6	462.783138
263	2	4 Floors (12m)	161	60.879452	12	730.553421
264	2	3 Foors (9m)	90	35.579994	9	320.219949
265	2	3 Foors (9m)	90	38.950013	9	350.550116
266	2	4 Floors (12m)	161	34.121324	12	409.455893
267	2	3 Foors (9m)	90	59.137732	9	532.239591
268	2	4 Floors (12m)	161	45.760248	12	549.122978
269	2	5 Floors (15m)	30	22.899924	15	343.498866
270	2	4 Floors (12m)	161	53.12335	12	637.480203
271	2	4 Floors (12m)	161	51.699172	12	620.390069
272	2	3 Foors (9m)	90	47.234292	9	425.108624
273	2	3 Foors (9m)	90	46.110688	9	414.996191

274	2	3 Foors (9m)	90	45.694161	9	411.247453
275	2	3 Foors (9m)	90	34.961598	9	314.65438
276	2	3 Foors (9m)	90	43.378521	9	390.406689
277	2	4 Floors (12m)	161	47.433775	12	569.205299
278	2	3 Foors (9m)	90	49.286859	9	443.58173
279	2	3 Foors (9m)	90	78.872121	9	709.849092
280	2	4 Floors (12m)	161	137.232292	12	1646.787507
281	2	4 Floors (12m)	161	39.507287	12	474.087442
282	2	5 Floors (15m)	30	38.76128	15	581.419197
283	2	3 Foors (9m)	90	60.892388	9	548.031495
284	2	5 Floors (15m)	30	112.363207	15	1685.448106
285	2	4 Floors (12m)	161	96.696576	12	1160.358917
286	2	3 Foors (9m)	90	27.471091	9	247.23982
287	2	3 Foors (9m)	90	28.883079	9	259.947713
288	2	3 Foors (9m)	90	39.873187	9	358.858682
289	2	4 Floors (12m)	161	32.909375	12	394.912503
290	2	3 Foors (9m)	90	38.412626	9	345.713637
291	2	3 Foors (9m)	90	55.540873	9	499.867858
292	2	3 Foors (9m)	90	74.733031	9	672.597276
293	2	3 Foors (9m)	90	41.742828	9	375.685451
294	2	3 Foors (9m)	90	50.269936	9	452.42942
295	2	3 Foors (9m)	90	55.035546	9	495.319913
296	2	3 Foors (9m)	90	63.189727	9	568.707543
297	2	3 Foors (9m)	90	52.109531	9	468.985783
298	2	3 Foors (9m)	90	54.385471	9	489.469242
299	2	3 Foors (9m)	90	51.13187	9	460.186831
300	2	3 Foors (9m)	90	44.050569	9	396.455123
301	2	3 Foors (9m)	90	31.936152	9	287.425372
302	2	6 Floors (18m)	222	46.626379	18	839.274828
303	2	6 Floors (18m)	222	14.744194	18	265.3955
304	2	2 Floors (6m)	50	28.239963	6	169.439776
305	2	3 Foors (9m)	90	41.612132	9	374.509187
306	2	3 Foors (9m)	90	42.889691	9	386.00722
307	2	2 Floors (6m)	50	55.514699	6	333.088195
308	2	2 Floors (6m)	50	42.876252	6	257.257514
309	2	3 Foors (9m)	90	59.173935	9	532.565411
310	2	3 Foors (9m)	90	69.41135	9	624.702148
311	2	2 Floors (6m)	50	41.649437	6	249.896624
312	2	3 Foors (9m)	90	40.85604	9	367.704364
313	2	2 Floors (6m)	50	37.983039	6	227.898236
314	2	4 Floors (12m)	161	31.37981	12	376.557722
315	2	2 Floors (6m)	50	38.83574	6	233.014441
316	2	4 Floors (12m)	161	18.576619	12	222.919428
317	2	3 Foors (9m)	90	48.644996	9	437.804964
318	2	4 Floors (12m)	161	28.930012	12	347.160141
319	2	6 Floors (18m)	222	43.147332	18	776.651978
320	2	4 Floors (12m)	161	50.242508	12	602.910097
321	2	2 Floors (6m)	50	51.370293	6	308.221761
322	2	2 Floors (6m)	50	45.44581	6	272.67486
323	2	3 Foors (9m)	90	46.301377	9	416.712389
324	2	3 Foors (9m)	90	39.944923	9	359.504307
325	2	2 Floors (6m)	50	45.806027	6	274.836165
326	2	3 Foors (9m)	90	42.947303	9	386.525728
327	2	3 Foors (9m)	90	39.103948	9	351.935529
328	2	2 Floors (6m)	50	32.201703	6	193.210215

329	2	6 Floors (18m)	222	50.349009	18	906.28216
330	2	2 Floors (6m)	50	37.73814	6	226.42884
331	2	4 Floors (12m)	161	37.489137	12	449.86964
332	2	3 Foors (9m)	90	36.108086	9	324.972774
333	2	4 Floors (12m)	161	43.448118	12	521.377411
334	2	2 Floors (6m)	50	34.99063	6	209.943778
335	2	1 Floor (3m)	210	34.266593	3	102.79978
336	2	3 Foors (9m)	90	55.687046	9	501.183412
337	2	4 Floors (12m)	161	55.849344	12	670.192133
338	2	1 Floor (3m)	210	32.202402	3	96.607206
339	2	3 Foors (9m)	90	31.792998	9	286.136983
340	2	3 Foors (9m)	90	26.215495	9	235.939456
341	2	2 Floors (6m)	50	31.936283	6	191.6177
342	2	3 Foors (9m)	90	44.00138	9	396.012422
343	2	2 Floors (6m)	50	29.871278	6	179.227666
344	2	3 Foors (9m)	90	28.099226	9	252.89303
345	2	4 Floors (12m)	161	50.628197	12	607.53837
346	2	3 Foors (9m)	90	45.003611	9	405.032499
347	2	3 Foors (9m)	90	42.341442	9	381.072976
348	2	3 Foors (9m)	90	42.051122	9	378.460097
349	2	3 Foors (9m)	90	46.55053	9	418.954772
350	2	3 Foors (9m)	90	49.918573	9	449.267155
351	2	3 Foors (9m)	90	25.084751	9	225.762759
352	2	6 Floors (18m)	222	50.797626	18	914.357268
353	2	4 Floors (12m)	161	39.684788	12	476.217459
354	2	4 Floors (12m)	161	50.178377	12	602.140524
355	2	4 Floors (12m)	161	52.676082	12	632.11298
356	2	4 Floors (12m)	161	44.643995	12	535.727944
357	2	3 Foors (9m)	90	33.319911	9	299.879198
358	2	2 Floors (6m)	50	42.196232	6	253.17739
359	2	2 Floors (6m)	50	49.4255	6	296.553003
360	2	3 Foors (9m)	90	47.953794	9	431.584143
361	2	4 Floors (12m)	161	41.080631	12	492.967569
362	2	3 Foors (9m)	90	42.548878	9	382.9399
363	2	3 Foors (9m)	90	45.80347	9	412.231232
364	2	4 Floors (12m)	161	46.442174	12	557.30609
365	2	4 Floors (12m)	161	54.650508	12	655.8061
366	2	2 Floors (6m)	50	48.638829	6	291.832971
367	2	4 Floors (12m)	161	54.782531	12	657.390375
368	2	2 Floors (6m)	50	50.148944	6	300.893663
369	2	6 Floors (18m)	222	57.58274	18	1036.489326
370	2	3 Foors (9m)	90	59.896475	9	539.068278
371	2	3 Foors (9m)	90	41.677817	9	375.100357
372	2	2 Floors (6m)	50	37.703589	6	226.221534
373	2	4 Floors (12m)	161	41.095874	12	493.150485
374	2	3 Foors (9m)	90	49.992953	9	449.936579
375	2	4 Floors (12m)	161	43.501167	12	522.014009
376	2	4 Floors (12m)	161	51.491887	12	617.902643
377	2	4 Floors (12m)	161	42.504252	12	510.05102
378	2	3 Foors (9m)	90	51.41873	9	462.768573
379	2	3 Foors (9m)	90	39.341067	9	354.069606
380	2	3 Foors (9m)	90	58.655169	9	527.896524
381	2	3 Foors (9m)	90	58.867569	9	529.808123
382	2	3 Foors (9m)	90	61.719295	9	555.473659
383	2	2 Floors (6m)	50	44.744429	6	268.466574

384	2	2 Floors (6m)	50	37.049028	6	222.294166
385	2	2 Floors (6m)	50	39.488434	6	236.930602
386	2	3 Foors (9m)	90	62.939771	9	566.457939
387	2	3 Foors (9m)	90	82.644425	9	743.799827
388	2	3 Foors (9m)	90	59.147209	9	532.324882
389	2	1 Floor (3m)	210	64.146279	3	192.438836
390	2	3 Foors (9m)	90	45.428163	9	408.853466
391	2	3 Foors (9m)	90	30.231614	9	272.08453
392	2	1 Floor (3m)	210	77.033629	3	231.100886
393	2	1 Floor (3m)	210	58.602587	3	175.80776
394	2	2 Floors (6m)	50	80.779208	6	484.675247
395	2	3 Foors (9m)	90	71.366495	9	642.298455
396	2	3 Foors (9m)	90	69.205468	9	622.849215
397	2	1 Floor (3m)	210	8.982772	3	26.948315
398	2	3 Foors (9m)	90	41.64678	9	374.821018
399	2	3 Foors (9m)	90	63.289409	9	569.604677
400	2	3 Foors (9m)	90	47.413066	9	426.717598
401	2	4 Floors (12m)	161	69.812382	12	837.74859
402	2	5 Floors (15m)	30	61.146807	15	917.202103
403	2	1 Floor (3m)	210	40.648172	3	121.944516
404	2	5 Floors (15m)	30	36.346086	15	545.19129
405	2	4 Floors (12m)	161	39.103933	12	469.247196
406	2	3 Foors (9m)	90	42.232935	9	380.096418
407	2	6 Floors (18m)	222	53.9396	18	970.912807
408	2	3 Foors (9m)	90	49.241538	9	443.173841
409	2	6 Floors (18m)	222	56.337022	18	1014.066393
410	2	4 Floors (12m)	161	44.458247	12	533.498959
411	2	4 Floors (12m)	161	56.926537	12	683.118443
412	2	3 Foors (9m)	90	53.028577	9	477.257195
413	2	1 Floor (3m)	210	42.081794	3	126.245381
414	2	3 Foors (9m)	90	67.590858	9	608.317721
415	2	6 Floors (18m)	222	66.998337	18	1205.970064
416	2	2 Floors (6m)	50	58.964694	6	353.788162
417	2	5 Floors (15m)	30	20.873075	15	313.096127
418	1	3 Foors (9m)	90	26.863324	9	241.76992
419	1	3 Foors (9m)	90	49.339952	9	444.059567
420	1	3 Foors (9m)	90	38.164268	9	343.47841
421	1	3 Foors (9m)	90	22.703759	9	204.333828
422	1	5 Floors (15m)	30	34.824684	15	522.37026
423	1	2 Floors (6m)	50	32.403121	6	194.418728
424	1	3 Foors (9m)	90	33.964933	9	305.684394
425	1	3 Foors (9m)	90	34.749837	9	312.748534
426	1	3 Foors (9m)	90	66.595387	9	599.35848
427	1	4 Floors (12m)	161	28.56308	12	342.756966
428	1	6 Floors (18m)	222	151.092702	18	2719.668643
429	1	6 Floors (18m)	222	105.298055	18	1895.364981
430	1	6 Floors (18m)	222	52.183273	18	939.298912
431	1	6 Floors (18m)	222	16.094409	18	289.699368
432	1	5 Floors (15m)	30	15.16735	15	227.510255
433	1	4 Floors (12m)	161	61.145157	12	733.741882
434	1	7 Floors(21m)	192	82.087877	21	1723.845409
435	1	6 Floors (18m)	222	84.647513	18	1523.65523
436	1	5 Floors (15m)	30	42.159786	15	632.396785
437	1	5 Floors (15m)	30	68.256004	15	1023.84006
438	1	6 Floors (18m)	222	70.174046	18	1263.132823

439	1	5 Floors (15m)	30	52.353887	15	785.308305
440	1	6 Floors (18m)	222	88.363841	18	1590.549133
441	1	6 Floors (18m)	222	15.95086	18	287.115481
442	1	4 Floors (12m)	161	11.108312	12	133.299741
443	1	4 Floors (12m)	161	61.134603	12	733.615238
444	1	3 Foors (9m)	90	29.814783	9	268.333048
445	1	3 Foors (9m)	90	45.380934	9	408.428407
446	1	3 Foors (9m)	90	38.770888	9	348.93799
447	1	3 Foors (9m)	90	93.095485	9	837.859361
448	1	1 Floor (3m)	210	32.597407	3	97.79222
449	1	1 Floor (3m)	210	33.930816	3	101.792448
450	1	4 Floors (12m)	161	48.992768	12	587.913218
451	1	3 Foors (9m)	90	46.339359	9	417.054235
452	1	4 Floors (12m)	161	39.162769	12	469.953231
453	1	4 Floors (12m)	161	60.813453	12	729.761431
454	1	3 Foors (9m)	90	98.658536	9	887.926824
455	1	5 Floors (15m)	30	76.612621	15	1149.189316
456	1	4 Floors (12m)	161	27.956379	12	335.476542
457	1	2 Floors (6m)	50	88.617827	6	531.706959
458	1	6 Floors (18m)	222	37.053274	18	666.958925
459	1	5 Floors (15m)	30	21.351398	15	320.270967
460	1	5 Floors (15m)	30	39.150909	15	587.263632
461	1	5 Floors (15m)	30	37.419732	15	561.295986
462	1	5 Floors (15m)	30	55.407558	15	831.113377
463	1	4 Floors (12m)	161	33.455748	12	401.468979
464	1	3 Foors (9m)	90	32.454115	9	292.087031
465	1	2 Floors (6m)	50	8.526647	6	51.159879
466	1	6 Floors (18m)	222	66.26866	18	1192.835873
467	1	3 Foors (9m)	90	45.502933	9	409.526399
468	1	1 Floor (3m)	210	22.532442	3	67.597326
469	1	2 Floors (6m)	50	39.063032	6	234.378192
470	1	3 Foors (9m)	90	37.406988	9	336.662888
471	1	2 Floors (6m)	50	41.659917	6	249.959501
472	1	3 Foors (9m)	90	18.894745	9	170.052705
473	1	3 Foors (9m)	90	52.485066	9	472.365591
474	1	3 Foors (9m)	90	40.781509	9	367.033585
475	1	2 Floors (6m)	50	32.472618	6	194.835706
476	1	1 Floor (3m)	210	58.164195	3	174.492584
477	1	1 Floor (3m)	210	39.551765	3	118.655296
478	1	1 Floor (3m)	210	37.69585	3	113.087551
479	1	1 Floor (3m)	210	55.294673	3	165.88402
480	1	3 Foors (9m)	90	23.893977	9	215.045793
481	1	2 Floors (6m)	50	34.884385	6	209.306311
482	1	2 Floors (6m)	50	18.910714	6	113.464281
483	1	2 Floors (6m)	50	31.855994	6	191.135961
484	1	1 Floor (3m)	210	35.932116	3	107.796349
485	1	1 Floor (3m)	210	106.868196	3	320.604588
486	1	3 Foors (9m)	90	49.145811	9	442.312295
487	1	2 Floors (6m)	50	43.394623	6	260.367739
488	1	2 Floors (6m)	50	72.107667	6	432.645999
489	1	6 Floors (18m)	222	46.96996	18	845.459275
490	1	3 Foors (9m)	90	104.230909	9	938.078178
491	1	1 Floor (3m)	210	30.127093	3	90.381279
492	1	1 Floor (3m)	210	34.005618	3	102.016855
493	1	1 Floor (3m)	210	52.777343	3	158.332029

494	1	1 Floor (3m)	210	33.359733	3	100.079199
495	1	1 Floor (3m)	210	57.100638	3	171.301915
496	1	1 Floor (3m)	210	37.674314	3	113.022943
497	1	2 Floors (6m)	50	44.182193	6	265.09316
498	1	2 Floors (6m)	50	57.347145	6	344.082868
499	1	2 Floors (6m)	50	26.53728	6	159.223683
500	1	2 Floors (6m)	50	24.828076	6	148.968456
501	1	1 Floor (3m)	210	88.573503	3	265.720509
502	1	1 Floor (3m)	210	29.757517	3	89.272551
503	1	3 Foors (9m)	90	56.699253	9	510.293274
504	1	1 Floor (3m)	210	21.827852	3	65.483556
505	1	1 Floor (3m)	210	40.380957	3	121.14287
506	1	1 Floor (3m)	210	26.937158	3	80.811473
507	1	1 Floor (3m)	210	105.162955	3	315.488866
508	1	3 Foors (9m)	90	27.910007	9	251.190063
509	1	1 Floor (3m)	210	24.2949	3	72.8847
510	1	2 Floors (6m)	50	54.16259	6	324.975537
511	1	1 Floor (3m)	210	25.914093	3	77.74228
512	1	1 Floor (3m)	210	26.783408	3	80.350223
513	1	3 Foors (9m)	90	30.562325	9	275.060924
514	1	3 Foors (9m)	90	25.284925	9	227.564323
515	1	3 Foors (9m)	90	39.886818	9	358.981361
516	1	2 Floors (6m)	50	37.837571	6	227.025425
517	1	2 Floors (6m)	50	44.05108	6	264.306483
518	1	1 Floor (3m)	210	43.874511	3	131.623532
519	1	3 Foors (9m)	90	38.824966	9	349.424698
520	1	5 Floors (15m)	30	30.493561	15	457.403408
521	1	1 Floor (3m)	210	47.545232	3	142.635696
522	1	1 Floor (3m)	210	51.581724	3	154.745172
523	1	1 Floor (3m)	210	27.008785	3	81.026356
524	1	1 Floor (3m)	210	36.11843	3	108.355289
525	1	1 Floor (3m)	210	31.533829	3	94.601486
526	1	2 Floors (6m)	50	20.600784	6	123.604707
527	1	1 Floor (3m)	210	43.209243	3	129.627729
528	1	1 Floor (3m)	210	48.745613	3	146.236838
529	1	1 Floor (3m)	210	41.177855	3	123.533566
530	1	3 Foors (9m)	90	21.192991	9	190.736923
531	1	3 Foors (9m)	90	39.086303	9	351.776727
532	1	1 Floor (3m)	210	93.18838	3	279.565141
533	1	3 Foors (9m)	90	50.759214	9	456.83293
534	1	3 Foors (9m)	90	86.946295	9	782.516654
535	1	3 Foors (9m)	90	65.915244	9	593.237199
536	1	3 Foors (9m)	90	93.712696	9	843.414265
537	1	1 Floor (3m)	210	38.557705	3	115.673114
538	1	3 Foors (9m)	90	35.122953	9	316.106581
539	1	2 Floors (6m)	50	56.622328	6	339.733966
540	1	2 Floors (6m)	50	68.146577	6	408.879465
541	1	4 Floors (12m)	161	105.456955	12	1265.483458
542	1	3 Foors (9m)	90	45.820167	9	412.381506
543	1	3 Foors (9m)	90	48.217165	9	433.954486
544	1	3 Foors (9m)	90	47.292108	9	425.628968
545	1	3 Foors (9m)	90	21.638175	9	194.743575
546	1	2 Floors (6m)	50	3.018344	6	18.110063
547	1	4 Floors (12m)	161	59.358854	12	712.306247
548	1	7 Floors(21m)	192	62.572759	21	1314.027939

549	1	4 Floors (12m)	161	50.825944	12	609.911326
550	1	4 Floors (12m)	161	23.161984	12	277.94381
551	1	2 Floors (6m)	50	59.696176	6	358.177054
552	1	7 Floors(21m)	192	47.954813	21	1007.051075
553	1	4 Floors (12m)	161	52.988119	12	635.857428
554	1	3 Foors (9m)	90	31.643737	9	284.793637
555	1	2 Floors (6m)	50	96.982797	6	581.896784
556	1	5 Floors (15m)	30	45.204091	15	678.061369
557	1	5 Floors (15m)	30	35.315621	15	529.734315
558	1	1 Floor (3m)	210	166.161843	3	498.485528
559	1	2 Floors (6m)	50	31.526873	6	189.161236
560	1	2 Floors (6m)	50	115.857831	6	695.146984
561	1	7 Floors(21m)	192	61.814893	21	1298.112743
562	1	7 Floors(21m)	192	61.694515	21	1295.58482
563	1	2 Floors (6m)	50	35.795197	6	214.771181
564	1	4 Floors (12m)	161	114.146603	12	1369.759239
565	1	7 Floors(21m)	192	125.256195	21	2630.38009
566	1	7 Floors(21m)	192	23.766679	21	499.100263
567	1	6 Floors (18m)	222	22.900697	18	412.21255
568	1	6 Floors (18m)	222	22.498421	18	404.971582
569	1	3 Foors (9m)	90	31.394573	9	282.551155
570	1	7 Floors(21m)	192	125.739811	21	2640.536021
571	1	5 Floors (15m)	30	44.712885	15	670.693271
572	1	3 Foors (9m)	90	55.447338	9	499.026043
573	1	7 Floors(21m)	192	43.004196	21	903.088115
574	1	1 Floor (3m)	210	49.959484	3	149.878452
575	1	3 Foors (9m)	90	33.497011	9	301.4731
576	1	3 Foors (9m)	90	24.038095	9	216.342852
577	1	3 Foors (9m)	90	37.161991	9	334.457916
578	1	4 Floors (12m)	161	40.693738	12	488.324855
579	1	3 Foors (9m)	90	51.498692	9	463.48823
580	1	4 Floors (12m)	161	54.509558	12	654.114691
581	1	4 Floors (12m)	161	38.313321	12	459.759849
582	1	2 Floors (6m)	50	64.440209	6	386.641254
583	1	3 Foors (9m)	90	35.046287	9	315.416584
584	1	5 Floors (15m)	30	36.658666	15	549.87999
585	1	3 Foors (9m)	90	49.023362	9	441.21026
586	1	2 Floors (6m)	50	55.668582	6	334.011492
587	1	2 Floors (6m)	50	27.587803	6	165.526816
588	1	4 Floors (12m)	161	71.001942	12	852.023308
589	1	3 Foors (9m)	90	59.94782	9	539.530384
590	1	4 Floors (12m)	161	57.221871	12	686.662453
591	1	4 Floors (12m)	161	51.13523	12	613.622755
592	1	4 Floors (12m)	161	79.438507	12	953.262081
593	1	3 Foors (9m)	90	26.085578	9	234.7702
594	1	5 Floors (15m)	30	21.613196	15	324.197935
595	1	6 Floors (18m)	222	50.306589	18	905.518604
596	1	6 Floors (18m)	222	56.717196	18	1020.909521
597	1	5 Floors (15m)	30	42.79395	15	641.909244
598	1	6 Floors (18m)	222	66.71536	18	1200.876478
599	1	4 Floors (12m)	161	69.826472	12	837.917667
600	1	7 Floors(21m)	192	36.203455	21	760.272562
601	1	5 Floors (15m)	30	67.512164	15	1012.682467
602	1	3 Foors (9m)	90	46.533176	9	418.798583
603	1	3 Foors (9m)	90	40.46947	9	364.225232

604	1	4 Floors (12m)	161	43.699929	12	524.399146
605	1	3 Foors (9m)	90	64.842117	9	583.579053
606	1	4 Floors (12m)	161	46.172914	12	554.074964
607	1	3 Foors (9m)	90	74.675217	9	672.076956
608	1	3 Foors (9m)	90	113.9863	9	1025.876701
609	1	2 Floors (6m)	50	71.290006	6	427.740036
610	1	5 Floors (15m)	30	138.331405	15	2074.971079
611	1	4 Floors (12m)	161	30.856503	12	370.278037
612	1	7 Floors(21m)	192	76.753177	21	1611.816711
613	1	7 Floors(21m)	192	49.793283	21	1045.658951
614	1	3 Foors (9m)	90	53.076914	9	477.692224
615	1	3 Foors (9m)	90	38.676305	9	348.086741
616	1	2 Floors (6m)	50	41.143474	6	246.860846
617	1	2 Floors (6m)	50	39.377671	6	236.266025
618	1	3 Foors (9m)	90	68.133791	9	613.204122
619	1	4 Floors (12m)	161	43.813349	12	525.76019
620	1	5 Floors (15m)	30	11.531789	15	172.976835
621	2	4 Floors (12m)	161	370.219471	12	4442.633654
622	2	3 Foors (9m)	90	53.608713	9	482.478419
623	2	3 Foors (9m)	90	56.140311	9	505.262802
624	3	3 Foors (9m)	90	56.857875	9	511.720875
625	3	3 Foors (9m)	90	18.329742	9	164.967676
626	3	3 Foors (9m)	90	19.092042	9	171.828378
627	3	4 Floors (12m)	161	17.258901	12	207.106812
628	3	3 Foors (9m)	90	23.810251	9	214.292261
629	3	4 Floors (12m)	161	50.490662	12	605.887939
630	3	4 Floors (12m)	161	34.173522	12	410.082266
631	3	4 Floors (12m)	161	32.583507	12	391.002081
632	3	5 Floors (15m)	30	13.9368	15	209.051997
633	3	4 Floors (12m)	161	22.558756	12	270.705072
634	3	3 Foors (9m)	90	24.913302	9	224.219719
635	3	2 Floors (6m)	50	36.215507	6	217.293043
636	3	3 Foors (9m)	90	37.856229	9	340.706061
637	3	4 Floors (12m)	161	46.607116	12	559.285391
638	3	4 Floors (12m)	161	20.321348	12	243.856178
639	3	4 Floors (12m)	161	36.974791	12	443.697494
640	3	3 Foors (9m)	90	14.249085	9	128.241763
641	3	5 Floors (15m)	30	29.397696	15	440.965438
642	3	5 Floors (15m)	30	49.993253	15	749.898788
643	3	5 Floors (15m)	30	79.867584	15	1198.01376
644	1	4 Floors (12m)	161	1228.561424	12	14742.73708
645	3	5 Floors (15m)	30	63.552311	15	953.28467
646	3	4 Floors (12m)	161	68.175986	12	818.111834
647	3	4 Floors (12m)	161	22.546939	12	270.563268
648	3	5 Floors (15m)	30	33.499254	15	502.488817
649	2	2 Floors (6m)	50	113.316445	6	679.898668
650	2	1 Floor (3m)	210	68.996532	3	206.989596
651	2	4 Floors (12m)	161	16.359159	12	196.309908
652	2	4 Floors (12m)	161	26.489582	12	317.874979
653	3	4 Floors (12m)	161	72.15945	12	865.913404
654	3	4 Floors (12m)	161	26.637384	12	319.648613
655	3	3 Foors (9m)	90	70.051911	9	630.467202
656	3	3 Foors (9m)	90	28.397456	9	255.577105
657	3	3 Foors (9m)	90	20.942352	9	188.481164
658	3	5 Floors (15m)	30	13.869166	15	208.037488

659	3	5 Floors (15m)	30		12.540482	15	188.107231
660	3	3 Foors (9m)	90		34.84726	9	313.625339
661	3	3 Foors (9m)	90		19.883961	9	178.955653
662	3	4 Floors (12m)	161		18.311534	12	219.738411
663	3	4 Floors (12m)	161		28.214683	12	338.576202
664	3	4 Floors (12m)	161		34.663938	12	415.967251
665	3	4 Floors (12m)	161		31.465295	12	377.583538
666	3	3 Foors (9m)	90		40.901387	9	368.112486
667	3	3 Foors (9m)	90		78.899044	9	710.091394
668	3	6 Floors (18m)	222		27.562875	18	496.131742
669	3	6 Floors (18m)	222		55.827877	18	1004.901789
670	3	4 Floors (12m)	161		42.919657	12	515.035882
671	1	4 Floors (12m)	161		50.308194	12	603.698333
672	1	7 Floors(21m)	192		107.800406	21	2263.808531
673	1	5 Floors (15m)	30		40.192728	15	602.890927
674	1	2 Floors (6m)	50		40.094	6	240.563997
675	2	1 Floor (3m)	210		15.695199	3	47.085598
676	2	1 Floor (3m)	210		16.592635	3	49.777906
677	3	4 Floors (12m)	161		20.240944	12	242.891327
678	3	4 Floors (12m)	161	Bar_Rest	26.596717	12	319.160608
679	1	3 Foors (9m)	90		14.953411	9	134.580696
680	1	3 Foors (9m)	90		115.073639	9	1035.66275
681	1	3 Foors (9m)	90		54.76685	9	492.901652
682	1	3 Foors (9m)	90		46.087456	9	414.787107
683	1	3 Foors (9m)	90		28.027844	9	252.250598
684	1	3 Foors (9m)	90		50.598884	9	455.389954
685	1	2 Floors (6m)	50		42.87065	6	257.223897
686	1	5 Floors (15m)	30		54.415964	15	816.239466
687	1	4 Floors (12m)	161		68.781287	12	825.375444
688	1	4 Floors (12m)	161		38.177296	12	458.127554
689	1	1 Floor (3m)	210		49.607296	3	148.821888
690	1	4 Floors (12m)	161		66.887194	12	802.646326
691	1	3 Foors (9m)	90		135.829805	9	1222.468246
692	1	3 Foors (9m)	90		40.364815	9	363.283338
693	1	3 Foors (9m)	90		129.801155	9	1168.210392
694	1	3 Foors (9m)	90		8.581954	9	77.237589
695	1	3 Foors (9m)	90		39.655363	9	356.898263
696	1	3 Foors (9m)	90		14.038037	9	126.342335
697	1	3 Foors (9m)	90		40.36905	9	363.321446
698	1	3 Foors (9m)	90		42.479778	9	382.317999
699	1	3 Foors (9m)	90		64.933402	9	584.400618
700	1	3 Foors (9m)	90		64.933402	9	584.400618
701	2	1 Floor (3m)	210		13.317833	3	39.9535
702	2	4 Floors (12m)	161		24.295428	12	291.54514
703	2	4 Floors (12m)	161		32.191085	12	386.293017
704	2	3 Foors (9m)	90		103.443891	9	930.995016
705	2	3 Foors (9m)	90		112.893394	9	1016.040545
706	2	3 Foors (9m)	90		64.422351	9	579.801161
707	2	3 Foors (9m)	90		38.250545	9	344.254905
708	2	3 Foors (9m)	90		142.900061	9	1286.100552
709	2	3 Foors (9m)	90		99.43088	9	894.877918
710	2	3 Foors (9m)	90		46.283239	9	416.549149
711	2	3 Foors (9m)	90		68.204021	9	613.836192
712	2	3 Foors (9m)	90		109.678434	9	987.105907
713	2	3 Foors (9m)	90		19.149737	9	172.347636

714	2	2 Floors (6m)	50		75.413166	6	452.478994
715	2	1 Floor (3m)	210		13.065303	3	39.195909
716	2	1 Floor (3m)	210		52.727704	3	158.183111
717	2	1 Floor (3m)	210		38.6177	3	115.853101
718	2	3 Foors (9m)	90		32.707965	9	294.371689
719	2	4 Floors (12m)	161		144.839674	12	1738.076083
720	2	4 Floors (12m)	161		47.686751	12	572.241008
721	2	4 Floors (12m)	161		50.634869	12	607.61843
722	2	4 Floors (12m)	161		49.446021	12	593.35225
723	2	4 Floors (12m)	161		137.344783	12	1648.137396
724	2	4 Floors (12m)	161		41.070446	12	492.845351
725	2	4 Floors (12m)	161		58.797279	12	705.567342
726	2	4 Floors (12m)	161		76.680901	12	920.170813
727	2	4 Floors (12m)	161		43.684195	12	524.210337
728	2	4 Floors (12m)	161		101.400662	12	1216.807945
729	2	4 Floors (12m)	161		70.120455	12	841.445455
730	2	4 Floors (12m)	161		49.414837	12	592.978048
731	2	4 Floors (12m)	161		82.083833	12	985.005997
732	2	5 Floors (15m)	30		88.926739	15	1333.901089
733	2	5 Floors (15m)	30		33.583245	15	503.748668
734	2	5 Floors (15m)	30		37.11147	15	556.672046
735	2	5 Floors (15m)	30		31.693098	15	475.396469
736	2	6 Floors (18m)	222		146.327391	18	2633.893047
737	2	6 Floors (18m)	222		143.174559	18	2577.14207
738	2	6 Floors (18m)	222		26.16577	18	470.983856
739	2	7 Floors(21m)	192		168.692547	21	3542.543495
740	2	7 Floors(21m)	192		144.283062	21	3029.944308
741	2	8 Floors (24m)	160		130.587115	24	3134.090771
742	2	2 Floors (6m)	50		55.803791	6	334.822746
743	2	2 Floors (6m)	50		35.249866	6	211.499199
744	2	3 Foors (9m)	90		53.462844	9	481.1656
745	2	1 Floor (3m)	210		158.431637	3	475.294912
746	2	4 Floors (12m)	161		219.12272	12	2629.472639
747	2	1 Floor (3m)	210		126.35689	3	379.070671
748	2	1 Floor (3m)	210		74.009036	3	222.027107
749	2	1 Floor (3m)	210		117.933098	3	353.799293
750	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
751	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
752	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
753	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
754	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
755	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
756	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
757	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
758	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
759	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
760	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
761	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
762	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
763	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
764	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
765	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
766	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
767	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
768	3	1 Floor (3m)	210	Market	7.019843	3	21.05953

769	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
770	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
771	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
772	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
773	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
774	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
775	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
776	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
777	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
778	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
779	3	1 Floor (3m)	210	Market	7.019843	3	21.05953
780	3	4 Floors (12m)	161		51.228819	12	614.745824
781	3	3 Foors (9m)	90		26.918441	9	242.26597
782	3	1 Floor (3m)	210		36.954566	3	110.863699
783	3	4 Floors (12m)	161		37.087527	12	445.050323
784	3	3 Foors (9m)	90		17.798496	9	160.186463
785	3	4 Floors (12m)	161		17.183316	12	206.19979
786	3	1 Floor (3m)	210		19.424701	3	58.274104
787	3	2 Floors (6m)	50		8.199288	6	49.19573
788	3	2 Floors (6m)	50		4.001509	6	24.009052
789	3	4 Floors (12m)	161		23.284429	12	279.41315
790	3	1 Floor (3m)	210	Education	37.794679	3	113.384038
791	3	4 Floors (12m)	161	Education	28.005238	12	336.06285
792	3	3 Foors (9m)	90		27.027296	9	243.24566
793	3	4 Floors (12m)	161		34.631478	12	415.577731
794	3	6 Floors (18m)	222		70.002073	18	1260.03731
795	3	4 Floors (12m)	161		29.287925	12	351.455106
796	3	3 Foors (9m)	90		37.352557	9	336.173017
797	3	6 Floors (18m)	222		120.36429	18	2166.557219
798	1	3 Foors (9m)	0		1849.460739	9	16645.14665
799	3	3 Foors (9m)	0	Education	41.062902	9	369.566118
800	1	3 Foors (9m)	0		224.582425	9	2021.241825

Appendix 3

Datasheet of the types of Rocinha Zones 1, 2, and 6

FID	Number_A	Type	Diversity
0	6	F_Market	Necessary regular
1	6	F_Market	Necessary regular
2	6	F_Shopping	Necessary occasional
3	2	F_Bar_Rest.	Optional
4	1	F_Bar_Rest.	Optional
5	1	F_Shopping	Necessary occasional
6	1	F_Bar_Rest.	Optional
7	1	F_Shopping	Necessary occasional
8	1	F_Health	Necessary regular
9	1	F_Education	Necessary regular
10	1	F_Education	Necessary regular
11	6	F_Shopping	Necessary occasional
12	6	F_Shopping	Necessary occasional
13	6	F_Shopping	Necessary occasional
14	6	F_Bar_Rest.	Optional
15	6	F_Shopping	Necessary occasional
16	6	F_Market	Necessary regular
17	6	F_Market	Necessary regular
18	6	F_Market	Necessary regular
19	6	F_Market	Necessary regular
20	6	F_Market	Necessary regular
21	6	F_Market	Necessary regular
22	6	F_Market	Necessary regular
23	6	F_Market	Necessary regular
24	6	F_Market	Necessary regular
25	6	F_Market	Necessary regular
26	6	F_Shopping	Necessary occasional
27	2	F_Shopping	Necessary occasional
28	2	F_Shopping	Necessary occasional
29	6	F_Bar_Rest.	Optional
30	2	F_Bar_Rest.	Optional
31	1	F_Bar_Rest.	Optional
32	2	F_Education	Necessary regular
33	6	F_Bar_Rest.	Optional
34	2	F_Education	Necessary regular
35	1	F_Bar_Rest.	Optional
36	1	F_Waste	Necessary regular
37	2	F_Waste	Necessary regular
38	2	F_Waste	Necessary regular
39	2	F_Waste	Necessary regular

Appendix 4

Datasheet of the types of uses modified by the project PolimiparaRocinha Zones 1, 2, and 6

FID	Number_A	Type	Diversity
0	6	F_Market	Necessary regular
1	6	F_Market	Necessary regular
2	6	F_Shopping	Necessary occasional
3	2	F_Bar_Rest.	Optional
4	1	F_Bar_Rest.	Optional
5	1	F_Shopping	Necessary occasional
6	1	F_Bar_Rest.	Optional
7	1	F_Shopping	Necessary occasional
8	1	F_Education	Necessary regular
9	6	F_Shopping	Necessary occasional
10	6	F_Shopping	Necessary occasional
11	6	F_Shopping	Necessary occasional
12	6	F_Bar_Rest.	Optional
13	6	F_Shopping	Necessary occasional
14	6	F_Shopping	Necessary occasional
15	2	F_Shopping	Necessary occasional
16	2	F_Shopping	Necessary occasional
17	6	F_Bar_Rest.	Optional
18	2	F_Bar_Rest.	Optional
19	1	F_Bar_Rest.	Optional
20	2	F_Education	Necessary regular
21	6	F_Bar_Rest.	Optional
22	2	F_Education	Necessary regular
23	2	F_Market	Necessary regular
24	2	F_Education	Necessary regular
25	6	F_Education	Necessary regular
26	6	F_Education	Necessary regular
27	6	F_Bar_Rest.	Optional
28	6	F_Market	Necessary regular
29	6	F_Market	Necessary regular
30	6	F_Market	Necessary regular
31	6	F_Market	Necessary regular
32	6	F_Market	Necessary regular
33	6	F_Market	Necessary regular
34	6	F_Market	Necessary regular
35	6	F_Market	Necessary regular
36	6	F_Market	Necessary regular
37	6	F_Market	Necessary regular
38	6	F_Market	Necessary regular
39	6	F_Market	Necessary regular
40	6	F_Market	Necessary regular
41	6	F_Market	Necessary regular
42	6	F_Market	Necessary regular
43	6	F_Market	Necessary regular
44	6	F_Market	Necessary regular
45	6	F_Market	Necessary regular
46	6	F_Market	Necessary regular
47	6	F_Market	Necessary regular
48	6	F_Market	Necessary regular

49	6	F_Market	Necessary regular
50	6	F_Market	Necessary regular
51	6	F_Market	Necessary regular
52	6	F_Market	Necessary regular
53	6	F_Market	Necessary regular
54	6	F_Market	Necessary regular
55	6	F_Market	Necessary regular
56	6	F_Market	Necessary regular
57	6	F_Market	Necessary regular
58	6	F_Education	Necessary regular
59	6	F_Education	Necessary regular
60	6	F_Education	Necessary regular
61	1	F_Health	Necessary regular
62	1	F_Waste	Necessary regular
63	1	F_Waste	Necessary regular
64	2	F_Waste	Necessary regular
65	2	F_Waste	Necessary regular
66	2	F_Waste	Necessary regular
67	2	F_Waste	Necessary regular
68	6	F_Waste	Necessary regular
69	6	F_Waste	Necessary regular
70	6	F_Waste	Necessary regular
71	6	F_Waste	Necessary regular

Appendix 5

Links of the Verification videos in Rocinha zones 1, 2, and 6

Appendix 5

Links of the Verification videos in Rocinha zones 1, 2, and 6

1. Zone 1 - Rua Dioneia - Friday 13.12.19 at 11.38 am

https://drive.google.com/open?id=1oLWk_bCKtckHsOKMPu8miA7qpd1MJ25V

2. Zone 2 - Estrada da Gavea -Tuesday 17.12.19 at 2 pm (first vide)

https://drive.google.com/open?id=1-q11kETAFhMZicbI83XNk8FvXsAThjkM

3. Zone 2 - Estrada da Gavea -Tuesday 17.12.19 at 2 pm (second vide)

https://drive.google.com/open?id=1xb2KEiaW36ecGbnF9R-H1Pej-HlcAJpd

4. Zone 6 - Travessa Roma _ Saturday 14.12.19 at 2.25 pm

https://drive.google.com/open?id=1gWq5kpHjzgZ8PweAnv7S_gioQEIwnEKh