Transforming Urban Morphology and Environmental Perfornances via IMM®

The Case of PortoMaravilha in Rio de Janeiro.

M. Tadi, Vahabzadeh Manesh, M. Hadi Mohammad and F. Zaniol

I. INTRODUCTION TO IMM

The aim of this article is to demonstrate how urban morphology and environmental performance play a key role for achieving more sustainable urban development. Moreover, the article wishes to demonstrate the potential role that local scale interventions play in the whole Complex Adaptive System (CAS) [1] for optimizing its environmental and energy performances. This article presents the results achieved by the application of IMM methodology in a selected area inside the city of Rio de Janeiro by a join researcher team from IMM Design Lab and UFRJ [2]. The project addressing sustainable urban transformation issues in Porto Maravilha area demonstrated that the urban energy and environmental performances mostly depends on the formal arrangement of its components [3].

IMM® methodology is a multi-scale and holistic method, focused on the transformation of an existing urban system into a better performing one (Tadi M. et al. 2013). The main assumption of the IMM methodology is to consider the city as a Complex Adaptive System (CAS) [4]. Accordingly, cities are an arrangement of interconnected heterogeneous elements and the final result of the whole system is completely different from the performance of each individual element (Vahabzadeh S. et al. 2012). Each CAS is comprised of different elements or even smaller CAS(s) and each of these elements and "sub-systems" has the ability to learn from prior occurrences and experiences. [5]

The CAS is a complex hierarchical configuration of different sub-systems and elements working together as a whole. The hierarchical nature of CAS, therefore, requires a multi-scale approach if the intention is to improve the entire system's performance [6]. In order to achieve transformations on larger scales, IMM highlights mid-scale interventions through modifications on smaller-scale systems. Based on this methodology, the transformation in an intermediate level is the catalyst that initiates a chain reaction able to transform the entire CAS, regardless of its size. This means a selected study case area –as a subsystem- can play the "mid-scale intervention" role, transforming the whole structure of a system. The Porto Maravilha transformation's project based on IMM seen as an intermediate level and studying its effects on the arrangement of the entire CAS (the city of Rio de Janeiro) is the major goal of this article. So for this reason,

Hence, Porto Maravilha area seems to be an excellent case study for demonstrating how a Complex Adaptive system at any scale, even at the Megacity scale can be operated in order to optimize its environmental and energy performances [7]. Porto Maravilha's case study shows the substantial role that morphology plays and the possibility of changing a CAS through the IMM's multi-scale approach. Actually, it's crucial to notify that at any particular scale, the system is a sub-system of another larger system. Thus, due to its particular characteristic, Porto Maravilha's area has been an adequate example for understanding the inter-scalar behavior of a CAS and to modify it not following any sequential order. In particular, the Porto Maravilha's area as an intermediate scale plays a vital role to change the global scale (Rio de Janeiro scale) trough the local scale modification defined by the interaction of the constituents.

Actually in spite of its actual impoverished state and decay [8], due to the reduction of port activities and the construction of a rapid transit highway that turned the area into a passageway, the area is strategically very well located and it has a lot of potentials to bridge between the local and the global scale. The area has been treated, in its own intermediate scale characteristic, as a potential originator of a greater chain reaction able to influence larger scales even to implement the whole city's environmental performances. In this paper, a special role has been assigned to the comprehension of the role played by the Ordering Principle (DOPs) [9]. In IMM, methodology DOPs are tools/instruments used to arrange the structure of the CAS. The application of these principles affects the CAS's structure and its performance. Due to the fact that DOPs are associated with IMM's Assessment Indicators, they play the role of addressing the transformation and retrofitting the new CAS obtained by the transformation.

The role of Design Ordering Principles (DOPs) in IMM is to address lead the transformation in an environmental oriented manner by addressing the contextual issues.

The DOPs (Design Operator Principles) are tools/instruments used to arrange the structure of the CAS. The application of these principles intends to modify the structure of the CAS and consequently affect its performance. DOPs are not a fixed list of design recommendations but a dynamic and active structure of integrated Design Principles every time being arranged in with consideration of the specific conditions of the CAS and specifically organized to deal with the local weaknesses of the system. In particular their role is to modify the malfunctioning of the individual components of the CAS, responsible of its own actual performances. Therefore, rather than being a list of universal commandments, they address the issue locally, and by their local-oriented arrangement they lay the foundation of transformation. It is crucial to consider that the DOPs are associated with the Environmental Indicators, which are used for the assessment of the actual Energy performance of the CAS (this phase is named First Measurement of the state of the Actual CAS) as well as for the CAS Retrofitting process (phase named: Second measurement of the modified CAS) [10].
Besides strengthening the integration between analysis, assessment, and design, this strong link between DOPs and Indicators permits to objectively verify the role of DOPs in the CAS modification process, and consequently to test the CAS performance after the transformation and to eventually to modify wrong assumption and also to proceed towards further optimization of the CAS through local modification of already transformed System.
The DOPs (Design Ordering Principles) application is consequent to the previous its phases in IMM (Investigation and Assumption) and it is a fundamental stage of the IMM Phasing process. Main role of the DOPs application is to address the modification process of the CAS towards a more sustainable and efficient form. It is really important to note that the DOPs are completely integrated with the structure of the methodology; actually, they are simultaneously organized in association with Key categories (First Level of Superimposition) and with Determinants (Second Level of Superimposition) and consequently they entirely cover Morphology, Typology and Technology. Furthermore they are practical devices able to actively modify each single ligand (Key categories) of the CAS separately and to control any possible effect on the others, following an anticipated scheme. Concurrently, they are associated with a list of Environmental Indicators used in IMM process on one side to estimate the actual Energy performance of the CAS (Data Collection-Step 1c) and later in a CAS Retrofitting process (Step 4a-Second measurement) with the goals to objectively size the implementation of the CAS after the transformation. In IMM, the mentioned indicators and the DOPs form a core set of elements specifically based on environmental themes but interlinked with other themes (i.e., social, economy). They are tools used for objective measurement and comparing the performance of different systems (External comparison), or the system performance assessment prior and after the transformation design process (Internal comparison). IMM's DOPs are "Table. I":

TABLE I

	Design Ordering Principles (DOPs)	**Key Categories**	**Determinants**
Morphology	1. Balance the ground-use 2. Fostering local energy production. Building as components of Community Energy System 3. Promote Walkability	Porosity Porosity Proximity	**Compactness**
Typology	4. Fostering mixed-use development 5. Create connected open space systems, activating urban metabolism 6. Protect urban biodiversity	Diversity Interface	**Complexity**
Technology	7. Promote Cycling 8. Reinforce the public transportation 9. Change multi-modality to inter-modality concept	Efficiency Efficiency Accessibility	
Management	10. convert the city to food producer 11. Prevent the negative impacts of waste 12. Implement water management	**Governance**	

D.O.P Table (source: IMM Design Lab)

II. THE SITE: WHY RIO

Evidently, in the course of its development, Rio is facing an exponential growth of its urban area. The population of the city increased nearly 60% since the 50´s. [11]. This article aims to investigate how a local transformation could create a global chain reaction within the city, when the city considered as a complex adaptive system, boosting its actual performance and leading to a sustainable and liveable environment.

The goal is to highlight also the correlation between the urban morphology and environmental performances in the central area of the city of Rio de Janeiro, known as Porto Maravilha by the application of the IMM´s Design Principle Ordering (DOPs). The IMM method investigates any particular insider sub-system in a multi-scale approach creating adaption abilities in order transform the entire complex adaptive system enhancing the system performance [12]. In this case study, the Porto Maravilha area plays the "mid-scale", or the subsystem, aiming to transform the entire structure of the complex adaptive system, in the case the City of Rio de Janeiro. "Fig.1".

Figure 1. Rio de Janeiro Porto Maravilha Area (source: Google Earth)

Composed by eleven neighborhoods (subsystems), nowadays, the Porto Maravilha reached a deep stage of decay, despite its geographical and historical importance. Moving the port activities to another location and the construction of the peripheral highway crossing the entire area altered the local economy, and transformed the area into a mere urban corridor, without identity. "Fig.2".

Figure 2. Porto Maravilha Eleven Sub-System
(source: Google Earth/ IMM Design Lab)

The Rio de Janeiro case is not different as a number of cities in the world, where old port areas became obsolete and decadent, and in the same way, the Porto Maravilha area is calling for full attention by urban designers and authorities. The renovation of such areas can, when properly done, enhance not only the local quality of life, but powering these areas environmentally, economically and socially.

III. INVESTIGATION PHASE: DISASSEMBLING THE SYSTEM

During the Investigation Phase, the analysis of the horizontal and vertical components of the CAS detected dysfunctions regarding the Void Layer, corrupting the urban network.

Porto Maravilha now is acting just as an urban corridor for urban travelers moving between the city center and suburban areas. The under construction Peripheral Highway together with the Avenida Presidente Vargas, practically block any connection inside the local scale and isolates Porto Maravilha both from the waterfront and the downtown area. Furthermore, moving the port activities to the northern bay at the Caju neighborhood, transformed the old warehouse into a huge empty space, made the urban blocks twice bigger than their usual local size, and cut the movement network within the local scale.

However, with considering that malfunctioning in the Void Layer causes the analysis of Porto Maravilha shows that this major drawback could play the potential opportunity for triggering the transformation. "Fig.3".

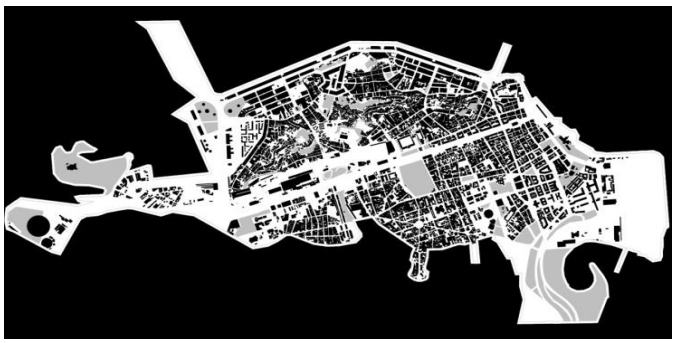

Figure 3. Void Layer (source: IMM Design Lab)

IV. INVESTIGATION PHASE: DISASSEMBLING THE SYSTEM

The reactants as products of the system's or subsystem's modification will be the layers to be modified in the chain reaction process. In other words, they react to the local modification of the catalyst layer (in this case the Void layer). Here, the horizontal reactant layers are respectively Function, Volume and Transportation. Interface, Porosity and Diversity have the role of vertical reactants.

According to the IMM Methodology, the Formulation Phase, as the half-way between the Investigation Phase, where the city as a CAS is divided in 4 Horizontal Layers and 6 Key Categories (KC) to further analysis, and Transformation steps, establishes what is the Catalyst and the Reactants in the system [13]. The Analysis and Investigation phase reveals that those malfunctioning in the network's Interface were affecting

not only the Porto Maravilha's local area, but also the entire area in the Intermediate Scale. Thus, Interface and Void layer have been selected as the Transformation Catalysts.

For modifying the situation, the chief goal is to integrate the local scale with the whole system by defining powerful connections in the less accessible areas, and redesigning the empty spaces using the existing parks in order to create a connected urban green system. "Fig.4".

Figure 4. Transformation globally acting locally
(source: IMM Design Lab)

Besides creating a connected urban green space, the new network will also boost drastically the performance of the Interface. It will redefine a proper proportion for urban blocks and reshape the potential volume to be built in the area it will also define a new urban grid and make a the new configuration for the local empty spaces, hence, affects Porosity and Diversity too. By enhancing the urban complexity and compactness, it will also provide a better urban quality to the local area. "Fig.5". "Fig.6".

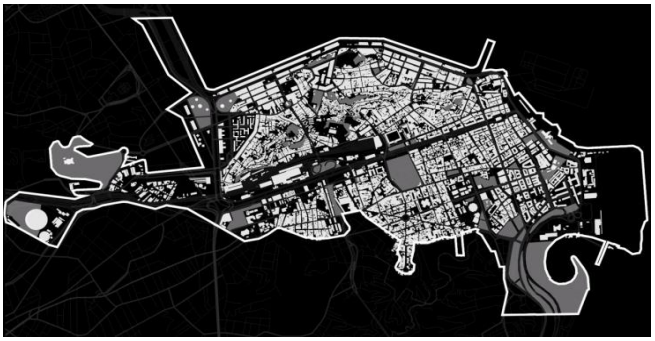

Figure 5. Porosity Key Category (source IMM Design Lab)

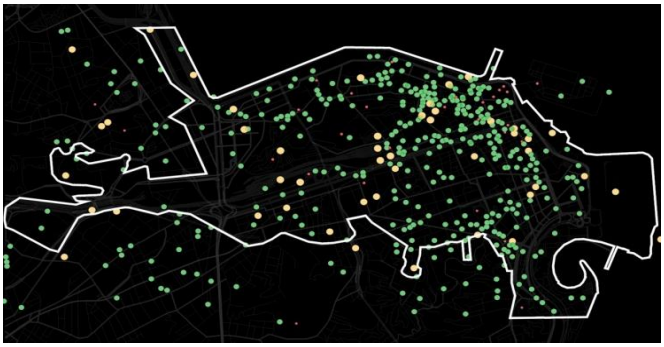

Figure 6. Diversity Key Category (source: IMM Design Lab)

The Investigation and the Formulation phases give evidence pointing out possibilities to, when working holistically, enhancing the KC´s performances, will be automatically increased the social aspects in a specific area. It confirms the relationship between the urban morphology and environmental and social spheres.

Nevertheless, the topography in this case also plays a fundamental role. When analyzing the Interface in the Intermediate scale this fact comes to the spotlight. Located at the hills that divide the Porto Maravilha in two parts, north and south, the *favelas* (*Morro Providencia-Livramento* and *Morro do Pinto/São Diogo*) as well the *Morro Conceição* assume the role of major drawback to the local mobility. The topography, together with the informal settlement, composed very dense core in the area, creating disconnected narrow links, unfeasible for car driving and biking most of the times, and sometimes even too much narrow even for pedestrian uses.

The actual landscape configuration reinforces the fact that the mobility within the Porto Maravilha is not a merely for those who lives into those areas, but a problem regarding the entire Interface as well.

The following images illustrate first the actual urban network, then the Interface map using a range between blue and red color referring to the quality of the voids connections, being blue to lower values and red to the higher values. The lines in blue amorphous shapes represent the *favelas.* "Fig.7" "Fig.8".

Figure 7. Urban Network (source: IMM Design Lab)

Figure 8. Interface Key Category (source: IMM Design Lab)

Analyzing the overlapped Key Categories, defined by the IMM method as the Second Layer o Superimposition "Fig.9", "Fig.10" and "Fig.11", it is possible to define that by increasing the number of links in the areas where the Interface presents its lower values; mobility in Porto Maravilha will be enhanced, automatically increasing Effectiveness and Accessibility. Next, transport nodes, depending on inter-modality or on the number and presence of different

modalities, should be surrounded by new appropriate functions, in order to improve the system's Diversity. Functional nodes grow in the surroundings of the transport nodes since that function and transport produce urban metabolism, feeding each other.

Figure 9. Compactness (source: IMM Design Lab)

Figure 10. Complexity (source IMM Design Lab)

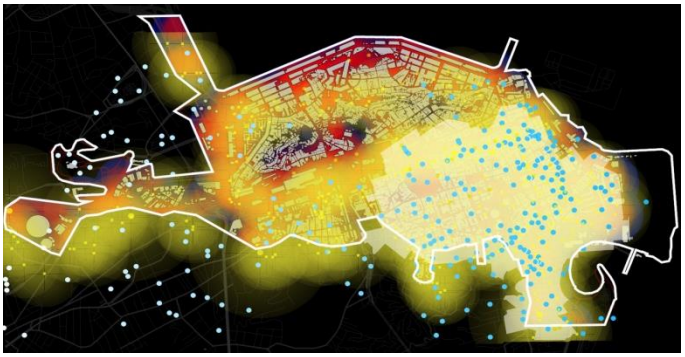

Figure 11. Connectivity (source IMM Design Lab)

The further steps will take will consideration the decisions made regarding the actual system performance and all the potentialities detected during the Investigation and the Formulation phases will guide the Transformation Phase. After, through the catalyst, local transformations will be in charge to activate the aimed chain reaction and lead the CAS to a better performance. Thus, the strategy to fulfill the area requirements will take in consideration the reactions of the KC´s through the modification of the horizontal and vertical catalysts. Furthermore, leaded by the IMM's Design Ordering Principle (DOPs), the transformation will be made to ensure the enhancement o the entire CAS.

V. Intervention and Application of D.O.Ps in Rio

The IMM´s DOPs, as tools used in order to create a structure of the intervention, will play a major role during the intervention process in the Rio´s case. After the analysis of the data obtained during the investigation and assumption phases, the 12 DOPs were rearranged and defined as the following order:

- Create connected open spaces system and activate urban metabolism;
- Make Biodiversity part of urban life
- Fostering mixed-use spaces;
- Promotion of walkability and cycling;
- Reinforcement of public transport;
- Balance the public transportation potential;
- Promote ground use balance
- Change from multimodality to inter-modality transportation concept
- Foster local energy production
- Implement water management
- Prevent the negative impact of waste
- Convert the city in a food producer

Due the fact that the intervention will be made using the void as the catalyst layer and following the first and second DOP´s, the first action taken is planning how to connect the empty urban space in order to create a intermediate scale void network. The connections to the global scale urban biodiversity will be made using the two surrounded parks, the *Aterro do Flamengo* as the south boundary, and the *Quinta da Boa Vista*, located at the west limit of the intermediate scale, in a role of green plug-ins. "Fig.12".

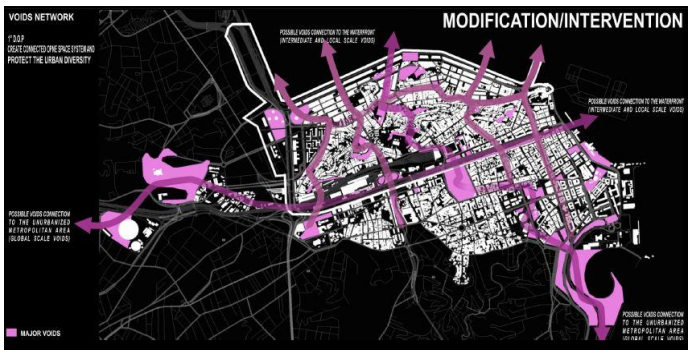

Figure 12. Void Network Modification (source: IMM Design Lab)

Further, following the third and fourth DOP´s (fostering mixed-use spaces and promotion of walkability and cycling), were point nodes where the detected empty spaces create opportunity to improve simultaneously the Diversity and the Interface. It will allow also transforming the morphology at the waterfront lines, actually composed by superblocks holding the warehouses, remains of the port activities, connecting to the city´s existing morphology and enhancing the possibility of urban links.

Also regarding the walkability and cyclability, as well as the promotion o the public transportation, clearly was possible to detect drawbacks related to the local morphology and topography located at the hills, sloped and compact area, which for sure has the biggest contribution not only for the

malfunctioning of the local area, also to the entire system. However, through some simple strategies it is still possible to achieve small improvements, increasing the mobility within the area. “Fig.13” “Fig.14”.

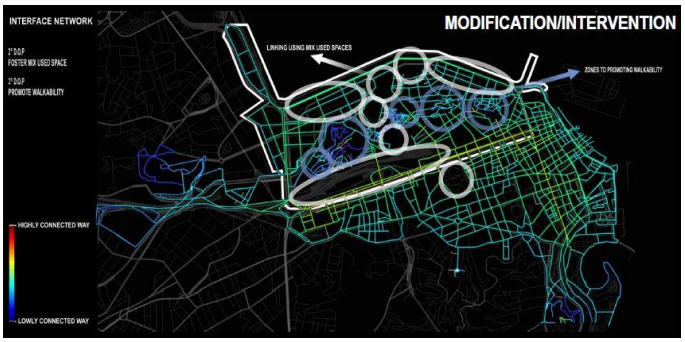

Figure 13. Interface Modification and the 2° D.O.P. Intervention (source: IM Design Lab)

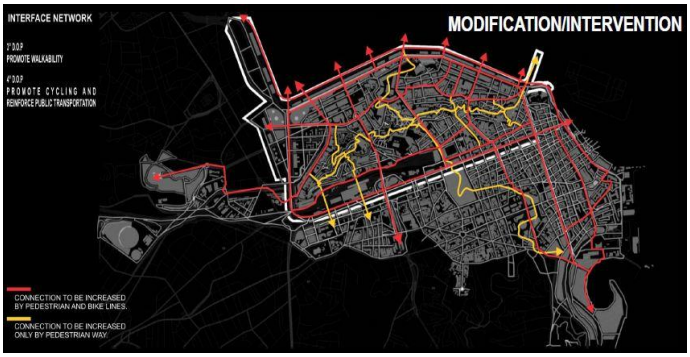

Figure 14. Interface Modification and the 3° D.O.P. Intervention (source IMM Design Lab)

The planned intervention aimed mostly the enhancement in terms of mobility, accessibility and diversity, mainly consequences from the Void and Interface changes. As a result from the reaction by the other KC´s, the action intent to, when creating a new morphology, enhance the integration between the area and the global scales.

Thus, the actions when implementing the DOP related to the open spaces and the urban biodiversity will take place firstly detecting the local empty spaces, to then boost them according to their actual conditions (in term of pavement, presence of vegetation and uses). After the actions will be defining the spaces to be recovered completely, spaces to be enhance or spaces to be linked, to finally, after cataloging the voids availability, connecting theses spaces between themselves and with the two green plug-ins using the so-called green fingers, composed by five major confections, thereby linking the area to the global scale, creating a urban green belt. In this context and in order to achieve the expected result, the proper use of the spaces located at the waterfront, as well the spaces of the *Vila Olimpica da Gamboa* and the courtyard of the *Cidade do Samba* will be essential, “Fig.15” “Fig.16”.

Figure 15. Void Conditions (source: IMM Design Lab)

Figure 16. Voids Recovered and Boulevards and The Green Fingers (source: IMM Design Lab)

The following action will be regarding the third, fourth, fifth and sixth DOP´s, and will take place especially at the intermediate scale, and will be mainly regarding the local Interface. The biggest intervention act will consist in breaking the superblocks at the waterfront area, converting them in a more suitable dimension. For this, were analyzed the blocks where the city has notorious better environmental performance, such as Downtown area, Copacabana, Ipanema, and Leblon. The mentioned transformation will not only improve the Interface performance, providing a more fluid mobility grid and fitting better with the DOP´s requirement regarding the walkability and cicling promotion, the enhancement of public transportation (providing a new grid will simultaneously enhance the easiness in accessing the public transportation node as well will the transportation network itself) and will also increase the attractviveness in the area, once it will be more accessible.

Thus, created intermediate scale network will also balance the local compactness in line with the seventh DOP (Promoting the ground use balance), moderating the heat-island effect, increasing shaded areas and reducing air pollution “Fig.17”.

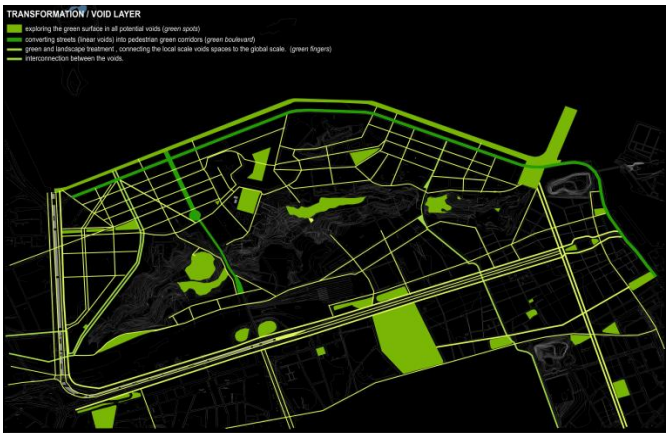

Figure 17. Promoting the Ground Use Balance
(source: IMM Design Lab)

In the areas where the topography represents the major obstacle, an effective strategy is mapping the actual most important connections to, by improving the surface coverage (the type of pavement) enhance even discretely the within walkability. This action could eventually provide the opportunity to considering new ways of building pedestrian pathways, going further then the common technologies, in order to increasing the interest by people in walking on them, as well using the renewed surface as a source of passive energy generators (through kinetic of solar production) and exploring these lines as spines where could be spread efficient water and sewage systems to those areas, meeting the needs suggested by the DOP´s regarding the local energy production and water and waste management.

At the end, strategic points through the railway lines will deal with the intermediate Interface, linking it to urban facilities and enhancing the entire CAS. “Fig.18”.

Figure 18. Mobility Enhancement and Local Energy Production
(source: IMM Design Lab)

After the implementation phase, through the application of the IMM DOPs, the Porto Maravilha will be well integrated to the Rio´s urban tissue, having enhanced not only the environmental performance regarding its internal area, as it will improve the performance considering the entire complex system that is the city of Rio de Janeiro. . “Fig.19”.

Figure 19. Porto Maravilha New Arrangement
(source: IMM Design Lab)

VI. CONCLUSION

Comparing the actual situation with the projection considering the implementation of the DOPs gives us a chance to understand how the system could perform. Considering that the density requested by the Porto Maravilha consortium, the new arrangement could represent an enhancement in 4, 4% more spaces dedicated to the void layer, which represent a better ground use balance. Consequently, the new arrangement will also increase the opportunity for urban cavities. “Fig.20”.

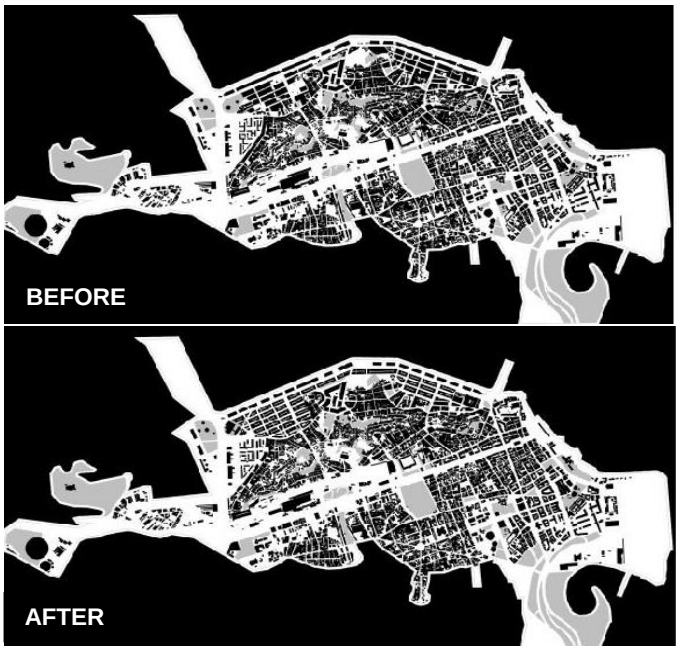

Figure 20. Void Before and After (source IMM Design Lab)

Regarding the implementation of the DOP´s which take place in the Interface, it is possible to note the dramatic improvement on its performance (precisely in 21% considering the entire intermediate scale), as a direct consequence from the new urban pattern as well the linkage in the Morro Providencia-Livramento, Morro do Pinto and Morro Conceição, at the core of the Porto Maravilha.

The treatment given in the empty spaces also provides sensible advantages regarding the urban connections,

especially at the *Cidade do Samba* courtyard and the *Vila Olimpica da Gamboa* if converted in public areas "Fig.21".

Figure 11. Interface Before and After (source: IMM Design Lab)

Hereafter, regarding the implementations in the transportation layer, the new grid gives the possibility to relocate the tram on local scale, at the *Santo Cristo* area, where the superblocks were broke, spreading the planned lines increasing the public transportation accessibility, especially for those who live in the hills. At the end, when superimposing the Void and Volume layer, it is possible to detect also an increasing regarding the Porosity, as well Proximity and the opportunity to increase the Diversity. Furthermore, Effectiveness will react with the new ground use balance and the new transportation network.

The presented case study has as intention to highlight effective strategies applicable to the urban design. When done correctly, performance measurement can lead urban actors to think about wider issues. The more effective performance a system will have, the more it will give benefit for those who with them interact. In the case of understanding the city as a complex system, it´s performance will return in benefits to the society in term of economy, sustainability, safety, livability and resiliency.

When living in society, the social interaction plays the major role in bounding people and the environment, and works as a base structure for the proper development of the human behavior, interpersonal relations and as well the community itself. Thus, is possible to define a strong connection between the environment performance and the social capital, mostly reflected in the access of information by the local communities [14]. Nowadays the information plays the powerful catalyst with the ability to transform urban social networks, and it is what the presented research wish, to support the Porto Maravilha communities in the dialog with the urban actors, filling the gap of a good communication which is actually leading the city to isolate the local communities even more in their *favelas* and, at the same point as is now wasting their potential, is driving the entire city towards an unsustainable environment.

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