An urban management system for the sustainable regeneration of the favela of Rocinha

Francesco Causone
Department of Energy, Politecnico di Milano

Gabriele Masera
Department of Arch. Built Environment and Construction Engineering, Politecnico di Milano

Massimo Tadi
Department of Arch. Built Environment and Construction Engineering, Politecnico di Milano

Angela M. Gabriella Rossi
Escola Politécnica / Engenharia Urbana (PEU), Universidade Federal do Rio de Janeiro

Abstract

By the middle of the current century, the world's population is projected to grow exponentially, becoming one of the major concerns for low-income settlements in megacities of developing countries, where the vulnerable population is expected to grow even faster, in an environment with little urban regulation. The population growth will increase the demand for basic, and often still lacking, city services such as sanitation, healthcare, energy, transportation, waste management and public spaces. In developing countries, nevertheless, the promotion of urban technologies could reduce the environmental impact of cities development and of slums renovation, creating employment opportunities for locals and economic opportunities of investment. However, deploying this in slums is a complex and challenging task. This paper 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. It foresees the deployment of an urban management system (UMS) to manage and integrate several urban services including sanitation, energy, mobility, waste, food delivery and growing and the flows of information connected to them, with the aim of reducing the environmental impact while improving the quality of life of citizens. Each service 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 resource management.

Introduction

More than half of world's population currently lives in urban areas [1,2] and the rapid urbanization contributed to increase poverty, inequality and social exclusion in slums that surround large and megacities. Most of the megacities are located in developing countries where also several large cities are projected to become megacities by 2030 [3]. In the world, one in eight people live in slums, and in total, around a billion people live in slum conditions [4]. Slums are the results of a complex combination of political, geographic, social and economic aspects of rapid urbanization; vulnerable people live there with lack of water, sanitation, urban amenities, adequate nutrition and housing. Improving living conditions of slums dwellers is, therefore, a crucial challenge for making cities and informal settlements sustainable, resilient, inclusive and safe.

In the developed world, the technological answers to the problems posed by rapid urbanisation are often gathered under the label "Smart City"; a vision of a built environment constantly connected and crossed by different flows (information, energy, goods, vehicles, etc.). Smart Cities are supposed to make use of the information and communication technology (ICT) to promote sustainable economic growth and quality of life, with a wise management of natural resources, through participatory governance [5,6].

Nevertheless, in order to reach this remarkable and challenging objective, electricity and internet access should be adequate, and, at the same time, local policymakers need suitable analysis tools and forecasting scenarios [7,8]. The number of people without access to electricity declined from 1.7 billion in 2000 to 1.1 billion in 2016 and the majority of them is in Asia and in sub-Saharan Africa [9]. In 2016 about 97% of the population living in developing countries in Latin America had access to electricity, 89% in Asia, 43% in sub-Saharan Africa and 93% in the Middle East [9]. However, according to the New Policies Scenario of 2030, described in the Energy Access Outlook 2017 by the International Energy Agency (IEA), these percentages are projected to increase and about universal access to electricity will be achieved due to grid extensions and investments in renewable energy.

In 2016, about 80% of the population in developed countries had internet access, compared to 40% in developing countries and 15% in least developed countries [9]. Internet penetration rates in 2018 was still low across much of Africa (e.g. 39% in Western Africa, 12% in Middle Africa, 27% Eastern Africa) and Southern Asia (36%), but these regions are also seeing the fastest growth in internet adoption. The internet penetration rate in South America is higher and equal to about 68% [10], including slums.

Although the good access both to electricity and internet, in South America most of the slums remain at the margins of the cities, as settlements constructed on vacant land and developed informally, often with illegal connections. During the last few decades, the rural exodus and the lack of affordable housing in urban centres stimulated the creation of hundreds of such settlements, called "favela", throughout Brazil [11]. In this context, the use of ICT could be seen as an asset to promote a sustainable regeneration of favelas as foreseen by the project "PolimiparaRocinha", developed by the Politecnico di Milano in partnership with the Federal University of Rio de Janeiro and "Il Sorriso dei Miei Bimbi" a non-profit organization engaged with the community of the favela of Rocinha.

The regeneration process has been initially simulated according to the Integrated Modification Methodology (IMM) [12,13], via the definition of thematic actions/projects including energy, waste, food, sanitation and mobility. These should eventually be implemented via an urban management system (UMS) able to manage and integrate several urban data and services and capable to drive the regeneration of the favela.

Integrated modification methodology

Rocinha is one of the largest favelas of Rio de Janeiro, it is characterized by poor housing, and lack of basic and safe infrastructures. The favela is disconnected from the city of Rio de Janeiro both socially and physically and the high-density context created an irregular morphology with a malfunctioning voids' system and minimum connections. The composition of the social structure and the geomorphological situation of Rocinha has influenced its urban development; the limited space for expansion has prejudiced construction patterns, leading houses to be built on top of one another, moreover, the condition of informal settlements and the low-cost construction materials are often at risk from natural disasters such as landslides or flooding also depending on the geomorphological context of the favela. Uncollected waste in the streets, limited access to healthy food and clean water and an ineffective mobility system are among the basic issues. To tackle them effectively, it is necessary to target the urban context first, creating a flexible connected system, and then, defining local strategies. Focus zones inside the favela have been selected to implement the project, intended as the inception of the regeneration process of the entire favela.

The theoretical background of the project is the Integrated Modification Methodology (IMM), a scientific intervention method developed by Politecnico di Milano as a methodological interpretation of the UN's Sustainable Development Goal number 11 [8]. It offers synthesis and assessment tools for built environment transformation. Regardless of its size, the urban context is considered as a Complex Adaptive System and, based on its systemic relations, modification and retrofit scenarios are developed. PolimiparaRocinha encompasses various dimensions, each of them framing a broad work theme: ecosystem services, waste management, wastewater management, food production, mobility, energy and information technologies. Morphology is the common hub through which each theme is related to the rest and the aftermath of all interventions is measured with reference to it; IMM defines indeed set of parameters clustered in seven categories to express various functioning mechanisms of the built environment: Porosity, Proximity, Diversity, Effectiveness, Accessibility, Permeability and Interface.

Implementation via an urban management system

Within the favela, the electrical energy access is wide but it occurs through untraditional solutions, using informal, dangerous and illegal connections, "the gato", to the public distribution system as a way to keep electricity bills affordable. Concerning the internet access, the number of Internet users is considerable [14,15], indeed, nine out of ten residents of the favelas in Rio de Janeiro, under the age of 30, access the World Wide Web [14]. In a context like this, where ICT and electricity are widely used, the exploitation of Internet and its users can offer the winning solution to create an integrated system for managing data and services within the favela. PolimiparaRocinha project, tries to use ITC as an infrastructure to enable the renovation actions planned via IMM analyses. In order to upgrade or establish urban services, an UMS (Fig. 1), aimed at reducing environmental impact while improving the quality of life of citizens, will be deployed. Each of the proposed improvements requires the development of a specific project, that, empowered by the UMS will allow the circulation of information and feedbacks between citizens, who will become the main players of the whole system, promoting social inclusion and sustainable regeneration of the favela. The UMS will monitor, control, and optimize the information flows coming from the different sectors (Fig. 1) improving services for citizens as street lighting, electrical mobility, food delivery, waste management, goods delivery, etc. 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 behaviour in terms of waste collection and energy savings.

The following sessions describe two example of actions foreseen in Rochina, in particular energy and mobility. Similar actions have also been designed for water, wastewater, waste, food management, and altogether will be implemented via the UMS to promote the sustainable and participated renovation of Rochina.

Energy

Access to electricity is essential to guarantee citizens' wellbeing and satisfaction. The proposed energy project concerns the design of PV systems to be installed on buildings with more than 3 floors above ground, in a pilot area of Rocinha. The project aims at exploiting the abundant solar energy incident on the rooftops to fulfil households' electrical needs. The installation of PV panels may reduce energy

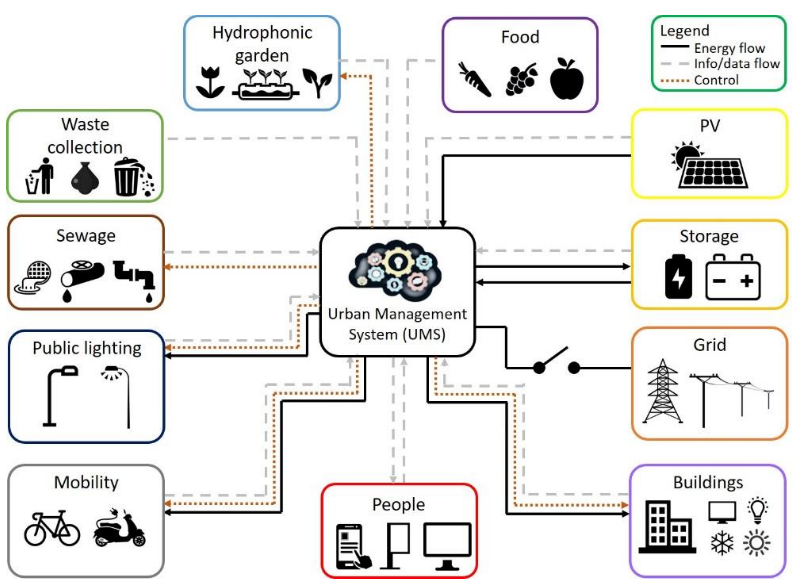

Figure 1. Urban Management System (UMS) scheme.

thefts inside the favela ensuring at the same time a more stable, legal and reliable power grid. To maximize energy self-consumption, to cover energy use during night-time and to further increase power grid reliability, PV panels can be coupled with battery storage systems. Hence, energy stored in the batteries may also fulfil electrical needs at city's level as public lighting, electrical vehicles charging, and powering systems for water pumping, irrigation and purification, etc. (Fig. 2). The UMS will manage energy flows coming from public and residential buildings inside the favela optimizing energy usage and maximizing energy self-consumption.

A solar potential map has been developed for the visualisation of the incident yearly solar energy on the roof surface of 4 to 8-story buildings in the selected zone of Rocinha through DIVA, an environmental analysis plugin for Rhinoceros 3D modelling program that can perform solar and daylight analysis via integration with Radiance and DAYSIM [16]. The maximum registered value of yearly global horizontal radiation is about 1850 kWh/m^2/year, and on average, the solar potential of the majority of the buildings' roofs is about 1760 kWh/m^2/year.

Starting from the results obtained from the solar potential map, the estimation of the electrical energy potential production of PV panels has been carried out considering solar polycrystalline panels (efficiency of 14%), with a module surface of 1.7 m^2 and a nominal power of 230 W. When the roof is flat, the area is completely usable for PV systems installation via pergola structures, whereas, in case of walkable roof, its surface will be used only partially (about 46%) for PV installation.

Rocinha's typical residential energy use is between 150 and 250 kWh/household/month or between 1800 – 3000 kWh/house/year [17,18]. Therefore, considering an average electrical energy use of 200 kWh/household/month (2400 kWh/household/year), and having estimated 951 apartments in the selected area, the total electricity needs of the selected residential buildings is 2,282,400 kWh/year. Electrical battery storages can maximize the energy self-consumption produced by PV panels, minimizing the interaction with the national grid. A storage system simulation has been carried out through the software HOMER for a typical 4-storey building with a floor area of 50 m^2 and for six battery sizes. The battery storage can manage building's loads and, according to the simulations results (Fig. 3), a 15 kWh Li-ion

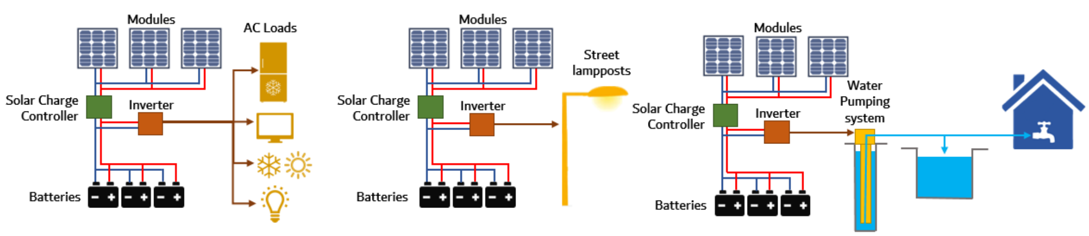

Figure 2. PV systems for domestic and public needs.

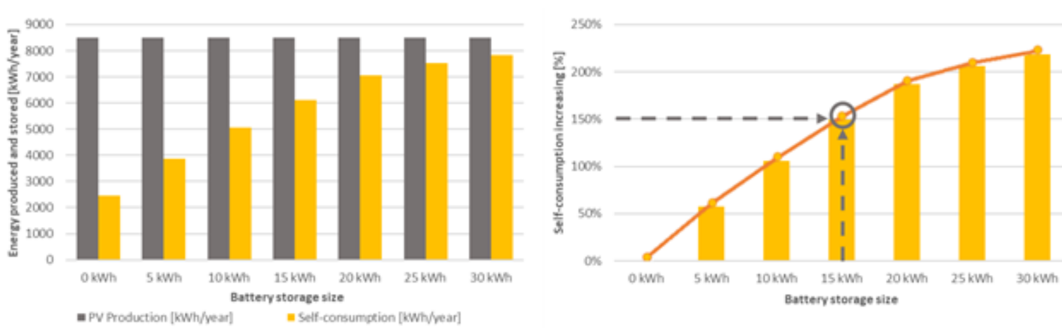

Figure 3. PV energy production vs energy self-consumption for different sizes of battery storage (left), self-consumption increasing for different sizes of battery storage (right).

battery can significantly increase the on-site consumption of PV generated energy of about 149% compared to the case without battery. This technical solution may have further positive implications if scaled up to the whole pilot area and to the whole favela. PV and battery storage systems could be installed in public buildings, such as schools to cover their electricity needs and part of electricity needs of urban services such as public lighting, water pumping and water purification systems, etc.

Mobility

One of the major problems in Rocinha is mobility. Although the presence of the São Conrado Metro Station on the eastern part of the Favela increases the potential of overall accessibility, Rocinha lacks in a mobility system able to smoothen the internal flows and support the subway station for external urban trips. The public transportation facilities are in their absolute minimum degree covering only limited areas alongside the da Gávea Street through a bus line. Aside from making a low level of integrity, the streets could become stifling narrow and the topography is so erratic all over the area creating a laborious context for non-motorized mobility. Considering Rocinha's extremely high population density these circumstances could be the root of many other organizational problems including safety and waste collection. The mobility objective in PolimiparaRocinha is to create an affordable and integrated bike sharing system which activates the internal connections and assists the existing public transportation infrastructure. According to width and slope standards, the street structure has been analysed and an optimum joined network created by streets which are qualified for conveying bicycles traffic (Fig. 4). In particular, the analysis showed that 13 of 18 neighborhoods have favourable morphological characteristics while the others 5 ones are not accessible by bikes due to the high slope. The analysis of the favela's population made possible to estimate the potential of the system where about 18% of residents is composed by bicycle's owners. The daily trip per person, introducing the mobility index value, that permits to calculate the average daily trip made by a single person, has been considered to estimate the dimension of the bike sharing system as composed by 180 electric bikes, distributed in 12 bike stations each of them with a max capacity of 30 bicycles. This system will include electric bikes, mechanical conveyors and cycle stair channels for the steep streets. The UMS will offer services of recharge for electric bikes via the use of PV produced

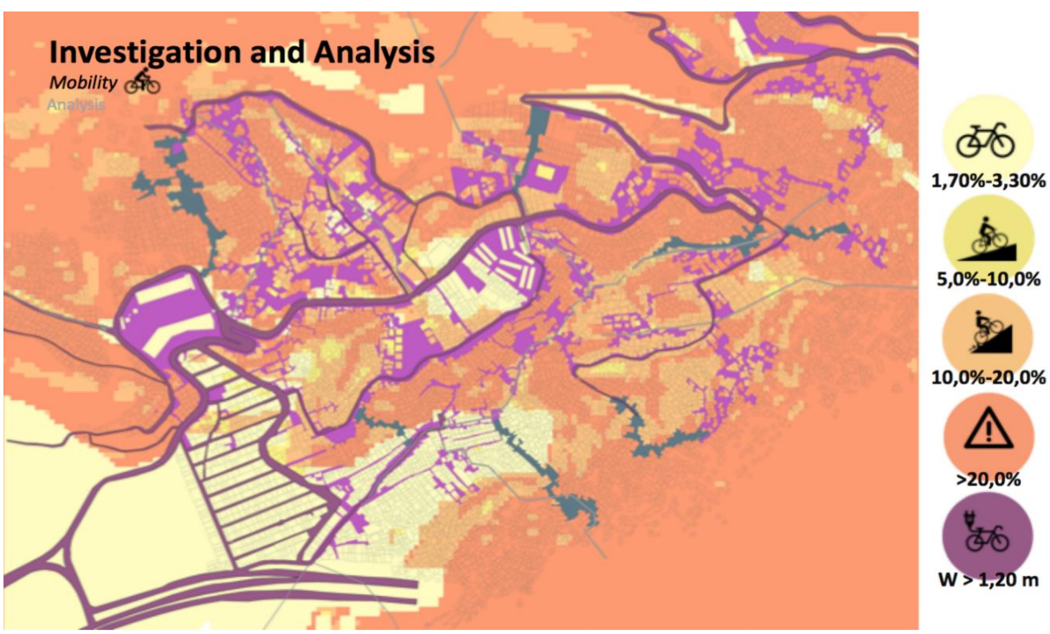

Figure 4. Map of the definition of a network qualified for conveying bike sharing system in consideration of the topography of the Favela and the selected transformation area (in blue).

energy and will produce mobility data on which further management strategies could be based, and users informed about bike availability and environmental and health benefits. This data may be used also to improve similar initiatives such as “Win a Bike” and “Bike on Home”, by creating a sustainable transport community in the favela [19].

Conclusions

Urban technologies can help overcoming the limitations of traditional urban planning approaches, especially in contests as informal settlements. These technologies have a lot of potential in developing countries and, with the active participation of citizens, they allow the promotion of social inclusion and the sustainable regeneration of slums. Urban expansion in the next decades will take place, indeed, mainly in developing countries and with sound urban planning and management the world’s urban spaces can become inclusive, safe, resilient and sustainable, as well as dynamic hubs of innovation and enterprise. The monitoring and measurement through management systems able to optimize information and other data flows coming from several urban sectors could be the key to sustainable development of informal settlements. ICT can help improving city governance, energy and resources use, delivery of urban services, and creating employment opportunities.

The UMS is meant to support sustainable food and goods delivery, electric mobility service, energy usage, waste collection inside slums as well as to avoid blackouts, malfunctioning of sewage wastewater systems, and to promote social inclusion. The community can benefit of new and more efficient urban services created, implemented and used within the slum that will contribute to shape a new culture on the use of energy and urban services through the active participation of consumers. Moreover, investors might appreciate a better risk management for their investments in contests otherwise complex and full of uncertainty.

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