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Towards the definition of a sustainable Smart Model for the suburbs redevelopment

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Mangialavori, M., Pompei, L., Nardecchia, F., Bisegna, F., Fichera, A., Rizzo, G., et al. (2020). Towards the definition of a sustainable Smart Model for the suburbs redevelopment. Institute of Electrical and Electronics Engineers Inc. (IEEE) [10.1109/EEEIC/ICPSEurope49358.2020.9160674].

Availability:

This version is available at: <https://hdl.handle.net/11585/772196> since: 2020-09-20

Published:

DOI: <http://doi.org/10.1109/EEEIC/ICPSEurope49358.2020.9160674>

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(Article begins on next page)

This is the final peer-reviewed accepted manuscript of:

M. Mangialavori *et al.*, "Towards the definition of a sustainable Smart Model for the suburbs redevelopment," *2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe)*, 2020, pp. 1-6.

The final published version is available online at:
<https://dx.doi.org/10.1109/EEEIC/ICPSEurope49358.2020.9160674>

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Towards the definition of a sustainable Smart Model for the suburbs redevelopment

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Abstract— Starting from the analysis of the problems that characterize the Italian suburbs, the application of a Smart Methodology to a real peripheral area is presented. In literature, several studies underline the urgent request of the city's periphery, enhancing local and national projects to increase the quality of life in the suburbs. In this framework, authors propose a multifunctional centre development, characterized by modern technologies (both structural and plant) to implement energy efficiency and social aggregation, in line with the citizen's needs. Once the simulation model of alternative solutions, such as construction type, energy system and social services, was elaborated in Matlab/Simulink, the application of a smart methodology was necessary to draft the priority ranking of the various strategies. Results highlight which solution obtained a positive impact on the overall smart axes, providing a useful approach for designers to plan a sustainable and smart project.

Keywords— Smart cities; Suburbs redevelopment; Simulation model; Smart methodology.

I. INTRODUCTION

The Smart Cities theory was born in the 90s, trying to solve contemporary city problem, from environmental pollution to socio-technological marginalization, proposing a model of sustainable and holistic development for the urban context. The strength of this theory is to include different aspects, both social and energy, but also economic [1] at the same time. In this way, technologies are spread equally within the territory to create an interconnected network, capable of concretely improving the quality of life of citizens [2].

In the last century, phenomena of the conurbation and uncontrolled migratory flows, combined with a lack of planning and absent governance, have led to a porous urban context, characterized by the clear contrast between the centre and the periphery, [3] so much so that in the time the term periphery has increasingly taken on a negative meaning. In the Italian context, these areas are characterized by social marginality, unemployment, a lack of public services and the presence of organized crime [4]. Therefore, it is still essential to propose a redevelopment that pays attention to peripheral areas, to develop a more socially and sustainable city. This process can be the result

of a malleable and fluid bottom-up method, not pre-established, but built starting from the real needs expressed by the citizens themselves who become the promoters of the design of the new face of the city, thanks to the distribution of a survey [5]. On the other hand, Multi-Criteria Decision Analysis (MCDA) [6] can be used to solve a wide range of city problems or a model that reproduces the possible behaviour of the citizens, based on empirical data [7], especially when the intervention dimensions become prohibitive for direct field research.

For the requalification of neglected areas, the UN (United Nation) ratified in 2015 an Agenda for Sustainable Development aimed at resolving the polarization of urban contexts between central and peripheral neighbourhoods. Over the years, numerous projects have been presented and implemented, such as the one on the South Park of Milan [8] or the one on the roman district of Bastogi [9]. Regarding the [8], the energy efficiency of buildings and alternative mobility are the key points of the redevelopment, aimed at improving the lives of citizens, thanks to better environmental and infrastructural conditions; the second one [9] starting from the collaboration of the citizens and local authorities, well-being was studied as an expression of the degree of education, health and social inclusion, implementing a methodology aimed to reduce the inequality between peripheral and central areas.

The presented work has the aim of applying the theoretical principles of Smart Cities for the redevelopment of a large green area located in the centre of Tor Bella Monaca. To respond to the local problems, the creation of a multifunctional centre, powered by renewable sources and equipped with innovative technologies, was planned. This new complex will host several activities for different citizen ages: from child to elderly people. A comprehensive model was developed capable of describing both the plants and the structural elements, to compare the alternatives considered, both from an energy and economic point of view. Furthermore, thought the Performance Indicators calculation, it was possible to analyse deeply the results obtained. Finally, a global ranking of the proposed strategies will be elaborated which shows the impact and the transversal effectiveness of the various interventions in a smart perspective. Moreover, this smart process could be applied to different urban context, highlighting problems

and identifying smart solutions, in a more modular and organic way.

II. METHODOLOGY

This work lays its bases on a smart method previously defined in the works of [10,11]. Starting from this, the research is focused on the inclusion of stakeholders within the steps of the method, to consider more concretely the problems expressed by the citizens themselves. The steps of the methodology applied to the case study are:

1. Preliminary planning: the project was born with the scope to apply the Smart theory to the context of Tor Bella Monaca, a suburb area of Rome;

2. Smart axes definition: those smart fields are the macro-area investigated [10] (Smart Economy, Smart People and Living, Smart Mobility, Smart Environment and Smart Energy);

3. Problem categorization through a survey: to obtain data and information relating to the project area, a questionnaire was created and distributed, physically and electronically, to a wide range of citizens. Then the results were analysed and tabulated to have a global view of the problems expressed and to outline the guidelines for Smart design;

4. Planning of strategies starting from the results of the survey, several interventions were drawn up to solve the critical issues organically and effectively;

5. Simulation of strategies: thanks to the use of Matlab/Simulink and Dialux tools, the proposed interventions have been simulated and analysed;

6. Smart ranking through the Performance Indicators and their standardization: thanks to the PI, it was possible to define the priority ranking of the proposed strategies, highlighting which of them achieved a positive or negative impact, according to the methodology.

A. Preliminary Planning

The intervention area (about 65390 m²) is a municipal green area, in front of a high school and neglected parking, which hosts the remains of an ancient Roman villa. This area is now abandoned and intended for the occasional disposal of waste or the occasional residence of the homeless. The neighbourhood, in which the considered area is located, is a periphery characterized by the lack of specific social and job policies [12] and socio-technological attractiveness [13]. A series of problems can be identified, such as:

1. social exclusion
2. unemployment
3. crime
4. juvenile discomfort.

B. Problem categorization through a Survey

The questionnaire was distributed both physically and electronically, to a heterogeneous sample, in terms of age and profession, made up of over 200 people belonging to the local population. In the survey (Table I), people had to give a mark from 1 insufficient to 5 excellent for the questions asked.

TABLE I. SURVEY

Questionnaire	
Question 1: How do you judge...?	Mark
Recreational activities	X
Health care	X
Waste management and recycling	X
Park and green areas management	X
Presence of green areas in the neighbourhood	X
Events of social aggregation	X
Social solidarity events	X
Educational activities with professional outlets	X
Youth gathering places	X
Neighbourhood abandonment level	X
Question 2: How much those strategies could increase the quality of life for the neighbourhood ...?	Mark
Photovoltaic panels	X
Rainwater recirculation system for the urban gardens	X
Didactic area with courses on the energy theme	X
Courses about Eco-Design	X
Mini wind turbines	X
Refreshments in the parks	X
Urban gardens	X
Facilitated access to parks for elderly or disabled people	X
Multifunctional centre with high energy efficiency	X
Free surgery	X
Car parking near the metro station	X
New bowling club	X
Video surveillance	X

The results show unequivocal conclusions:

1. The level of degradation was judged insufficient by 77% of the sample;
2. Social aggregation activities were judged insufficient by more than 70% of the sample;
3. The connection with the world of work was judged insufficient by 94% of the sample;
4. The possibility of installing renewable resources was rated positively by more than 80% of the sample as regards photovoltaic panels, while the mini turbines were judged unwelcome by 82% of the sample;
5. Having been deemed insufficient by more than 80% of the sample to maintain green areas, its possible requalification was deemed positive by more than 60% of the sample;
6. The possibility of creating new aggregation points (such as a multifunctional centre) was judged positive by more than 80% of the sample

C. Planning of Strategies

To solve problems exposed by the survey, different interventions are proposed:

1. Structural Interventions: aimed at the construction of the structures in which the multifunctional centre is carried out (Table II);
2. Plant Interventions: aimed at equipping the redeveloped area with performing systems (Table III);
3. Socio-Technological Interventions: aimed at the implementation of technologically innovative services to encourage social aggregation (Table IV).

TABLE II. STRUCTURAL CHARACTERISTICS

Typology	Alternatives	Transmittance [W/K*m ²]
Wall stratigraphy	1. Frame X-Lam; 2. Normablock; 3. Aerogel; 4. Rock wool;	1. 0,129; 2. 0,149; 3. 0,273; 4. 0,149
Roof	1. Frame X-Lam; 2. Rock wool;	1. 0,13; 2. 0,182
Floor	• Wood	• 0,182
Glass surfaces	1. Double low-emission glasses with PVC frames and argon; 2. Double low-emission glass with aluminised wood frames and argon; 3. Triple low-emission glasses with PVC frames and argon; 4. Triple low-emission glass with aluminised wood frames and argon;	1. 2,419; 2. 2,34; 3. 1,956; 4. 1,877
Interior finishes	• Airlite	• 0,077

TABLE III. ENERGY SYSTEM STRATEGIES

Plant Interventions	
Typology	Alternatives
Photovoltaic panels	1. Double-sided modules; 2. Modules with integrated power optimizers;
Storage	• Electrochemical batteries;
Heating and Cooling System	• Heat pumps external to the structures that feed the internal fan coils;
Rainwater Recirculation System	• Made up of conveyor, collection and distribution systems;
Illumination System	• LED light sources accompanied by automatic dimming; • Solar brick; • Mobile shading systems;

TABLE IV. SOCIAL STRATEGIES

Socio-Technological Interventions	
Typology	Alternatives
Perimeter video surveillance	Made up of video cameras equipped with own photovoltaic and storage;
Outdoor gym	Powered by the kinetic energy of users;
Wi-Fi Zone	Tor Bella Monaca is one of the few areas in Rome without free hot spots;
Urban gardens	Aims for social integration and cohesion between urban and natural dimensions
Recovery of the Roman Villa	Restoration of the remains present to create a historical route;
Smart Benches	Powered by own photovoltaic and storage;
Automatic watering	Intended for both urban gardens and the turf of the park;
Smart Parking	Through the images captured by three video cameras, the final users will see the availability of places on their smart phones;
Permanent charging stations for electric vehicles	For charging both low and high-power electric vehicles.

Since the area considered, according to the Catasto di Roma" as "public green and public services of a global level", the 5% of the total area is buildable, about 3269,125 m². Given the large area available, the construction of a multifunctional centre is proposed, which is divided into different areas:

1. Didactic area: aimed at teaching for students in front of high school and professional courses;
 2. Refreshment area: by creating a meeting point, such as a bar and restaurants.
 3. Rooms for infancy and childhood: the neighbourhood is densely populated by low-income families (more than 70%);
 4. Rooms for elderly people: space for educational and social activities;
- Moreover, other outdoor activities will be located inside this area, dedicated to:
1. Relax area: equipped with smart benches for recharging electrical appliances;
 2. Urban gardens: enslaved by the rainwater recovery system;
 3. Outdoor gym: self-sufficient thanks to the revolutionary Green Heart technology;
 4. A new path through the Roman Villa;
 5. Games area: in front of the playroom for young people;
 6. Parking: recovering the area located at the main entrance..
- D. Simulation strategies*
- Thanks to the Matlab/Simulink simulation software, it was possible to create a model consisting of various sub-models:
1. Thermal model: using the data of the structural components stratigraphy's, the thermal behaviour of the various structures was analysed separately, separating the summer regime from the winter one. Climate data used for the simulation are extracted from the nearest measuring station of ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale). For thermal loads of the envelopes has been considered also the presence of thermal bridge and infiltrations. Finally, internal gains are calculated with concerning the presence of people, electric utilities and solar component [14]. The usefulness of this step lies in the possibility of obtaining values for the sizing of the heating and cooling system, but also to understand which is the best of the structural alternatives. The results of the thermal model show the high peaks of each structure; starting from the summer ones, the sizing of both the external heat pumps and the internal fan-coils were carried out for each structure, considering the load variation imposed by switching the structural alternatives. This must be done before modelling the electric one, as it constitutes a load [15];
 2. Electric Model: Among the various electrical utilities, lighting can be divided into two macro areas: the indoor (for the four structures) and the outdoor (for the park and parking). Thanks to the 3D Dialux design software, starting from the results of the Flux Method [16], it was possible to size the sources by defining the climatic conditions and to propose their automatic dimming by studying the interaction with natural light. Finally a model was created based on the data of the various users, divided by structure, by season, by time band (having the dimming valid in this interval) and considering the alternatives of the structural elements;

3. Sizing of photovoltaic system and storage: for the photovoltaic panels it was done using data of the electric model, to cover all the energy needs; both the double-sided modules and those with integrated optimizers, were dimensioned in parallel. For the storage, an electrochemical one was studied for those loads that consume energy during the night, when the plant doesn't produce, but which, in any case, fall within the energy sizing of the photovoltaic field, avoiding the introduction into the network of the daytime energy surplus produced;

4. Sizing of rainwater recirculation system: this alternative has been analysed, using as a rainwater collection surface the playroom for infancy and childhood excluded from the sizing of the photovoltaic system;

5. Analysis of socio-technological interventions: this strategy doesn't have a consistent impact or advantage to be observed, because they implement a service that is absent today. Therefore, to evaluate their effectiveness, they were compared with similar technologies to calculate the economic savings throughout their life cycle, the net of the initial investment difference.

E. Performance Indicators

The proposed interventions can be described through the performance indicators which are useful to compare different solutions and evaluate their influence on the final asset [10,17]. The indicators chosen for this analysis are reported below (Table V):

TABLE V. PERFORMANCE INDICATORS

Axe	PI	Formula	Acronym	Unit
Energy	Reduction of energy consumption compared to the base case	Base case energy - Energy intervention	RECB	kWh/yr
	Production of energy from renewable sources	$Area \cdot h_{eq} \cdot \eta_{BOS}$	PFR	kWh/yr
	Energy destined for self-consumption by renewable sources	Total energy produced - Energy fed into the grid	EA	kWh/yr
Environment	Reduction of emissions of CO ₂	$PFR \cdot 0,32678$	RC	kg/yr
	Reduction of emissions of CO ₂ on the lifespan	$RC \cdot Lifespan$	LS	kg
Mobility	Parking facilities served	Number of cars	PARC	/
Living-People	Technological Services	Covered are	ST	m ²
	Safety	Covered are	SIC	m ²
	Rating	Rating >4 in the survey	GRAD	/
Economy	Initial investment	$C_{INV} + C_{LABOR}$	INV	€
	Economic savings from the production of renewable energy	$(PFR - EA) \cdot C_{kWhGRID} + EA \cdot C_{kWhSELPROD}$	RECONRES	€/yr
	Economic income compared to the base case	$(RECB \cdot C_{kWh} - INV_{BASECASE} - INV_{INTERVENTIONS}) / Lifespan$	CFCB	€/yr

The standardization and weighting process of those indicators is taken from the work of [18]. Following authors described briefly all the steps of this procedure, highlighting a specific modification applied to the scaling phase.

1. Standardization: the method is called "distance to mean method", in which the average (M_i) of all the indicators (x_{ij}) is calculated and then their distance from the average (a_{ij}). Equation (1) is reported below:

$$a_{ij} = (x_{ij} - M_i) / M_i \quad (1)$$

2. Scaling: compared to the work of [18], an evaluation score was assigned to the various ranges between 0 and 10, not between -5 and 5: this modification was done to avoid the negative values, obtained especially for a group of strategies. In this way, final results are more homogenous and coherent.

3. Correction factor: a corrective value of -1 is applied, to all those indicators that receive the highest value and most negatively affect the overall assessment, while a factor of 1 to all those indicators that receive the highest score and most positively affect the final ranking;

4. Economic and time feasibility: to the various indicators considered, two other PIs must be added, which describe the economic and temporal feasibility; these will be normalized to obtain a value between 0 (worst case) and 1 (best case).

III. RESULTS

A. Thermal Model

Regarding the thermal model results, Table VI below reported the worst and best case obtained for each alternative construction components, considering the summer thermal peaks. As showed in Table VI, aerogel has got a summer peak higher than 1000 kWt compared to the X-Lam and over 600 kWt compared to the other two alternatives. On the other hand, the triple glass solution obtained a higher savings respect to the double one (2100 kWt). Finally, regarding the frames, the difference between those alternatives is less than 50 kWt.

TABLE VI. THERMAL MODEL RESULTS

Thermal Model Results		
Typology	Best Case	Worst Case
Wall stratigraphy	Frame X-Lam	Aerogel
Glass surfaces	Triple low emission;	Double low emission;
Frames	Aluminised wood	PVC

B. Electric Model

Considering a distinction of the electrical loads in three categories, it is possible to define their annual consumption (Table VII):

1. Loads of the structures: considering all the possible structural variations;
2. Constant loads of the park;
3. Non-constant loads of the park.

TABLE VII. ELECTRICAL MODEL RESULTS

Annual electrical consumption [kWh/yr]	Options			
	X-Lam-Double Glasses.	X-Lam-Triple Glasses.	Rock wool-Double Glasses.	Rock wool-Triple Glasses.
Loads of structures	17190	16753	18211	17730
Constant loads of the park	56180			
Non-constant loads of the park	51228			

C. Photovoltaic and storage systems

Considering the four structural alternatives (Table III), the peak (kW_s) necessary to satisfy the total electrical requirements oscillate between 88.09 kW_p and 89.21 kW_p. Starting from a common value of 90 kW_p (the values found are however the result of simulations), the two alternatives proposed were compared with a monocrystalline photovoltaic module: there is a saving, in term of modules, of 86 units for the double-sided modules and 15 units for modules with optimizers. Consequently, the sizing of the system was carried out (arrangement of the modules and inverters) by considering the available areas separately, without the playroom for the infancy and childhood. Finally, the storage system requires 9.47 kWh.

D. Rainwater Recirculation System

They were sized thanks to the model:

1. Conveying systems: the length is 80 m;
2. Pumps: calculating the losses along the route, a prevalence of 138 m is required, for a total of three units, equipped with an integrated electronic card for automatic start and stop;
3. Tanks: 3 underground tanks of 4 m³ in plastic material, preferring a slight under sizing which favours the natural overflow of water. or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

E. Socio-Technological Interventions

The simulation model shows the following results (Table VIII).

TABLE VIII. SOCIAL STRATEGIES

Intervention	Saving	Alternative
Smart Parking	19991 €/lifespan	Sensors and control unit
Video surveillance	15015 €/lifespan	Video cameras without photovoltaic system
Gym Green Heart	7408 €/lifespan	Tools attached to the power supply
Smart Benches	2150 €/lifespan	Benches without recharge
Charging stations	11270 €/year	No charging stations

F. Performance Indicators

The final ranking of the interventions considered is shown in Table IX, in which the double-sided modules obtained the higher score and the urban gardens the lower. Analysing in detail the ranking of priority obtained, it is possible to observe a clear separation between the types of strategies, since in the first places there are the plant interventions, after the socio-technological ones and finally the structural ones. This issue could be related to the transversal influence obtained by energy system solutions. On the other hand, structural strategies had a low impact on the rest of the smart axis, explaining their worst position inside the ranking.

TABLE IX. GLOBAL FINAL RANKING

Global ranking	
70,7	Double-sided modules
66,7	Modules with integrated power optimizers
59	Solar Brick
46	Smart Parking
44,8	LED with Dimming

38	Video surveillance
37,8	Cooling and heating system
35,8	Storage system
31	Recharge station
28	Wi-Fi
27	Gym
18,9	Mobile shading systems
16,8	Recovery of roman villa
16	Smart Benches
15,9	Triple low-emissivity glass with aluminised wood frames and argon
15,8	Triple low-emissivity glass with PVC frames and argon
14,9	Rainwater recirculation system
13,8	Double low-emissivity glass with aluminised wood frames and argon
12,8	Triple low-emissivity glass with PVC frames and argon
12	Automatic irrigation of turf
11	Automatic irrigation of urban gardens
8,6	Wall stratigraphy with X-Lam frame
7,3	Wall stratigraphy with rock wool /Normablock
7,2	Roof with X-Lam
5,1	Roof with rock wool/Normablock
4,3	Floor
0,7	Urban gardens

This separation has led to the elaboration of partial rankings (Tables X-XI-XII), distinguished by category of intervention, useful for evaluating in various cases (such as for example the type of photovoltaic modules or the type of roof) which is the most effective alternative.

TABLE X. STRUCTURAL STRATEGIES RANKING

Ranking of Structural Interventions	
15,9	Triple low-emission glass with aluminised wood frames and argon
15,8	Triple low-emission glass with PVC frames and argon
13,8	Double low-emission glass with aluminised wood frames and argon
12,8	Double low-emission glass with PVC frames and argon
8,6	Wall stratigraphy with X-Lam frame
7,3	Roof with rock wool
7,3	Roof with Normablock
7,2	Roof with X-Lam
5,1	Roof with rock wool/Normablock
4,3	Floor

TABLE XI. ENERGY SYSTEM RANKING

Ranking of Plant Interventions	
70,7	Double-sided modules
66,7	Modules with integrated power optimizers
59	Solar Brick
44,8	Dimming-LED
37,8	Cooling and heating
35,8	Storage system
18,9	Mobile shading systems
14,9	Rainwater recirculation system

TABLE XII. SOCIAL STRATEGIES RANKING

Ranking of Socio-Technological Interventions	
45,9	Smart Parking
37,9	Video surveillance
30,9	Recharge station
27,9	Wi-Fi
26,9	Gym Green Heart
16,8	Recovery of roman villa
15,9	Smart Benches
11,9	Automatic irrigation of turf
10,9	Automatic irrigation of urban gardens
0,7	Urban gardens

Partial rankings are useful to understand deeply the priority inside these macro-areas. Regarding Table X, the

best solution is the use of Triple low-emissivity glass with aluminised wood frames and argon instead the double ones; the X-LAM stratigraphy for the new buildings obtained a good score, is the best solution compared to the wall constructions ones. As aforementioned, double sided-modules had a consistent impact on different smart axes, obtained a higher score (Table XI). Finally, the smart parking development is the best strategies for the Socio-Technological solutions (Table XII), underlining its importance for the green area and the neighbourhood too.

IV. DISCUSSION AND CONCLUSION

The following work aimed to define a smart planning model for the suburbs of cities, through the construction of a simulation model and through the application of a smart methodology for strategies prioritization. The role of the stakeholders was the fundamental key for the definition of the urban and social renewal proposals. However, the use of a methodology, that can guide the choice of those interventions that obtained a greater impact for the smart axes, is still an essential issue. Furthermore, through the model developed with Simulink, it was possible to study the interventions and quantify them in energy and economic terms. The smart assessment was done using performance indicators that allowed the quantification of the impacts of even purely social strategies, which are difficult to manage and unfortunately remain in the background. Thanks to these tools, it was possible to study the redevelopment of a green area in Tor Bella Monaca, by building an efficient multifunctional centre both from an energy and social point of view. Future developments foresee the application of this model to different realities of urban suburbs, in order to test and implement both the model created and the proposed methodology.

ACKNOWLEDGMENT

This work was carried out within the research project n. 201594LT3F which is funded by PRIN (Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale) of the Italian Ministry of Education, University and Research.

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