CSE Journal
City Safety Energy

International Journal of Geology, Planning and Land Safety,
Sustainable Urban Mobility, Environmental Design, Building Technologies,
Energy Efficiency in Buildings and Districts, Materials Engineering

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EDITORIAL

A new journal for interdisciplinary cooperation

by the Scientific Panel

This journal aims to explore and define new perspectives on the modernisation of human habitats, of how we adapt to ecological requirements.

The identity crisis of European countries caused by political uncertainty, aggravated by the current economic crisis, requires joint efforts to increase the influence of research upon decision-makers. The attitude of European countries towards environmental problems – from soil use to emissions into the atmosphere, from territorial and urban safety to energy efficiency – is far from homogeneous: some countries have adopted promising though still inadequate measures; others are lagging behind and have difficulties taking decisions. On the whole, Europe appears weary, lacking the creative enthusiasm which was the hallmark for so many centuries of their history. Rather than seeking to change the appearance of their landscape and their cities, they should focus on protecting the cultural heritage they have built up over centuries: they have to modernize their urban capital stock. This great commitment requires enthusiasm and creativity.

Europe presents an extraordinary, fascinating variety in all its forms. The thousands of towns, cities, streets, coasts and fields express the living testimony of an ancient history. It is the physical representation of a common stratified civilisation, recognized as a unifying influence and a cultural point of reference. Protecting and safeguarding this heritage is not enough: it is necessary that it be respected in line with the laws of nature, guaranteeing the reproducibility of resources. Urban areas with an ancient heritage are to be closely protected, while at the same time conforming to present-day standards of structural and energy efficiency. In order to make this happen, the contribution of researchers to environmental issues has to acquire greater importance, overcoming the limits of mono-disciplinarity and involving in an integrated fashion various scientific fields relevant to the physical human environment and its interrelations with the natural environment.

Those other countries which are undergoing a phase of strong economic and cultural growth are paying less attention to the effects of an often invasive expansion, of unchecked development which – together with the growth in production and income – produces severe economic imbalances and environmental damage. In this scenario, a boundary line between town and countryside, between built and unbuilt areas, is no longer identifiable. A building bonanza is still going on undisturbed, while in built-up areas technologically backward systems with high heat dissipation continue to burn costly fossil fuels.

In Mediterranean European countries, such as Italy or Greece, the high seismicity of extensive areas requires general updating of construction standards. This need is often stressed: unfortunately earthquakes are frequent and are unfailingly followed by accusations and criticism, but this does not translate adequately into long-term policies. Littoral zones have been mostly built up, seriously damaging the coastal equilibrium. The short-sighted policy of favouring road transport over rail transport also leads to massive consumption of fossil fuels.

The problems created by the lack of suitable safety standards compound those created by the fragility of the land. Landslides and floods are common, but the damage they cause to urban areas is greatly increased by the lack of foresight in, and control over, building. Impermeability of the soil surface accelerates run-off, and the practice of building on unstable soil surfaces increases exposure to landslide risk. The quantity and diversity of regulations governing urban development is ultimately an obstacle to sound management of the land and the natural environment.

From a European perspective, it is important to overcome the idea of the historical environment as the heritage of each single nation. A broader view needs to be taken, adopting common lines of action to promote development based on energy efficiency, transport rationalisation and emissions control, thus enhancing the quality of life and attractiveness of European cities whilst ensuring the environmental compatibility of activities and use of spaces. The broader the application of innovative measures for environmental modernisation, the more effective they are: the need for environmental regeneration is such that improvements limited to restricted, even regional, areas are futile if obsolete approaches to soil use, production and energy consumption persist over wide areas.

For the purposes of promoting environmental quality, there is a real need to coordinate, target and fund research, both in the public and private sphere, in order to overcome sectoralism and combine efforts to achieve common priority objectives. Such objectives entail

- establishing a permanent dialogue between the worlds of research, production and public administration, replacing division with synergy;
- enhancing the protection of our cultural heritage with the action of private citizens, through simplification of public regulations, aimed at ensuring regional and environmental regeneration, and overcoming bureaucratic fragmentation;
- establishing a permanent dialogue between the worlds of research, business and public administration, creating a synergy as an alternative to compartmentalised approaches;
- ensuring that studies and research results translate into practical applications, integrating thought and action, reflection and practice.

In this collective effort, the role of scholars and researchers is crucial, but on condition that, in the research world, know-how is pooled and the various skills are integrated, thereby overcoming divisions and mistrust, as well as the obsolete dichotomy between the human and natural sciences. Consistent with what has been stated, the journal CSE is conceived as a space for researchers and scholars that supports exchanges based on ongoing or finished research and debate on environmental development and the improvement of natural and man-made environments, both in terms of visible aspects and of their function, technology, energy efficiency and safety.

The journal is open to analyses and proposals based on disciplinary integration, in which topics are viewed from different scientific perspectives converging towards an integrated vision. Our invitation is hence directed at all scholars, researchers and experts wishing to participate in the growth and spread of knowledge in the environmental field; but on condition that their approaches remain open to dialogue and integration, whether based on geology and volcanology, urban-regional planning, architecture – with landscape projects, history and urban design – or engineering with its different structural, technological and industrial branches, or energy efficiency at different scales. Contributions should be drawn from different disciplines; priority should be given to connections, to links and to consensus building.

CSE is divided into the following sections: Geology, Planning and Land Safety, Sustainable Urban Mobility, Environmental Design, Building Technologies, Energy Efficiency in Buildings and Districts, Materials Engineering. These sections, however, are not sealed compartments, but osmotically related areas, whose goals may be synthesised to enhance the environment from various standpoints.

Geology

The soil/subsoil system represents the indispensable space for establishing and developing human activities. For this purpose, knowledge of the system, closely linked to other components of the environment (air, water and life), becomes essential for planning activities and the use of space. This is ever more necessary given the current global climatic changes. Thus, geological features are considered crucial resources for human well-being, hence in need of safeguarding. However, in environmental design it is just as important to consider the factors causing severe geological processes in the environment (earthquakes, volcanic eruptions, landslides, floods, storm surges, and so forth). Such events can cause fatalities and considerable damage to the region concerned. Though it is not always possible to predict or mitigate the hazardousness of such effects, acknowledging the probability of occurrence becomes feasible through insights and modelling techniques. The intent of the new CSE journal is to promote and disseminate these goals in combination with other disciplines in order to make the sustainability of design and planning more effective.

Planning and Land Safety

In terms of sustainability, due reflection is needed to establish which development modes should be promoted. While there is overall demand for limiting the consumption of natural and agricultural soils, there is also the urgent need for the regeneration of existing building stock. The question becomes one of economic balance, involving the increasing cost of infrastructures, the need to exploit the value of urban land, the internalisation of environmental impacts, and so forth. Setting targets for land use appears a possible solution, but more research is needed on how this strategy should be applied at different scales and in different contexts.

Sustainable Urban Mobility

An important objective of this section is to narrow down the concept of sustainability, focusing on its meaning in relation to mobility, given that the term "sustainability" is in many cases misused and often generates confusion and misunderstanding. The issue of sustainable mobility can be tackled from many perspectives: social, economic, environmental, in terms of energy use, and so on. A common, shared definition thus needs to be agreed upon. Focusing on mobility in urban areas and through the use of case studies, research and best practice are used in this section to promote the debate, in the national and international scientific world, on issues concerning: the quality of routes available (especially those dedicated to non-motorised road users); levels of accessibility of those urban attractors which generate significant traffic flows; road safety, with particular attention to more vulnerable road users; the integration of traffic, mobility and urban planning techniques; the assessment of the contribution brought by application of ITS to this topic.

Environmental Design

In the context of urban planning, the goal of sustainability is pursued mostly at the neighbourhood level, establishing the formal, functional and environmental conditions for "good living", especially for existing neighbourhoods. There are many ways in which urban planning can be usefully integrated with other strategies to achieve "good living". Various examples may be cited, such as so-called soft mobility, with the related proposal of restructuring dominant models based on car mobility and the location and distribution of parking areas; controlling the microclimate in public buildings; urban waste management, the recovery and recycling of rainwater; use of trees to abate air and noise pollution.

Building Technologies

With regard to aspects related to building technologies, today in the context of the complex dialectic between technical solutions and sustainable forms of architecture the theme of sustainability is essential. The widely debated subject of sustainable building has led to the drawing-up of design codes, which include building systems, materials, new technologies, parts and components. A sound approach to building technologies today entails careful analysis in terms of a wise, rational use of resources and materials, and careful evaluation of their life cycle.

Energy Efficiency in Buildings and Districts

In this field, sustainable future development should include the creation of new energy-efficient buildings and districts, as well as suitable energy refurbishment of existing buildings and urban areas. Indeed, even if some differences can be noted across EU countries, the building turnover rate remains quite low all over Europe, with an average of 1–4 % per year. Thus, a sustainable future for the EU is possible only by adopting energy refurbishment as a key strategy. Against this scenario, institutions, politicians, policy makers, urban planners and building designers have to promote high-performing HVAC and active energy systems, besides integration with renewable sources. All these topics must be developed at both building and district level. In this direction, the new CSE journal supports the most recent of the European Union's goals, such as those ratified by EU Directive 2010/31/EC, which strongly promotes near-zero and net zero energy buildings for the near future.

Materials engineering

The application of a new approach to building sustainability includes the use of materials which reduce environmental impact. Such an approach includes compatibility with existing constructions, energy consumption, performance optimisation and all the issues which can make the difference, in relation to the materials normally used in structures. Again, close collaboration with other research fields is imperative and CSE represents an effective opportunity for researchers and the other actors involved in defining urban space to discuss, interact and remain abreast of the latest developments.

This first number contains articles on urban planning, land safety, sustainability, recycled materials, energy production and slow mobility. With this number we intend to initiate what we trust will be a productive and lively debate.

Urbanisation costs and charges: an italian perspective

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Keywords: urbanisation costs, development charges, public works, real estate market, municipal budget.

Abstract

The paper illustrates some parameters about urbanisation costs as an useful tool to set up the urbanisation charges in a more balanced way. From the theoretical point of view, the link between urbanisation costs and charges is clear in Italy, but it is not assumed in the legislation nor in technical guidelines for public administrators or professional consultants.

Already in the 70s, some researches proposed parameters to evaluate urbanisation costs. Those results were not considered within the urban dynamic management and the attention on them fell down. Then the problem was faced only to prove the different costs of facilities for high and low density settlements, aiming at demonstrating that sprawl is an expansive urban dynamic.

Now municipal budgets are facing serious problems to balance incomes and outcomes, due to the new urbanisation areas; also the gain of private developers, that in the past was higher when compared to the public one, is tailing off.

Nevertheless, the right balance of public and private gain is essential: without a clear evaluation of the costs and benefits obtained by every player, it is impossible to support the real estate market.

Some parameters will be proposed in the paper, whereas more detailed ones might be implemented in future researches, especially in relation to the secondary urbanisation works.

Applied researches should also be developed, where one or more municipalities could test the effect of the parameters on the urbanisation costs and on the real estate market.

The urbanisation costs: a renown topic

Evaluating urbanisation costs at local level is a main issue: per capita parameters or per square meter can help to evaluate the size of investments of municipalities.

The emphasis on economic parameters finalised at urbanisation was strong in Italy in the 70s. Forte and De Rossi (1974) proposed a list of about thirty parameters to evaluate size and unit costs of main supply and social services (road network, water supply, sewerage, electricity, gas network, school buildings, municipal buildings, hospitals and green areas). Bruno and Piccinato (1977) proposed a method to evaluate urbanisation costs using specific functions. They also observed that municipalities did not take into consideration the discount rate when realising the works. Furthermore, at different steps of realisation, the decision makers did not assure a complete optimal solution because they tried to minimize the costs of their single section (cf. system theory).

The law n. 1102/1971 was the first attempt in Italy to integrate urban planning and economic programmes: it established a new authority to administrate group of municipalities in the mountains (the so called Mountain Communities), with the aim of producing a plan for social and economical development along with an urban plan. Nevertheless, the authority was abolished in a short time.

After the 70s, urban planners and administrators were paying less attention to account urbanisation costs, with the result that most of urban charges are now underestimated.

The law n. 10/1977 connected the urbanisation works (water supply, sewerage, electricity, road network, etc.) with the building permission. The link between urbanisation costs and land development became more evident from a practical point of view. The *master plan* indicates the theoretical urban capacity in terms of new population, surfaces and volumes. The *plan of public works* defines the public facilities to be built in three years time, along with municipal budget.

No connection is expected between building costs of public services and urbanisation charges for the developers in urban areas. The amount of urbanisation charges should be set according to: demographic growth, geographic features and land use. The service costs are not appointed and the maintenance costs are never considered by local or supra-local authorities. The dependency of public services on municipal revenues is heavy and the quality of services in-

fluences land values. The municipal revenues come largely from property taxation (in continuous) and building fees or urbanisation charges (one time). The process of updating the value of property taxation and the urbanisation charges do not include the assessment of real urbanisation costs.
The need to coordinate urban and economic plans is evident, but its application is difficult. The urban plan is a mid-long term process, while the economic planning needs to be continuously and rapidly updated. A possible way out is to bypass the strategic view and work on single situations: the so called operational planning, that is a bottom up approach.
Property taxation, based on market values, should be also upgraded. The system to evaluate property taxation is obsolete: it used to be a great income for the municipalities, but the main tax on housing was abolish in 2008 (D.L. N° 93/2008), being re-introduced again in 2012 (L n. 214/2011) with a different name, but with less incidence for the incomes of the municipal budget.

A tool for the evaluation of urbanisation costs

Many researches on urbanisation costs try to compare low and high density settlements (e.i. Camagni, Gibellini, Rigamonti, 2002; Castel 2005; Hortas-Rico, Solé-Ollé, 2010; Guelton, Navarre 2010). These researches proved the possibility to estimate urbanisation costs, but they did not use the results obtained to improve the knowledge about urban management. The aim was to prove that the extensive settlements will face higher costs than the intensive ones.
A recent research (Tira and Richiedei, 2011) evaluated the urbanisation costs for residential areas in Lombardy (Italy): the results obtained could be scalable and used as parameters to update urban charges. The case study analysed the realisation and the maintenance costs for some public works: the realisation costs include water supply, sewerage, electricity and gas network, whether the maintenance costs include green areas, electricity, parking and road network. The costs were calculated for a sample of residential areas between 2,700 and 62,500 sqm. The settlements were built between 2006 and 2011 in a municipality near Brescia (Rovato).
Table 1 shows the average realisation costs for different facilities including some additional measurements. The average of about 20 €/sqm (of residential extent) has been proved to be the minimum amount to cover the urbanisation costs.
The *unitary costs for residential parcels* are calculated by using the below formula, where total costs for the facilities are shown:

Unitary costs for residential parcel (€/sqm) = Total cost of facility (€) / extent of residential parcels (sqm)

Parking, road network and green areas may generate additional realisation costs: these facilities were evaluated by using useful operational suggestions of Brescia municipality technical staff. The average of realisation costs for residential parcels is roughly: 3 €/sqm for parking, 15 €/sqm for road network and 4.5 €/sqm for green areas.
The overall unit costs is about 40 €/sqm and it includes the realisation of primary facilities for residential area as requested by the Law 10/1977.
Some of those facilities need continuous maintenance: for example parking places, road network and green areas. Table 2 shows the yearly maintenance costs for the above mentioned facilities.
The road networks have the main incidence in the yearly expenses for maintaining public spaces. The incidence of green areas and parking are equivalent. The average of yearly maintenance costs for residential areas is 1.54 €/sqm.
Other maintenance costs are not evaluable because they are covered by public service corporations, for example about water supply, sewerage, electricity and gas network.

Table 1 – Average of realisation costs for residential parcel, unit cost per square meter and incidence of facilities over total urbanisation costs.

Facilities	*Average costs (€)*	*Unit cost for residential parcels (€/sqm)*	*Incidence (%)*
Water supply	26,918	2.332	13
Sewerage	167,865	10.602	61
Gas network	33,527	2.117	12
Additional measurements	38,106	1.269	7
Electricity	18,231	1.151	7

Table 2 – Average of maintenance costs for residential parcel of parking, road network and green areas.

Facilities	*Unitary costs for residential parcels (€/sqm)*
Green areas	0.75
Road network	15.00
Parking	3.00

Comparison between municipal income from urbanisation charges and expenses for urbanisation costs

Urbanisation charges are related to specific public works in Italy and both can be divided into primary and secondary ones. The primary public works are mainly: road network, water supply, sewerage, electricity and gas network. The secondary public works are, among others: school buildings, municipal buildings, hospitals and main green areas. No cost parameters of these public works are proposed by legislation or supra-local authorities to help municipalities to evaluate the amount of charges.
An analysis of a sample of municipalities in the province of Brescia proves a significant underestimation of the amount of urbanisation charges. The average of primary urbanisation charges for residential areas is about 4 €/sqm, with a minimum of 1.50 €/sqm and a maximum of 9.0 €/sqm. The average of secondary urbanisation charges for residential areas is slightly more than 7.0 €/sqm, with a minimum of 1.2 €/sqm and a maximum of 15.0 €/sqm.
Considering a favourable situation to use all primary and secondary urbanisation charges to build only primary public works, the imbalance is clear: 9 €/sqm or 24 €/sqm of charges to build 40 €/sqm of public works, bearing in mind that parameters for evaluating secondary public work are not available and they will be explored in future researches.
There are also two kind of charges linked with the urbanisation: the *equivalent building cost fee* and the *cash in*. Even when including this components in an unique *building fee*, the evaluation of balance between income and outcome to manage urbanised areas by the municipalities is unfavourable. An easy analysis on residential areas proves that less than a half of building fee derives from urbanisation charges (figure 1): 35% from equivalent building cost fee, 25% from cash in, 23% from secondary urbanisation charges and 17% from primary urbanisation charges.

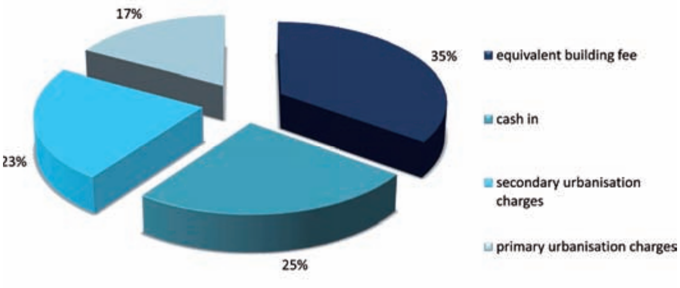

Figure 1 – Components of building fee for residential ares.

The municipalities seem to provide new development areas in their Master Plans in order to cover public costs left from other urbanisation areas.

A law about the possible use of building fees (issued in 2004) worsened the situation: the building fees can be used to cover ordinary expenses, not related to public services and facilities. Since in 2008 (for example) the 60% of municipalities in Lombardy had problems in ordinary budget (Richiedei, 2013), the lack of balance in ordinary expenses forced the Administrators to use building fees to cover ordinary over-spending (figure 2). As a consequence, some municipalities had to plan new urban development areas where buildings and services will be built, but the municipalities will also spend for new urbanisation works and management of public spaces, so increasing the balance problems and the soil consumption!
In the last ten years, that negative circle caused the increase of 15% of urbanised areas in Lombardy, without the necessary money to maintain them.
As a secondary effect, the forecast budget of the plan of public works was blown up by hypothetic incomes. The municipalities planned new areas (more then they needed) and forecast a lot of new incomes from building fees, so allocating more money to use for public services then the real last incomes.
Those findings will certainly be useful for the awareness of local and supra-local administrators and to define new proposals to review the use of urbanisation fees.

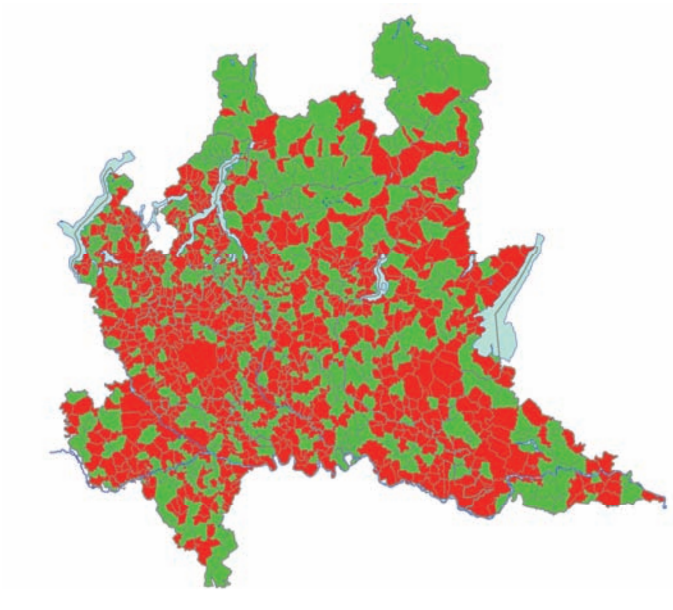

Figure 2 – Thematic map of Lombardy: in red the municipalities with ordinary budget problems and in green the municipalities without ordinary budget problems in 2008 (Richiedei, 2013).

Some possible rounding up/down

As briefly explained above, the primary and secondary urban charges are not the only contributions of private developers in public works. There are also two more components that can contribute to the building charges. Also including them

in the evaluation, the increase of construction charges have to be more than 60% in order to cover the costs of realisation and maintaince (for almost 25 years) of public facilities.
Another possible rounding up of construction charges could be given by environmental compensation. An increase of 6% of building charges can be enough to compensate the CO2 emissions for building and maintaining houses and mitigate the traffic generated in a residential area for 50 years. In other words a little increase should be useful to improve the environmental situation.
In a situation of real estate market crisis, the increase of private contributions can definitively block the market, which could be positive for containing sprawl. The real estate market crisis should be overcome with strong incentives of building renewal and brownfield regeneration. The redevelopment could be pushed by the decrease of redevelopment urban charges, as the public works already exist in those areas.
The *quality standards* could be another system to increase the income from urbanisation areas. This system rely on more charges or services to increase the quality of life. Since the land and building values increase thanks to urban development processes, a portion of the capital gain must be captured through additional charges. The amount of this quality standards could vary from double to six time the basic urbanisation charges.
The economic sustainability of this approach should be discussed with private developers, as the highest the charges are, the lower is the possibility of investments from real estate market actors.

Conclusive remarks

The paper investigated the use of parameters on urbanisation costs evaluation. Some case studies were analysed to produced some interesting results that could describe broader situation. The underestimation of the problem places the municipalities in a weaker position when negotiating with the private developers.
The paper highlighted the disequilibrium between urbanisation costs and charges requested by municipalities. The gap is a great disadvantage for the municipalities when the charges are lower than the urbanisation costs and the budget equilibrium suffers.
A limit of this paper is the stronger dependence on the case studies analysed, so that the results are somehow strictly valuable only in the specific context. Furthermore the costs of works are quickly changing, so a continuous update is necessary. Some other detailed public works should be taken into account as well.
Future researches should address the problem of evaluation of secondary urbanisation charges, that should define the optimal dimension of the parameter (per person, per surface, per volume, etc…). An interdisciplinary research with planners, lawyers and professionals on real estate market should be proposed in order to analyse the situation from different points of view and also an experimentation, according with some municipalities, should be brought forward.

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Ecologically oriented urban architectural renewal: three case studies[1]

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Keywords: redevelopment areas, building renovation, energy efficiency.

Abstract

In Italy, the complexity of regulations and of bureaucracy and the lack of an organic overall program make it difficult to carry out interventions aimed at safeguarding infrastructures and buildings against both seismic and hydrogeological risk and at making them more energy efficient.

Besides municipal permits, in protected landscape areas or in the case of protected historical or artistic buildings, any modification of the landscape or architectural intervention is subject to the authorization of the Ministry of Cultural Heritage. Unfortunately, there are no objective criteria for these authorizations and the subjectivity of the evaluation of the proposals often leads to different results in very similar cases. Also, while there are time constraints within which decision should be made, the deadlines are often extended. All this leads to an increase in management and operating costs, which are becoming increasingly unsustainable.

The present methodologically oriented paper deals with urban renewal and architectural renovation, presenting three case studies as examples of innovative approaches to the modernization of urban areas. In all three case studies, the traditional contents of urban planning are developed taking into account the guidelines imposed by regulations. In Italy, so-called "detailed executive urban plans" (piani urbanistici particolareggiati) often provide insufficient or uncertain indications with regard both to implementation and financial and management aspects. The present paper hypothesizes interventions to upgrade buildings technologically based on a multi-scalar and unitary idea of renovation, necessarily obtained through an interdisciplinary approach, which could be usefully adopted in actual practice.

SECTION 1 – UNDERLYING PHILOSOPHY

1.1 Introduction

Italian urban areas have a number of recurring elements: an historical center whose origins date to the Greek, Roman and/or Medieval period, in which (or on which) newer buildings were built up to the 1940s. Around this historical center we find a dense network of post-WWII buildings; this early modern area is succeeded by lower density areas and finally by the dispersed buildings in open countryside. Along with these areas, mostly reserved for housing and services, there are industrial and commercial areas, sometimes juxtaposed with residential ones and sometimes distinct from them, though generally contiguous with other urban areas.

With a few noteworthy exceptions, both historical and post-WWII buildings have a number of problems, which require different solutions depending on their age and construction technique. However, in Italy there is no general long-term program for safeguarding urban areas against seismic and hydrogeological risk and making them compliant with modern standards of energy efficiency, waste management, soil permeability and emission reduction.

The present paper discusses the urban and architectural renewal of three urban areas as methodologically useful case studies. Our goal is to demonstrate the possibility of regulating the modernization of urban centers in such a way as to make it more feasible while significantly reducing resource consumption.

Italian legislation makes it impossible to carry out extensive interventions based on general criteria; this is an obstacle to risk prevention and building maintenance in many areas of the country, including a sizable percentage of buildings deemed of historical and architectural significance.

For these buildings, any intervention must be first approved by the Ministry of Cultural Heritage. Specifically, any project must be examined and approved by ministry functionaries, who can also provide mandatory indications.

In the vast areas of the country declared of natural or environmental interest, any change in land use must be first approved by the local authorities. This authorization is then sent to the Ministry, which can approve or reject it. The authorization is not required, however, for ordinary or extraordinary maintenance, for static consolidation or for restoration interventions that do not result in a change in land use. Unfortunately, there are no objective criteria for such authorizations and the subjectivity of the evaluation of the

1. This work is the result of collaboration between two authors: Loreto Colombo has written section 1, Pasquale De Toro has written section 2.

projects often leads to different results in very similar cases. Also, while there are time constraints within which decisions should be made, these are often extended through requests for additional information and documents.
This system was created at the end of the 1930s and has remained basically the same in its approach (the citizens make a request, the government responds). However, it has become increasingly complex due to the growing legislation and the complexity of the relations between central and local administrations.
If one also takes into account the lengthiness of even the ordinary local authorization process, it becomes clear that the uncertainty and excessive duration of the procedures are a major obstacle to systematic urban and architectural renovation, notwithstanding its importance and urgency. This translates into unsustainable costs for individuals and society as a whole, and delays the modernization of the country.
What is more, while it is true that, even in protected areas, maintenance interventions are not subject to central authorization, many interventions aimed at making buildings more energy efficient, limiting resource consumption and ensuring seismic and hydrogeological safety do not always comply with legal requirements for ordinary and extraordinary maintenance, restoration or static consolidation and must be therefore authorized by the Ministry. For example, to install photovoltaic or thermal roof-tiles, insulate the walls, or lay a permeable external paving, each co-owner of a building must submit a individual application, which the bureaucracy often rejects for incomprehensible reasons.
It is necessary to overcome the centralist view for which citizens cannot take the initiative, but must be constantly monitored and controlled by the authorities through a complicated regulatory system, like a minor or a potential criminal. Eco-compatible interventions must be liberalized, freeing them from cumbersome authorization procedures that slow down the process and multiply the costs, to the point of making them unsustainable. In order for this to happen, it is necessary to subvert the long-standing relation between citizens and the authorities, replacing authorization with a general obligation to respect general guidelines, taking into account local traditions and styles. These should consist in regional or inter-municipal regulations for homogeneous areas, based on geographical, environmental, architectural and typological characteristics, specifying the technologies, materials and styles to be used for retrofitting buildings. Citizens will be responsible for applying these regulations.
The following case studies are all aimed at further developing and integrating the traditional content of urban renovation projects. The third planning level, that of executive plans, is often insufficient and uncertain in relation both to implementation and to financial and management aspects.
The present paper hypothesizes interventions of technological retrofitting of buildings based on a multi-scalar and unitary idea of renewal, which can only be ensured by an interdisciplinary approach, and which could be usefully adopted in actual praxis.

1.2 The historical center of Gaeta: the area of Sant'Erasmo[2]

The present condition and the research goals

The peculiar geography of the promontory of Sant'Erasmo, east of Mt. Orlando, led to the development of military fortifications and the construction of a mausoleum already in the Roman period. The urban settlement, surrounded by defensive walls, began to develop towards the end of the sixth century AD. Starting with the tenth century, the settlement began to extend increasingly outside the walls.
The study of current plans regulating the use of the municipal land and analysis of the buildings found in the historical center of Sant'Erasmo evidence a number of features: a type of tourism tied exclusively to the bathing season; isolation of the historical center notwithstanding its extraordinary potential; the presence of buildings in a poor state of repair or even in ruins and of others that are unused or used only partially.
The project goals are to acquire further knowledge concerning the art and historical heritage in order to promote tourism beyond beach holidays; develop a new form of hospitality that will promote local history and tradition; improve existing buildings and building standards.
Only 67 of the 172 residential buildings are used year round (figure 1). The absence of services is both the cause and effect of the absence of tourists in the low season and the decrease in residents and one of the reasons for the general lack of vitality of the town.
The above goals can be achieved through the *Distributed Hotel* model: a horizontal hotel, with a single management, based on rooms and services distributed among different but neighboring buildings to exploit the charm of the historical center. The aim is to promote, besides the usual recreational activities, new cultural experiences through the discovery of local identity.
For each building, the structure, the roof, the plastering, the technological services, and the decorative elements were examined, assigning to each of the aspects a weight based on its condition (figure 2).
This analysis allows us to evaluate necessary interventions for each building. Based on Italy's General Building Law (*Testo Unico sull'Edilizia)*, these interventions are distinguished in

2. Summary of the study by architects Agostino Buonomo and Laura Paone: *Recupero del Centro Storico Sant'Erasmo di Gaeta con destinazioni residenziali e ricettive*, 2012.

ordinary maintenance (*manutenzione ordinaria*); extraordinary maintenance (*manutenzione straordinaria*); restoration and conservative repairs (*restauro e risanamento conservativo*); building restructuring (*ristrutturazione edilizia*); urban restructuring (*ristrutturazione urbanistica*).

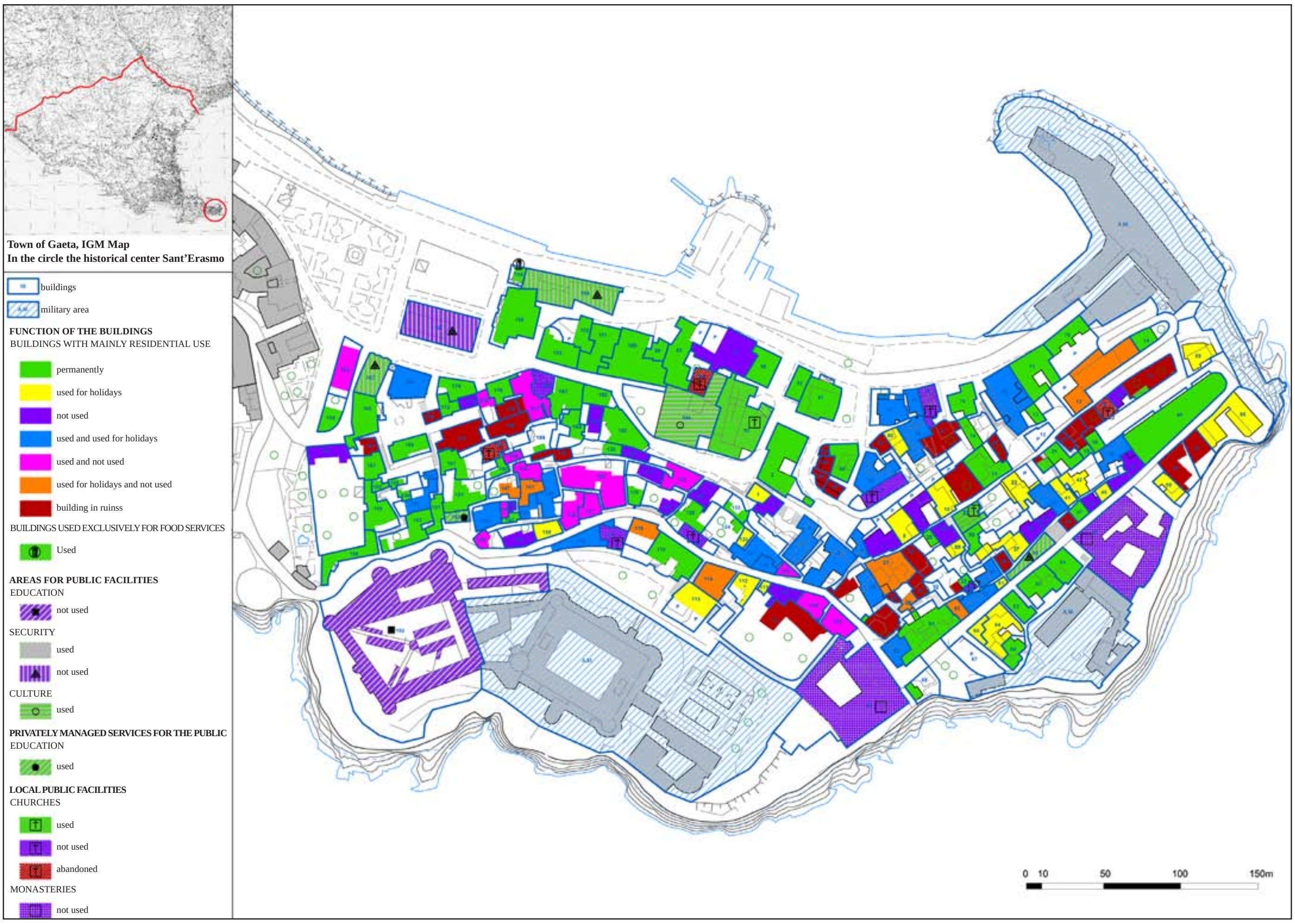


Figure 1 – IGM map. Use of buildings (summary of detailed catalog).

Unused or partially used buildings are reserved for: independent residential use, if sufficient in size; in other cases, if their characteristics allow, they are reserved as rooms and apartments for the distributed hotel or as services exclusively reserved for or having special agreements with the distributed hotel (figure 3). Uncultivated or abandoned land is to be transformed into parks with leisure facilities.

From the perspective of the protection, preservation and promotion of the architectural heritage, conceived as a testimony of historical and cultural values, requalification can be considered as the type of construction work with the greatest level of sustainability. However, requalification of small historical centers like Gaeta must be planned and carried out very carefully, since these are often the delicate product of the stratification of smaller elements, with strong ties to the local landscape, history and economy.

The historical center of Sant'Erasmo, starting with the post-WWII period, underwent much construction work that took little or no account of the importance of the traditional context. This has made it necessary to renovate it, respecting the character and historical importance of the place, reducing environmental impact, ensuring compliance with current environmental and energy standards, limiting the impact on resources and climate change.

Energy and environmental issues are global but our response must be local, taking into account specific climatic conditions, architectural culture, and traditional construction techniques.

Energy efficiency interventions

Since most roofs in Sant'Erasmo are pitched, the project calls for the installing, on the southern sides, of photovoltaic tiles, with embedded photovoltaic cells, or thermal tiles with embedded hot-water collectors (figure 4). The tiles are attached with aluminum elements or pre-mounted on thermally and acoustically insulated panels; their integration into existing roofs allows for a very limited aesthetic impact.

Considering that, in the historical center of Sant'Erasmo, the total surface area available for solar elements is around 9,200 m^2 and that there are around 2,000 users in the high

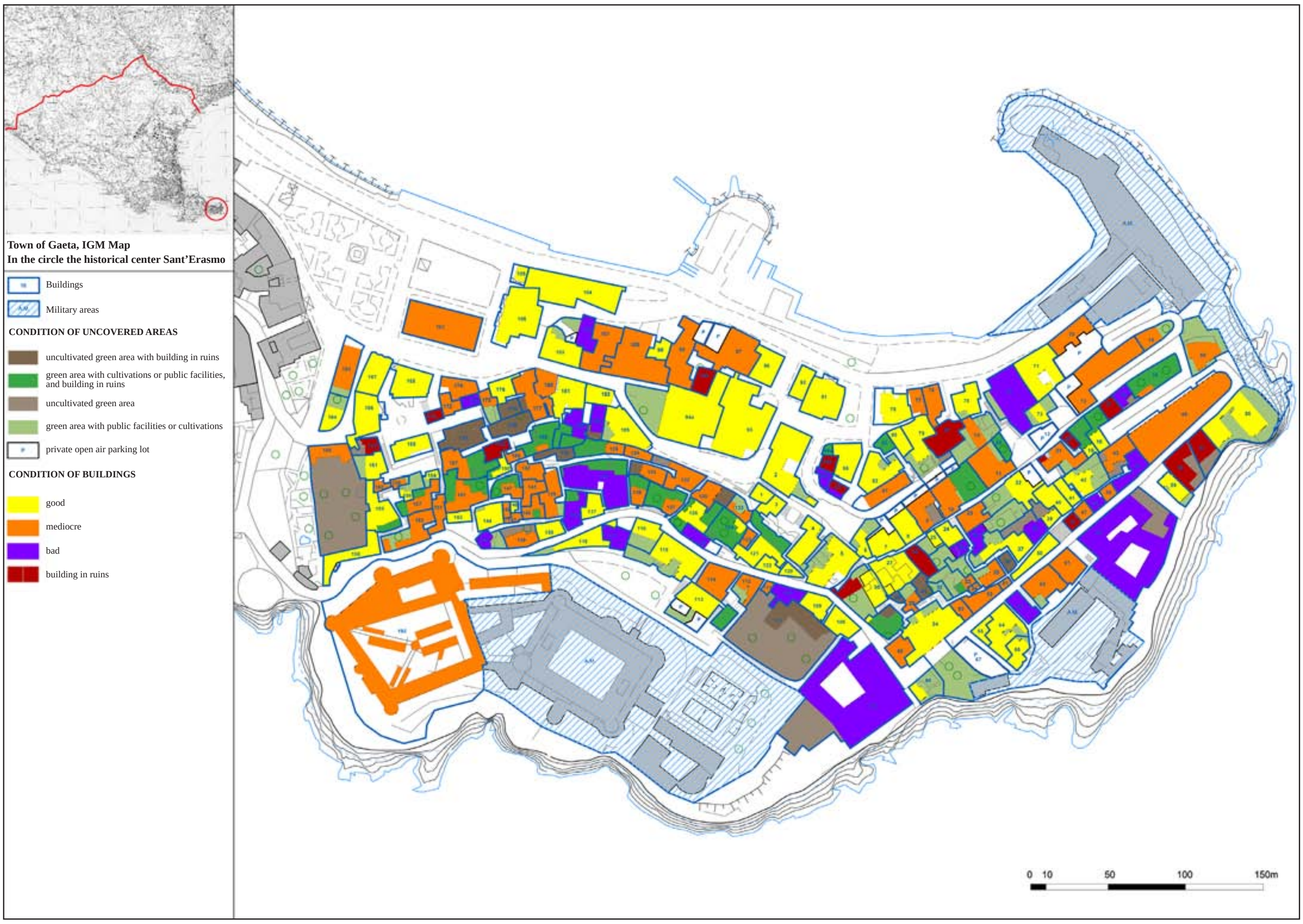


Figure 2 – IGM map. Condition of buildings and open areas (summary of detailed catalog).

season, two technological solutions, photovoltaic tiles and thermal tiles, were taken into consideration.

Photovoltaic tiles produce 1kWp for every 18 m^2 of tiles. Considering that an average four-member family requires 3kWp, using the entire available surface would satisfy the requirements of 700 people, i.e. 1/3 of the total population in the high-season. Instead, thermal tiles produce 50 l/h of warm water every 1 m^2 of tiles. They also require storage tanks to feed the hot water and heating systems. A four-member family requires 150 l/h. Using the total available surface area for thermal tiles would result in the production of 460,000 l/h which, even during the high-season, would exceed the total requirement.

Photovoltaic tiles allow for excess electricity to be fed back into the grid. By contrast, thermal tiles can distribute hot water only to the buildings they are installed on. Therefore, it is preferable to use thermal tiles for buildings that are permanently inhabited, opting for photovoltaic systems for all other buildings.

Recovery and recycling of rainwater

The recovery and recycling of rainwater to reduce waste, prevent water shortages and cut water provision costs, is highly conditioned by the natural environment and by the quantities required. The requirements of the population must be considered along with the average rainfall in the area and the possibility of installing storage tanks.

In the historical center of Sant'Erasmo, for example, we have planned a rainwater recyling system for a residential building, currently in ruins, which, in our project, is part of the distributed hotel with a capacity of fourteen guests. Given that the average annual rainfall in the municipality of Gaeta is 1,300 mm and that the building has a flat roof of 220 m^2, the system allows recovery of 280 m^3/year of rain water. Given that, in residential buildings, rainwater can be used for: water closets; washing machines; watering gardens and washing cars, the total rainwater requirement per person amounts to 18 m^3 / year per person. The 14 people in the building would therefore require 250 m^3/year.

Based on regulation E DIN 1989-1: 2000-12[3], a 12,000-liter

3. A. Campisano, C. Modica, *Performance of rooftop rain water harvesting systems for domestic use in Sicily* (Venezia, 2011).
Abdulla Al-Shareef, *Roof rainwater harvesting systems for household water supply in Jordan* (Elsevier, 2009).
C. Alvisi, M. Scagliarini M., *Progetto Non c'è acqua da perdere a Castel San Pietro Terme* (Provincia di Bologna, Settore Ambiente, 2008).

Figure 3 – IGM map. Use of the areas. Distributed hotel.

tank is required. In general, storage tanks can be positioned as follows:

- above ground: vertical tanks placed alongside the building beneath the downspouts;
- inside the building: tanks on the ground floor or in the basement;
- below ground: tanks buried in order to free up space and allow for greater capacity.

In the present project, the tanks are positioned in two existing rooms on the ground floor. Based on the products available on the market and the size of the rooms, we opted for three tanks connected in parallel per room, each tank having a capacity of 2,000 l, to be used for filtering and storing water. Being vertically positioned, the tanks use space efficiently and can be easily brought into the rooms. All devices that are to use recycled rain water must have a dual system, to be able to use recycled or regular water depending on availability.

Permeable paving

To help maintain the natural water cycle, and reduce the problems created by impermeable covering, it is preferable to use dry-laid paving techniques. A first layer of granular draining material is positioned with a thickness suited to the soil properties. Above this goes a layer of gravel and then the paving (figure 6).

This technique offers a series of advantages: rainwater drainage; adequate and constant level of naturally fed water tables; elimination of superficial water rivulets, increased safety during storms; more favorable microclimate since the land captures less heat during sunlight hours and irradiates less heat after sunset; less maintenance compared to asphalt. Historical paving can be restored and integrated to prevent total replacement, notwithstanding the practical impossibility of using the old techniques. An artisanal intervention can be used to improve the quality of the base product and of paving techniques. For new paving, local or in any case traditional materials are preferable. When traditional materials are not available or do not comply with functional or quality standards, a study must be carried out to identify compatible alternative materials.

In the historical center of Sant'Erasmo, for example, the durability of traditional paving is deemed insufficient for the parking areas of the distributed hotel. We therefore hypothesized the use of dry-laid concrete pavers, filling the spaces

Figure 4 – Example of pitched roofs: a) Thermal solar system integrated into tiles; b) Photovoltaic system integrated into tiles.

Figure 5 – Recovery of rainwater.

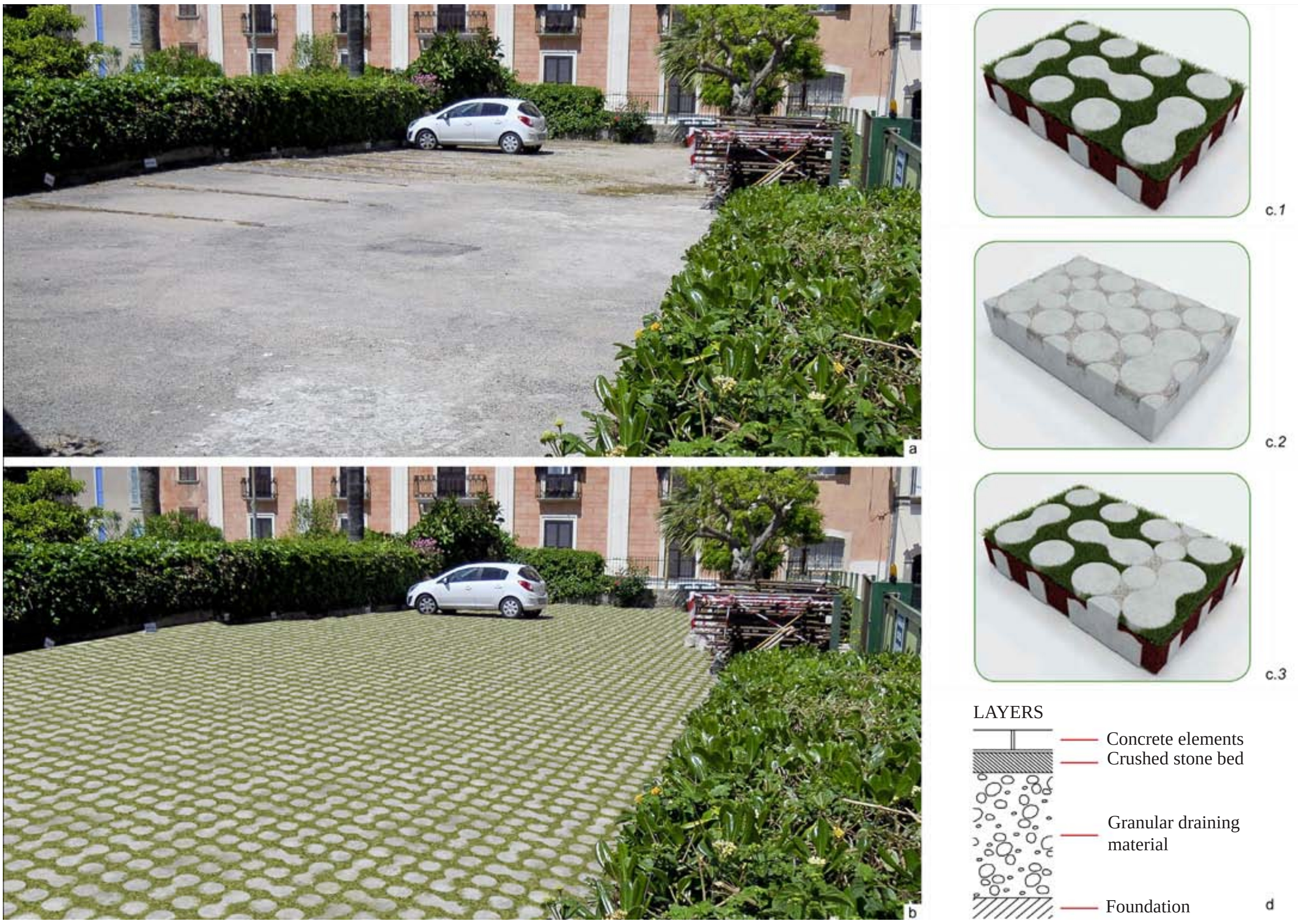


Figure 6 – Permeable paving made of concrete pavers, soil and gravel. a) Area reserved for parking in Via Pio IX, present state; b) Area reserved for parking in Via Pio IX, project; c) Type of filling for spaces between concrete pavers: c.1 soil; c.2 gravel; c.3 gravel and soil; d) Layers.

with either soil, to obtain a 'green' paving; gravel, to improve drainage; gravel and soil, for mixed paving.
Pedestrian routes are given priority over car routes since the historical center has few main streets crisscrossed by a dense network of stairways and alleys, which are too narrow for cars. This network should be preserved for its historical significance.

1.3 A '*vicinato*' in the Sassi of Matera[4]

Historical ecosystem

The so-called 'Sassi' (literally, 'rocks') of Matera are part of the historical center of the town of Matera. The Sassi are divided into two neighborhoods, the 'Sasso Caveoso' (figure 7) and the 'Sasso Barisano' (figure 8), which occupy two valleys separated by a small plateau where the 'Civita', the ancient acropolis, stands.
The two valleys, with their numerous lodgings partially dug into the hillside and underground, descend towards the 'Gravina' (figure 9), a ravine where the torrent of the same name flows, beyond which lies the Park of the 'Murgia Materana'. Beyond and above the Sassi, there is a plateau, 'il Piano', where the modern city stands.
Human occupation of the Sassi dates back to the Paleolithic period. They were inhabited up to the mid-twentieth century when the authorities decided to relocate the population for health reasons. Towards the end of the 1940s, the Sassi had about 13,000 inhabitants, mostly farmers, who occupied 2,997 houses, 2,552 of which consisted of a single room. There was an average of 4.36 people per room; 80% of the single-room houses were also used to house farm animals (figure 10). About 55% of the houses were dug into the cliff rock and were very damp, with little light or air.
Hygienic conditions were critical: the infant mortality rate was 44%; malaria, trachoma and tuberculosis were still very common. The publication of the autobiographical novel

4. Summary of the study by engineer Giuseppe Musano, *L'adeguamento tecnologico dell'edilizia storica. Una sperimentazione nei Sassi di Matera*, 2012.

Christ Stopped at Eboli by Carlo Levi[5] set in the area, marked the beginning of an intense debate on the condition of rural southern Italy, and Matera became the symbol of an archaic society. It was decided to provide the inhabitants of the Sassi with proper lodgings and since the Sassi were considered beyond restoration the people were relocated at the expense of the government.

Figure 7 – Sasso Caveoso.

Figure 8 – Sasso Barisano.

Figure 9 – The Gravina.

Three special laws were passed to relocate the population (619/52, 299/58 and 126/67). Only later were another two laws were passed for the restoration of the Sassi (1043/71 and 771/86). The 1956 Urban Plan (*Piano Regolatore*) outlined the future layout of the town. The relocation of the population was carried out in the 1950s and 1960s; the unsanitary habitations were expropriated by the government; new neighborhoods (Spine Bianche, Serra Venerdì and Lanera) and rural villages (La Martella, built with money from the Marshall Plan, and Venusio) were built and became symbols of the urban reforms of the post-WWII period.

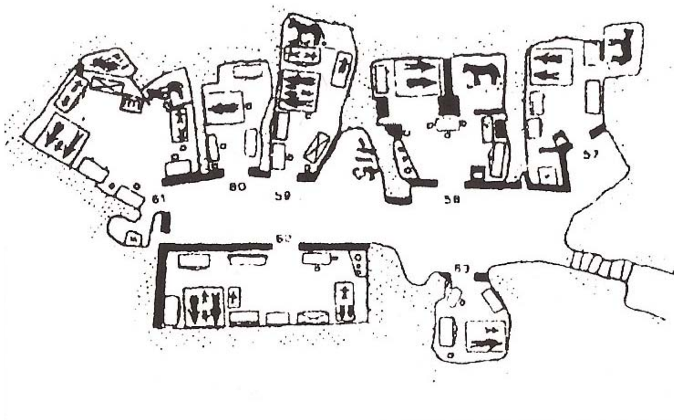


Figure 10 – Examples of houses dug into the slope.

For many years, nothing was done to restore the old houses, expropriated and abandoned. Only under Law 1043/71 was an international competition launched for the restoration and re-use of the Sassi, but none of the participating projects was deemed worthy of the first prize and therefore no project was approved. In the 1980s, however, initially through pilot plans and then with the two-year plans established under Law 771/86, the restoration began, still to be concluded.

In 1993, the Sassi became the first place World Heritage site to be listed by UNESCO in southern Italy. The following motivation was given: *The Sassi make it possible to time travel through all the ages of humanity. They bear witness to the capacity of humankind to create an environment suitable for living, while carefully and parsimoniously managing natural resources. The Sassi and the natural archeological park are a perfect testimony of ancient human activities. Their exceptional universal value springs from the symbiosis between cultural and natural values.*

More than simply an ancient historical town, the Sassi of Matera are an actual ecosystem (figure 11) made up of caves, cisterns, tunnels and galleries. Their present conformation is the result of building choices functional to the practical needs of everyday life. This extraordinary ecosystem allowed inhabitants to: gather rainwater into cisterns through a system of troughs; preserve food and mitigate the outside tem-

5. Written by Carlo Levi, an antifascist physician from Turin, and published in 1945, this autobiographical novel describes the discovery of the peasant world in the south of Italy during the author's exile by order of the Fascist government to Aliano, a small town in the province of Matera. The novel described a relatively unknown reality bringing to the attention of intellectuals and the wider public the problem of backwardness in provincial southern Italy.

perature during the rigid winters and torrid summers; ventilate the houses, thanks to the dense network of passages and tunnels; prevent erosion of the slopes of the Gravina through a system of terraced gardens. All building materials were obtained on site by excavating the caves or nearby quarries.

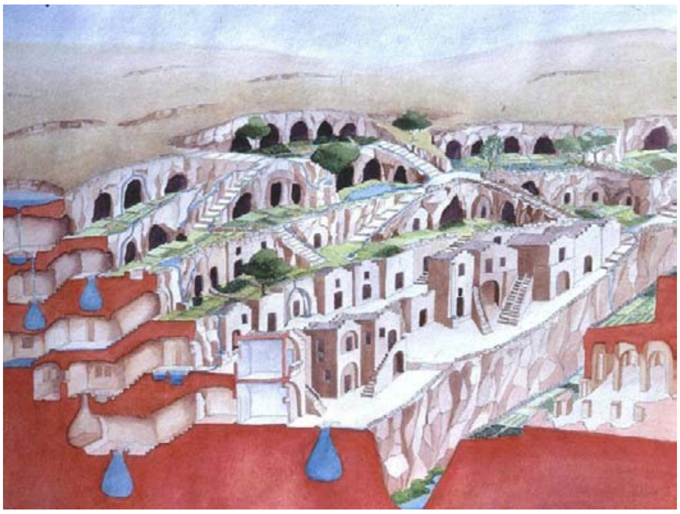


Figure 11 – The ecosystem of the Sassi.

The study of the ecosystem of the Sassi belies the idea of Matera as a backward place: this extraordinary settlement made the most of the harsh conditions imposed by the arid environment. The Sassi represent a living alternative to a notion of 'modernity' founded on the immoderate use of water and energy. They are an example of a 'low consumption' community, surviving in a harsh natural environment without wasting resources.
For all these reasons, any restoration of the Sassi cannot focus solely on individual buildings or areas but must acknowledge and preserve the unity of the ecosystem. The urban system can be subdivided for operative reasons only if the original relations between the parts are preserved, integrating different functions: a multifunctional town has a better chance of success compared to a monofunctional one. The residential function must be integrated with carefully evaluated tourism, productive, service and cultural functions, overcoming the historical divide between the Sassi and the new area of the Urban Plan, which has always excluded the ancient neighborhoods from the rest of the city.

Technological aspects

An organic legal framework for the restoration of the Sassi is found in the fifth and last special law for the restoration of the Sassi, Law 771/86, integrated by implementation regulations such as the Restoration Manual (*Manuale del Recupero*)[6] or the Code of Practice (*Codice di Pratica*).[7] However, there is still no systematic law governing the evaluation of environmental impact of interventions based on innovative technologies. Consider for example a hypothetical restoration of a typical '*vicinato*,' i.e. a public or private open space (courtyard, square, hanging garden, terrace) meant for collective use and surrounded by other rooms and dwellings. Various domestic and working activities took place here, making the *vicinato* a socializing space for various families.
Our case study is the *vicinato* in the area between Madonna delle Grazie and via San Clemente, in Sasso Caveoso (figures 12 and 13).

Figure 12 – *Vicinato* in Sasso Caveoso, in a photo from the 1950s.

Figure 13 – The same *vicinato*, today.

The buildings underwent static consolidation in the early 1990s but are still unused. The upper levels are suitable for social housing. At the lower level, some of the underground rooms could be used as basements or cellars (figures 14, 15, 16).
As in other *vicinati*, a cistern is found in the central court under the level of the house floors, collecting the rainwater that flowed through a network of troughs. The rainwater collection system could be reactivated by restoring the troughs, located inside or outside the outer walls, which could be lined

6. A. Restucci, *Matera: i Sassi, manuale del recupero* (Electa, 1998).
7. A. Giuffrè, C. Carocci, *Codice di pratica per la sicurezza e la conservazione del centro storico di Palermo* (Laterza, 1999).

Figure 14 – Maps of the *vicinato*.

Figure 15 – Maps of the *vicinato*.

with curved clay tiles and positioned on metal supports or on bricks inserted into the walls. The rainwater could be used to water a garden in the courtyard.

The thermal inertia of the underground rooms naturally regulates the temperature, providing cool air in the summer and warm air during the winter. As in the fingers of a hand, the central caves are deeper than the rest because they are the ones where the sunlight can penetrate the furthest. It is likely that even the inclination of the caves deliberately corresponds to that of the low winter sunrays, allowing the caves to capture the maximum heat during the winter, while preventing the near vertical summer rays from penetrating the caves, keeping the terminal areas of the caves cool during the hot season.

The caves are often interconnected by small tunnels, which favors air circulation; using raised pavements it is possible to create a forced ventilation system. When the old pavements cannot be restored, new ones should be made using terracotta tiles or local stones, while the vaults should be painted with quicklime, which allows the stone to transpire. The typical plaster used in the kitchen and bathrooms can be replaced with a plaster of *opus signinum*, which, once dried, has the characteristic of collecting humidity without absorbing it. To provide energy, the project calls for the use of photovoltaic tiles and glass (figures 17 and 18).

The basis on which the tiles rest is a thermally and acoustically insulated panel on which the curved tiles are placed. These frames can support both regular tiles and photovoltaic

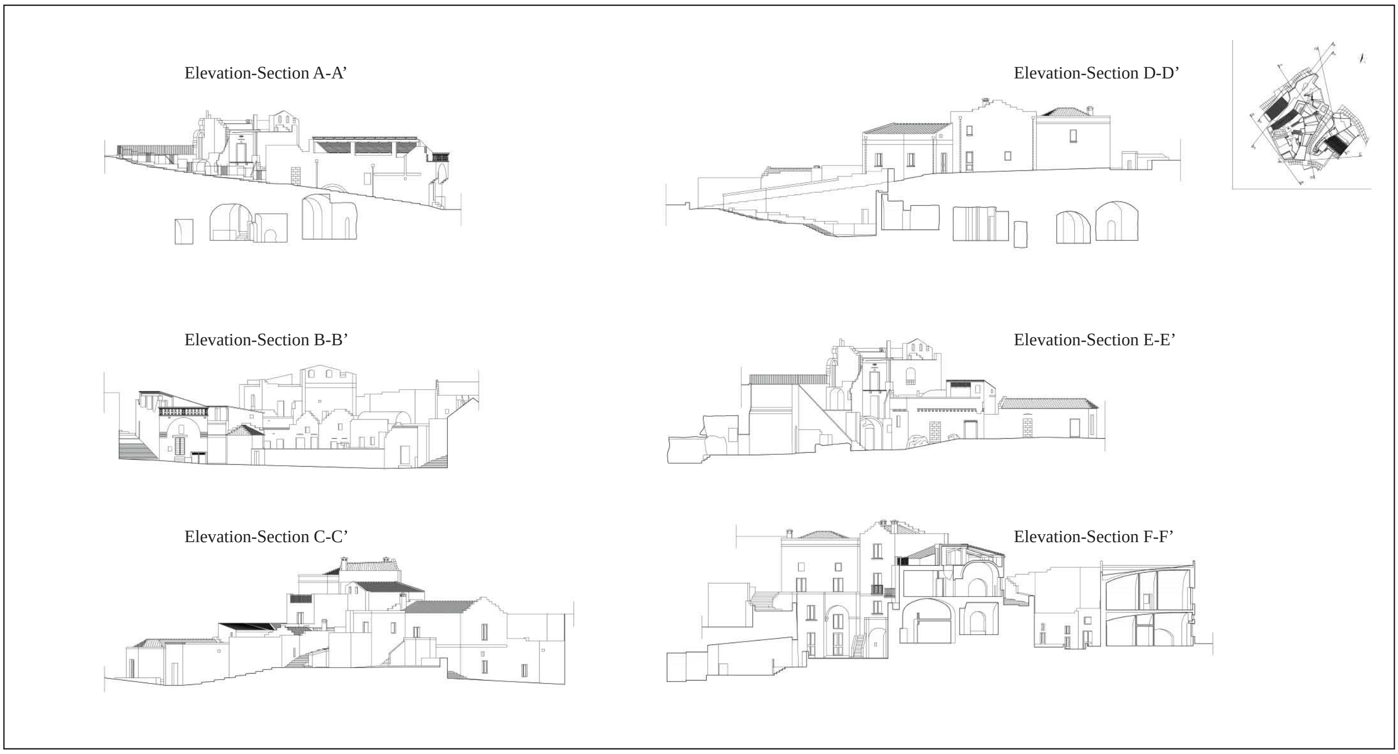


Figure 16 – Cross-section of the *vicinato*.

or thermal ones. The traditional tiles can also be installed without any need for structures or mortar. Curved tiles can be attached to the aluminum structures through joints.
The peak power of photovoltaic tiles is 3.8 Wp, obtained under standard conditions of 1000 W/m^2, 25°C and AM 1.5. To produce 1 kWp of electricity, 18 m^2 of photovoltaic tiles is necessary, i.e., about 250 tiles, each of which produces between 17 and 50 watts. The modules are joined both to the curved tiles underneath and to the other photovoltaic tiles further above and below on the roof, creating a single electric connection with the central system.
An electronic control unit collects data and identifies malfunctioning modules. A thermal tile has an embedded pipe through which a liquid flows. The sun heats it and the liquid warms the water used for washing or heating. The pipes in the tiles are connected to a main pipe, which in turn is connected to the building’s water system.
Part of the roof has been used for photovoltaic tiles and part for thermal ones. To reduce the visual impact, lines of normal tiles alternate with photovoltaic or thermal ones.
For the windows, wooden shutters identical to the original ones were chosen, while the panes consist of multilayer photovoltaic glass made up of:
- two external layers of glass;
- two films of Polyvinyl butyral (PVB), to prevent breaking;
- a central stratum of photovoltaic cells connected to the main electrical system.

In conclusion, non-invasive restoration techniques, applied while respecting and preserving the environment, the underground areas, the water network, the natural ventilation system and the hanging gardens, and the use of solar energy with adequate materials and techniques, can guarantee the future of this historical site, confirming the philosophy that underlies its ecosystem.

1.4 The conurbation of the Campanian plain: Densification, redesigning, consensus[8]

The area

The following emblematic case study concerns the plain south-west of Caserta, in Campania, occupied by a sprawling and continuous, mainly unregulated urban area, which extends west from Aversa all the way to Villa Literno. It is a tentacular conurbation, which includes seven municipalities whose urban centers have progressively extended over the countryside. Each town includes a historical center, surrounded first by a consolidated urban area and then by a sprawl that becomes progressively less dense as one moves towards the countryside. Unauthorized and unplanned construction is a typical trait of the area, especially in the peripheral urban areas (figure 19).
The expression ‘suburban sprawl’ can be used to describe this type of growth in peripheral or rural areas. There are, however, several types of suburban sprawl, which can be distinguished

8. Summary of the study by Marcello Ferrara, *Piano consensuale di assetto della città lineare diffusa Villa Literno - San Marcellino. Tutela, densificazione, trasformazione*, 2012.

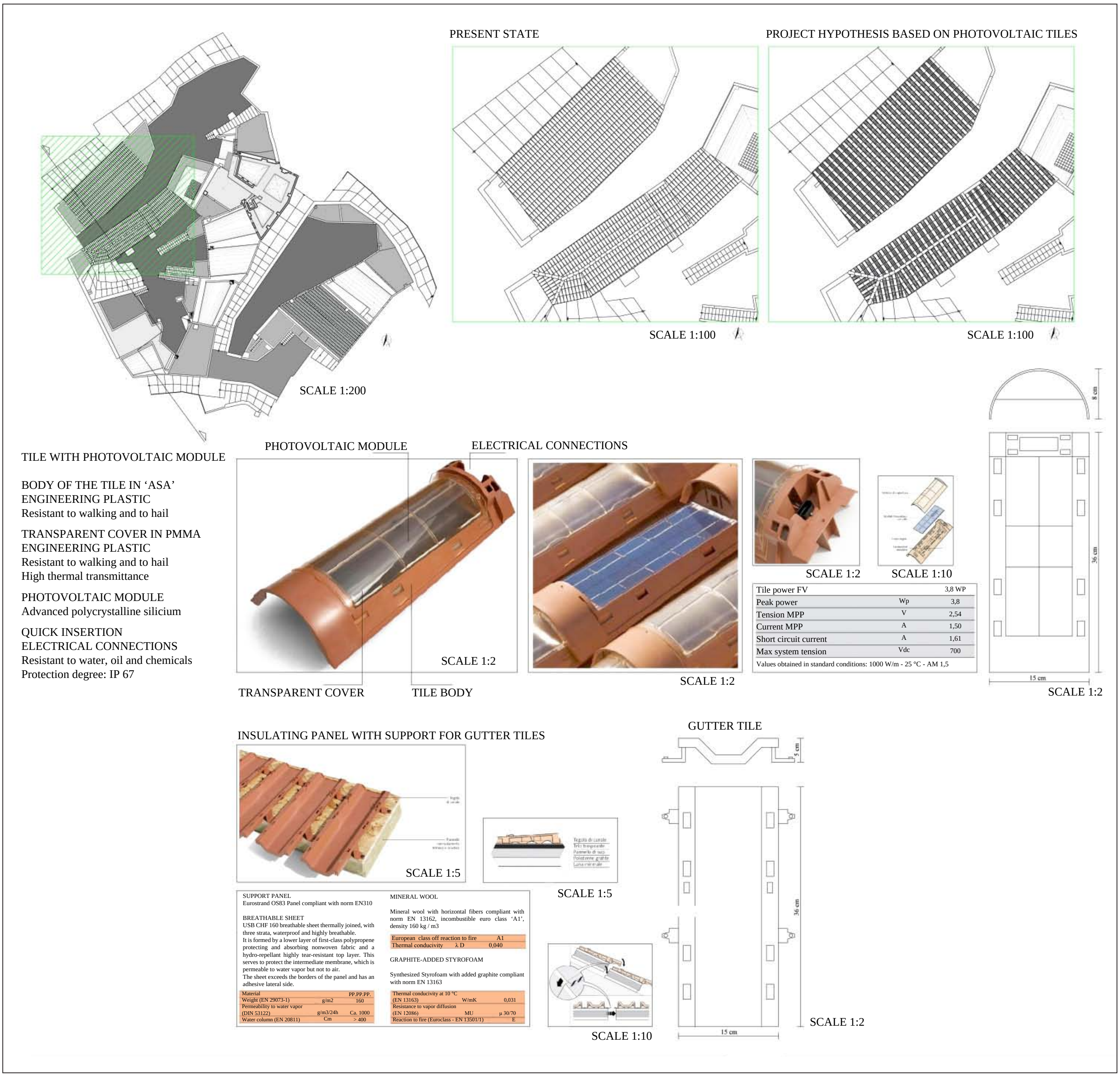


Figure 17 – Photovoltaic tiles.

based on their density, infrastructures, the old rural layout conditioning the present one, the type of buildings and the degree of authority control. The type of urban development described is typically present in the central-southern plains of Italy, where the presence of unauthorized buildings is at its peak.

Analysis of land use and the type of construction allows us to identify geometrical patterns and abaci (figure 20). First the fields are left uncultivated. Then they are divided into strips of width varying in size from 38 to 54 meters, which are then divided into building lots that are sold individually. Every two strips, room is left for a service road, of the necessary width (from 6 to 9 meters). The size of the lots varies, with an average of 20 m x 24 m (480 m^2). The houses usually take up half the available area (250 m^2) (figure 21). When all lots are built up, the average density is 4.2 m^3 / m^2. The typical buildings are one-family or two-family houses, made of reinforced concrete, with one or two stories, and possibly a basement, built at the center of the lot or along the boundary (figure 22).

Given the size of the phenomenon there is an urgent need for alternative solutions. At present these areas are almost entirely devoid of any urban or building quality. Specifically: There is a lack of even the most elementary services and infrastructures; old-fashioned, illegal and wasteful building technologies have been used; valuable agricultural land has been lost and the soil has been made increasingly impermeable; there is serious pollution from toxic waste dumps. New

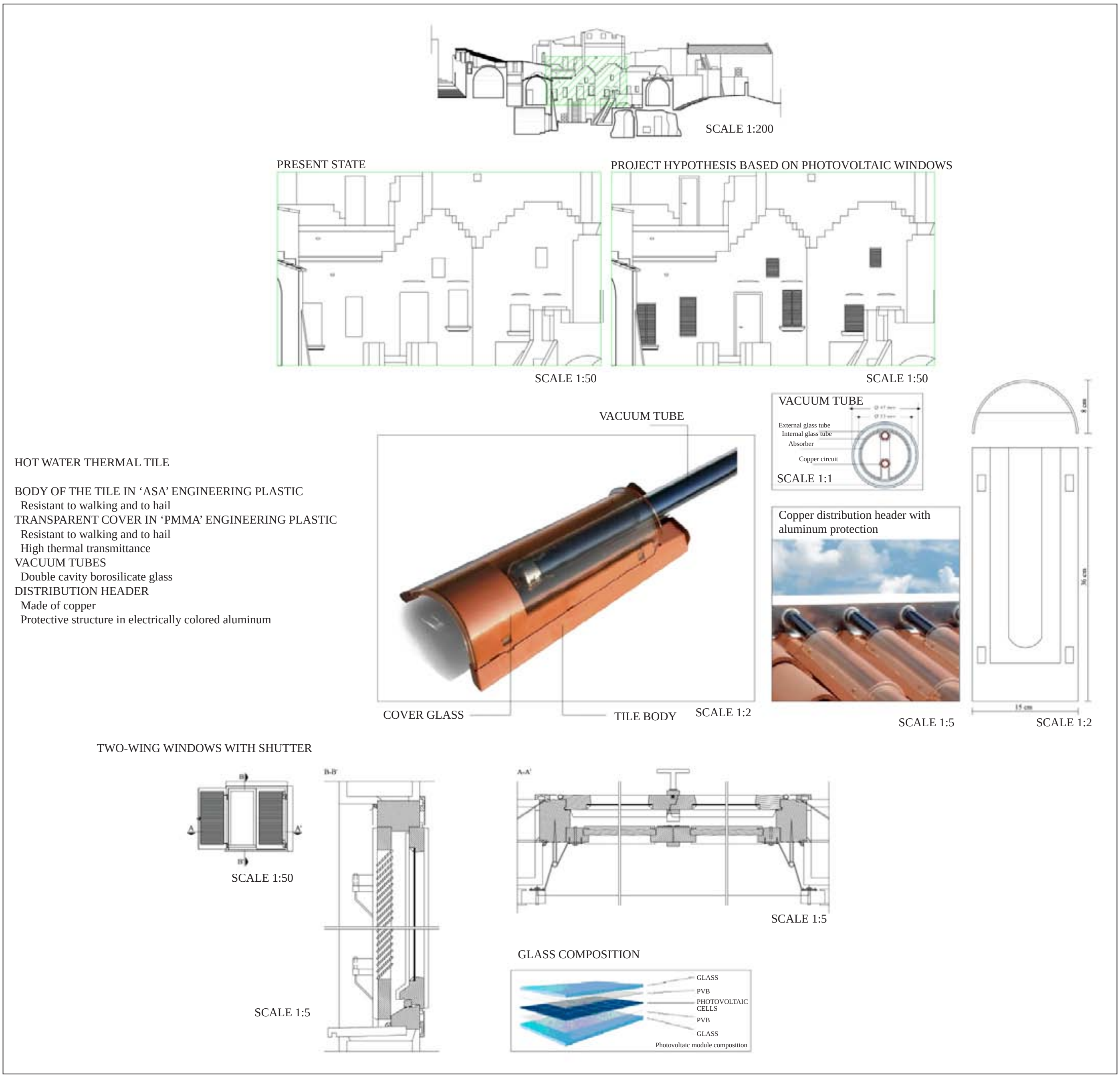


Figure 18 – Thermal tiles.

methods and approaches must be identified to improve the area moving from the urban scale to that of individual buildings (Lettieri, 2008).

The requalification plan[9]

The goals

Notwithstanding the enormous number of illegal buildings, we can assume that the normal measures prescribed by the law (confiscation and demolition) will not be applied (Totaforti, 2012; Nuvolati and Piselli, 2009).

It is necessary to ensure that, along with a rigid curtailing of any further illegal construction and a return to the rule of law, all the actors that have a legal or practical role be involved in regulating future land use.

The objective is to prevent further illegal construction while increasing the building concentration in urban-rural areas based on precise indications. Along with the general renewal, the plan establishes clear boundaries between town and country and the urban sprawl is to be provided with services and infrastructures that are currently absent or insufficient.

9. A work oriented in the same direction as the present study is the thesis– from which the text takes some contents and images – written under the supervision of the author, at the Department of Architecture at the University of Naples Federico II, by Marcello Ferrara; co-supervisor for economic and management aspects, Prof. Pasquale De Toro.

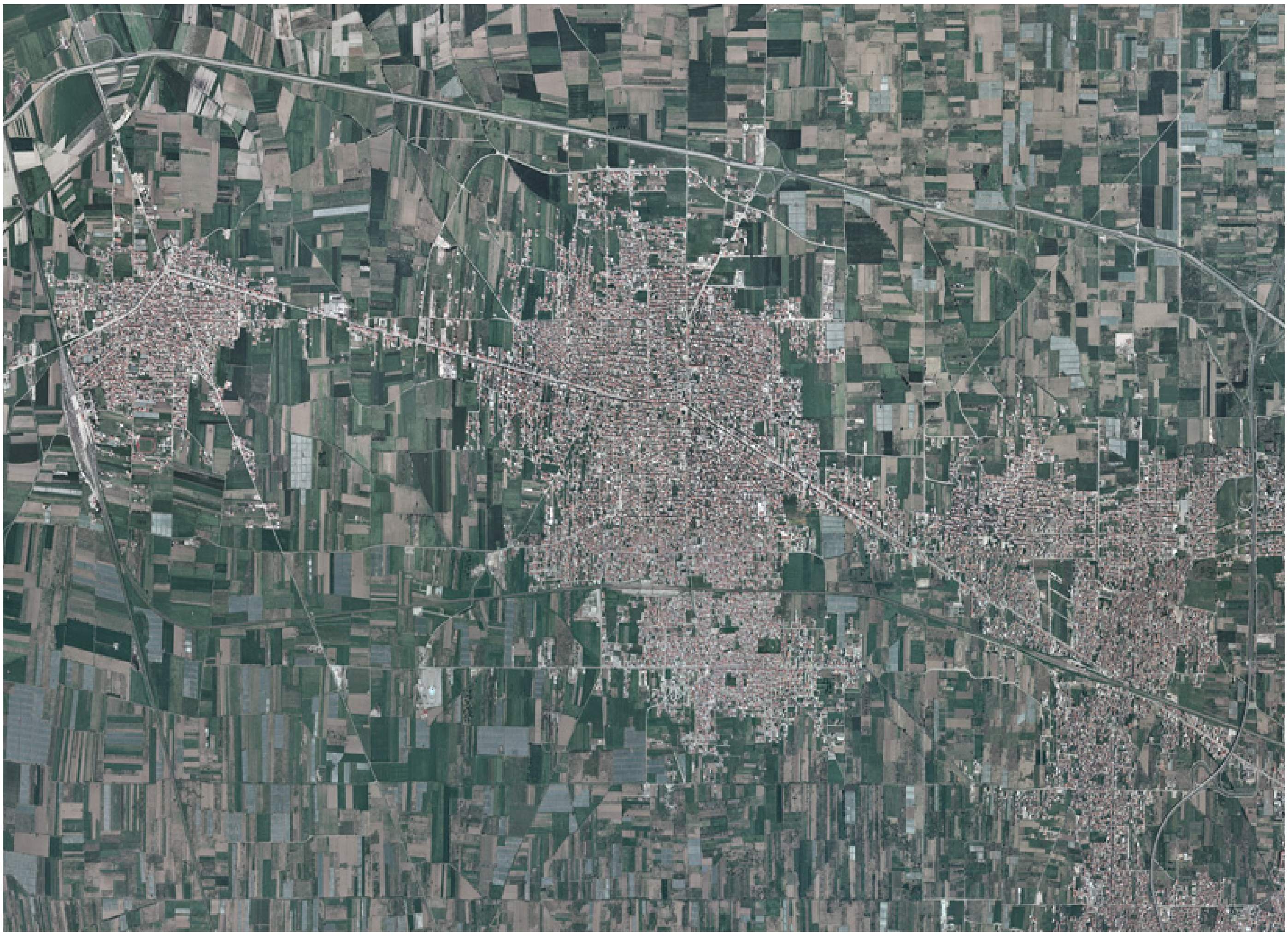


Figure 19 – The area of the case study is the conurbation that goes westward from Aversa all the way to Villa Literno.

These choices result in a plan that goes beyond the responsibilities of single municipalities and is necessarily of a special nature in terms of its goals and its management. There are no precedents in Italy, and the plan cannot therefore be directed following the complex ordinary laws governing urban planning.

Its ultimate goals are: to establish the boundaries between the urban sprawl and the country; preserve environmental, cultural, architectural quality through the preservation and promotion of natural, cultural and environmental values; preserve the quality of urban and extra-urban landscape as an aspect of historical and cultural identity; restore buildings and renovate settlements and non-urbanized areas, especially the more degraded ones, while furthering economic and social development.

The present plan is based on consensus: a necessary premise of the plan program is a series of public-private agreements to be reached through debate among all parties concerned. A fundamental role in the program is played by the professionals who will manage participation and by the facilitators, on account of the issues among the local population along with the objective complexity of the plan.

A significant percentage of public works are financed by the private sector which, in exchange for giving land to be used for public purposes, receives more extensive building permits and tax breaks. The plan therefore regulates the development of the area leveraging on the personal interests of individuals to promote the interests of society.

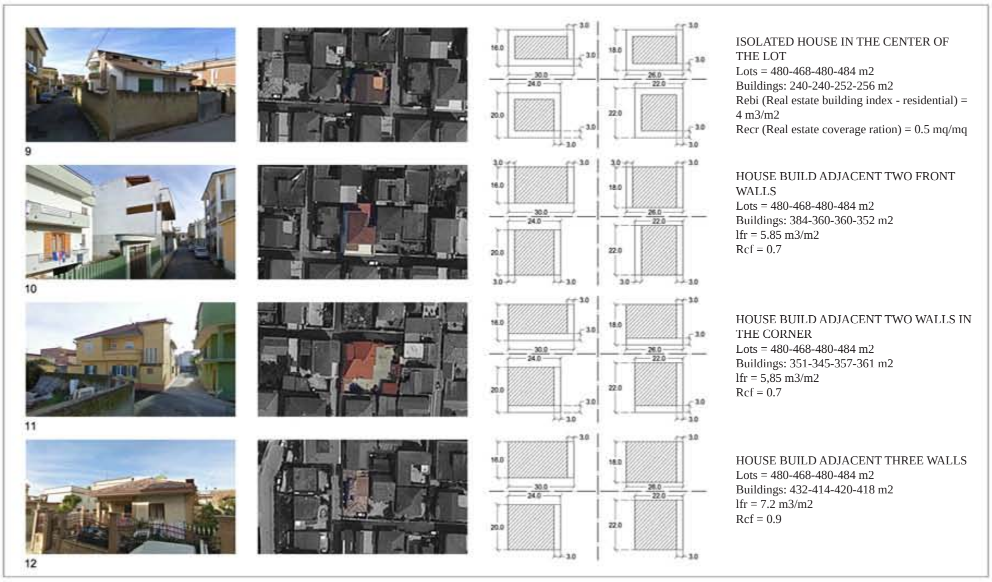
Population and requirements

The tendency that emerges from recent demographic analysis, i.e. constant level of internal factors (rate of birth and mortality) and external factors (immigration and emigration), shows a population increase in the seven municipalities (table 1). A variation in the composition of the average family is also foreseeable, which would result in an increased demand for housing and public services.

Based on more than one type of projection, we can foresee a population increase of 18% over the next 20 years, corresponding to 14,500 people. This implies the need for standard public infrastructures, which based on the criterion of 22 m^2 / inhabitant as necessary for an acceptable quality of living, results in more than 1,825,000 m^2 of surface.

Considering a unitary volume per room of 80 m^3, a ratio of

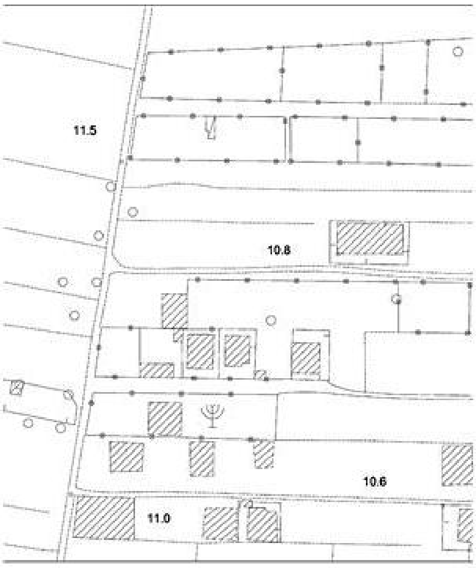
Abacus of building structures in the historical center



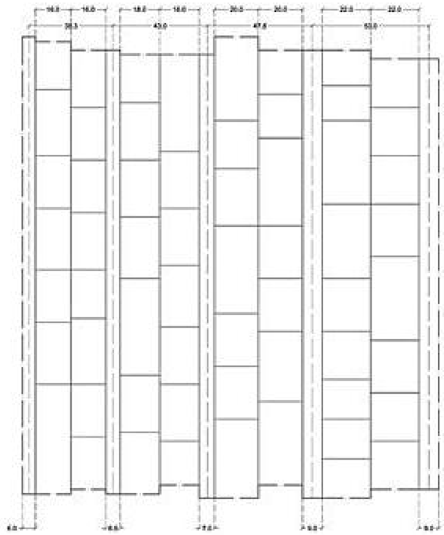
Abacus of the building surface / covered surface in the consolidated urban area

Abacus of the building structures in the spontaneous urban area

Figure 20 – The abacus of the buildings typically found in historical centers, in the consolidated city and in the developing city.



Urban periphery in the initial urbanization phase (Villa Literno)



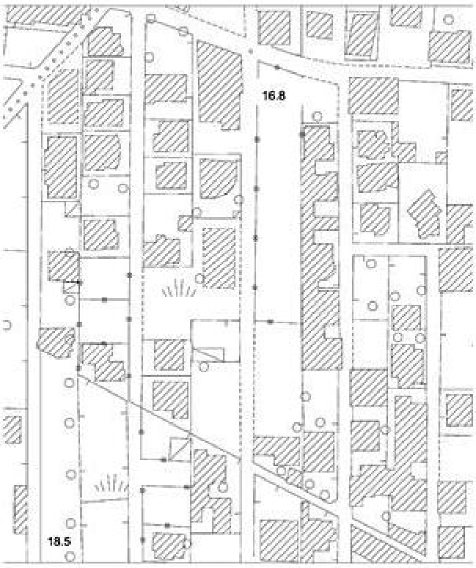
TYPICAL SURFACE DISTRIBUTION

Total surface
Ts = 38,260 m2

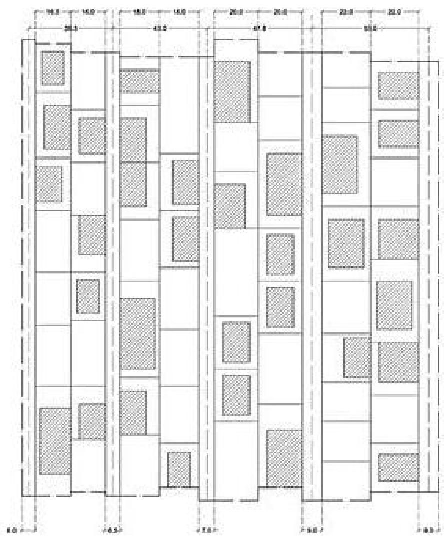
Public surface (streets)
Ps = 7675 m2

Real estate surface
Res = Ts – Ps = 30,584 m2

Geometrical matrix of the urban periphery in the initial urbanization phase



Spontaneous urban area in its final phase (San Cipriano Aversa)



TYPICAL SURFACE DISTRIBUTION

Total surface
Ts = 38,260 m2

Public surface (streets)
Ps = 7676 m2

Real estate surface
Res = Ts – Ps = 30,584 m2

Used land surface
Uls = Res – Fres = 17,612 m2 (60%)

Free real estate surface
Fres = 12,972 m2 (40%)

Territorial building index (residential)
Tbi = Vtr / Ts = 71,096 m3 / 38,260 m2 = 1.8 m3 / m2

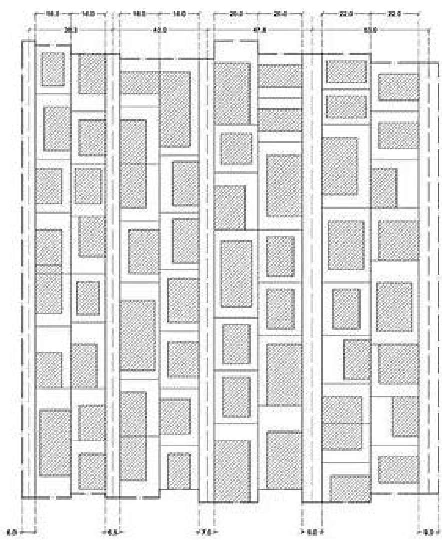
Real estate building index (residential)
Rebi = Vtr / Ts = 71,096 m3 / 30,584 m2 = 2.3 m3 / m2

Territorial coverage ratio
Tcr = Cs / Ts = 8,887 m2 / 38,260 m2 = 0.2

Real estate coverage ratio
Recr = Cs / Ts = 8,887 m2 / 17,612 m3 = 0.5

Geometrical matrix of spontaneous urban area in its final phase

Saturated spontaneous urban area (Frignano)



TYPICAL SURFACE DISTRIBUTION

Total surface
Ts = 38,260 m2

Public surface (streets)
Ps = 7676 m2

Real estate surface
Res = Ts – Ps = 30,584 m2

Used land surface
Uls = Res – Fres = 30,584 m2 (100%)

Free real estate surface
Fres = 0 m2 (0%)

Territorial building index (residential)
Tbi = Vtr / Ts = 125,032 m3 / 38,260 m2 = 3.1 m3 / m2

Real estate building index (residential)
Rebi = Vtr / Ts = 125,032 m3 / 30,584 m2 = 4.2 m3 / m2

Territorial coverage ratio
Tcr = Cs / Ts = 15,629 m2 / 38,260 m2 = 0.4

Real estate coverage ratio
Recr = Cs / Ts = 15,629 m2 / 38,564 m3 = 0.5

Geometrical matrix of saturated spontaneous urban area

Figure 21 – Layout resulting from urban growth.

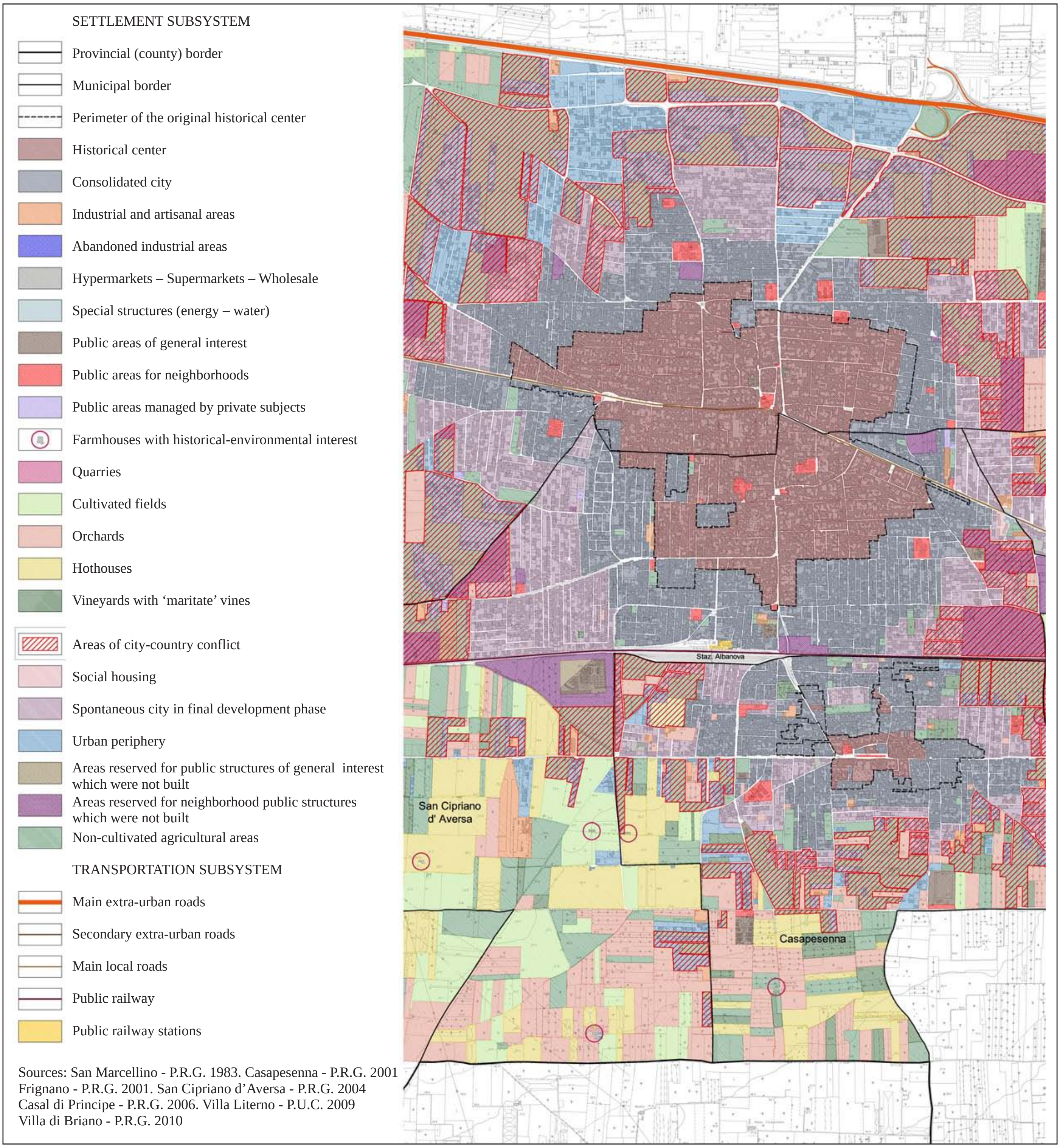


Figure 22 – Extract from existing urban plans Inside the Agricultural Zones of the plans the red-striped areas are the ones characterized by country/city conflict.

real estate coverage (*Rapporto di copertura fondiario*) of 0.3 m^2 / m^2 and an index of real estate building allowance of 1.3 m^3 / m^2, the total gross paved surface comes to 391,500 m^2 (table 2).

The contents

A complete restoration of degraded and altered historical centers is called for, to be achieved through the renewal of public spaces, the protection and restoration of surviving buildings of interest, a decrease in traffic, the modification of incongruous buildings. Recent buildings in reinforced concrete are restructured or replaced in line with pilot projects oriented towards sustainability (figure 24).

Consolidated urban areas, spontaneous sprawl and public buildings will undergo urban-architectural renewal and densification through architectural restructuring or replace-

Table 1 – Demographic projection to 2032.

MUNICIPALITIES	RESIDENT POP. 2011	VARIATION 2011-2032		RESIDENT POP. 2032
	ab	%	ab	ab
Casal di Principe	21.404	17,2	3.681	25.085
Casapesenna	6.874	8,1	557	7.431
Frignano	8.659	2,5	216	8.875
San Cipriano d'Aversa	13.085	10,4	1.361	14.446
San Marcellino	13.308	28,8	3.833	17.141
Villa di Briano	6.522	29,4	1.917	8.439
Villa Literno	11.676	26,7	3.117	14.793
TOTALE	**81.528**	**18,0**	**14.683**	**96.211**

Source: Istat data

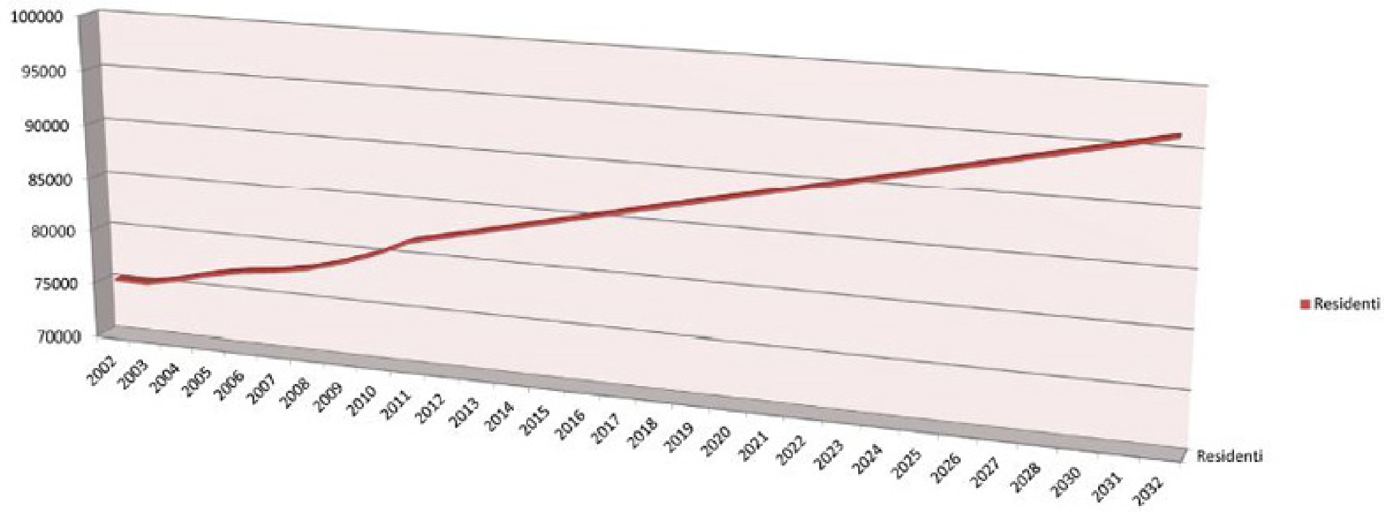


Table 2 – Housing requirements based on estimated population increase.

MUNICIPALITIES	Pop. variation 2011-2032	Housing requirements		Real estate surface	Real estate building index	Real estate building ratio	Gross Coverage surface	Max Heigt above ground
	pop.	mc/pop.	mc	mq	mc/mq	mq/mq	mq	m
Casal di Principe	3.681	80	294.480	277.108	1,06	0,3	98.160	12
Casapesenna	557	80	44.560	49.089	0,91	0,3	14.853	12
Frignano	216	80	17.280	36.447	0,47	0,3	5.760	12
San Cipriano d'Aversa	1.361	80	108.880	69.410	1,57	0,3	36.293	12
San Marcellino	3.833	80	306.640	95.090	3,22	0,3	102.213	12
Villa di Briano	1.917	80	153.360	101.507	1,51	0,3	51.120	12
Villa Literno	3.117	80	249.360	250.306	1,00	0,3	83.120	12
TOTAL	**14.683**	**80**	**1.174.640**	**878.957**	**1,3**	**0,3**	**391.520**	**12**

ment, with increases of up to 30% of the present volumes as incentives. Replacement and densification are integrated with density reduction schemes, with the compacting of volumes and the setting back of buildings to create green areas (figure 23).

All changes are aimed at reducing consumption, through passive energy-efficiency and water systems (solar hothouses, solar screens, triple-pane thermally insulated windows, water reclaiming and recycling) and active systems (photovoltaic), and through the use of recycled and renewable materials (figure 24). The boundary between town and country is established: inside the built-up areas, the plan calls for architectural densification and compacting, along with the integration of infrastructures and services, and compensatory transfer of building volumes. Densification is achieved by offering builders the possibility of increasing volumes in exchange for the creation of public infrastructures, complying with eco-compatible building standards and aiming for architectural quality (figure 24).

With a view to architectural renewal, the project identifies: areas for neighborhood public infrastructures in urban areas; run-down farmhouses in rural areas of historical and envi-

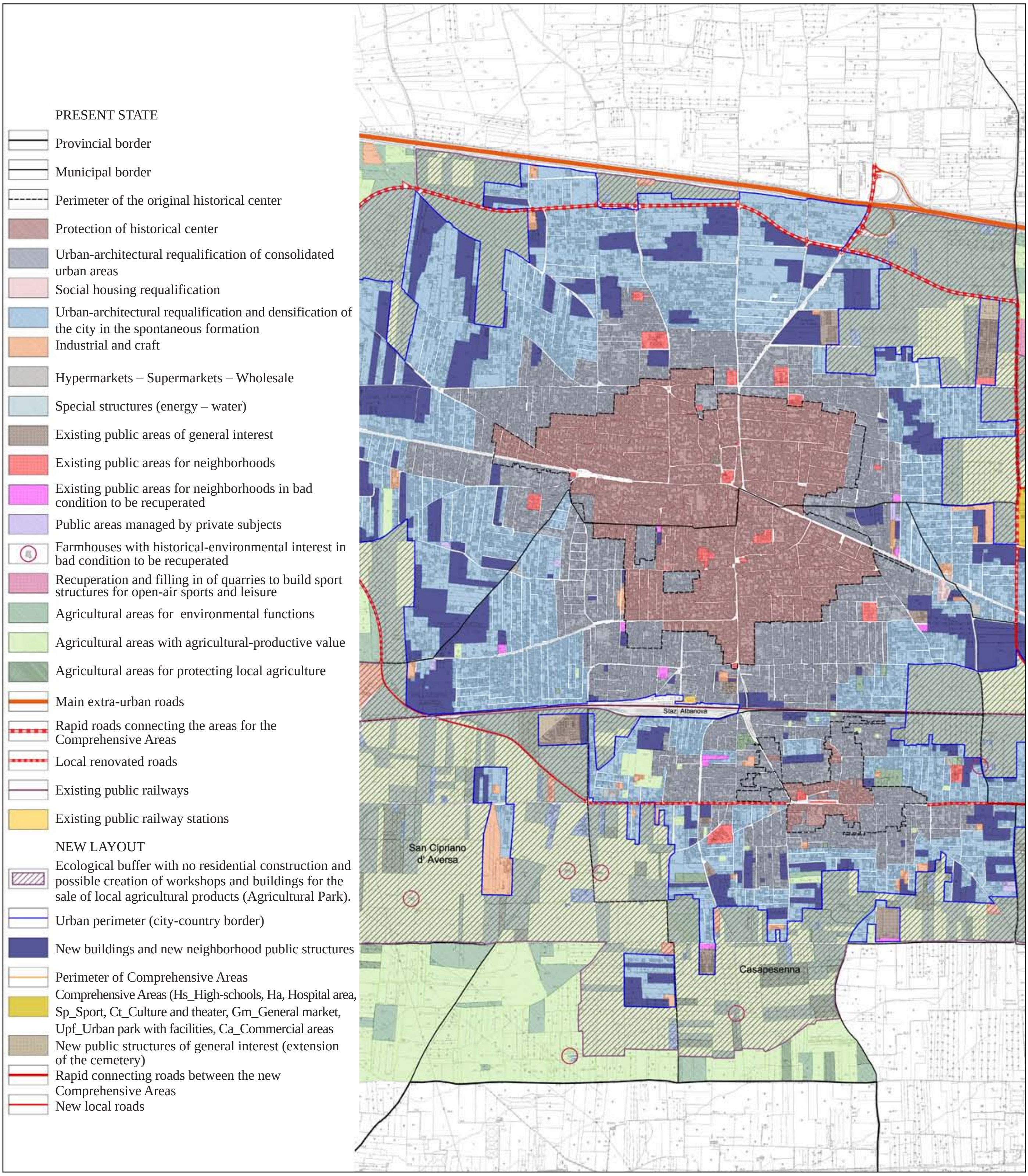
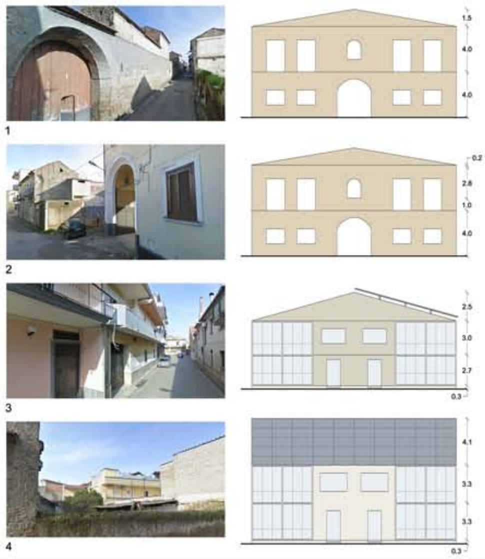


Figure 23 – Extract from the zoning map of the public consultation plan (*piano consensuale*).

ronmental interesting. Promoting artisanal and commercial activities likely to revitalize town centers is also envisaged.

An agricultural park along the town-country boundary functions as an ecological buffer between the urban sprawl and the prevalently green areas. Within the park, building is limited to farm production requirements (labs, silos, places for presenting and selling local products).

For the rural areas, the existing strategy of the Regional Territorial Plan (*for a new alliance between urban and rural areas*) is confirmed, in which rural areas are treated as a 'common good' regardless of ownership. There is focus on the multifunctionality of rural areas, on their capacity to produce



ORDINARY AND EXTRAORDINARY MAINTENANCE
Interventions on preserved buildings
Ordinary maintenance: interventions for reparation, renovation and replacement of the building finishes and to integrate or maintain the efficiency of existing technological systems.
Extraordinary maintenance: interventions necessary to renovate and replace parts, including structural parts, of buildings, as well as installing and integrating sanitary and technological systems, without however altering the total volume and surfaces of individual buildings and modifying their function.

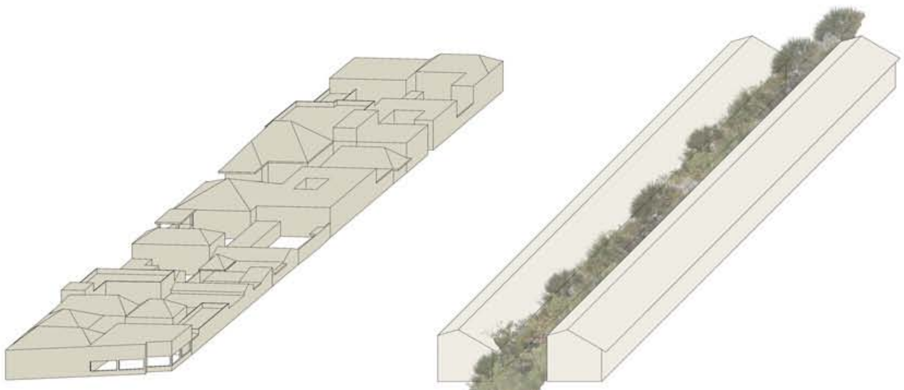
CONSERVATIVE RESTORATION
Interventions on altered buildings
Preservation of buildings and their functionality, through an organic series of interventions which, while respecting the type, and formal and structural characteristics of the buildings, will allow them to be used for compatible functions. The interventions include consolidation, restoration and renovation of the constitutive elements of the buildings, the introduction of accessory elements and of the systems required for their functions, the elimination of extraneous elements such as projecting verandas, reinforced concrete slabs, etc.

ARCHITECTURAL RESTRUCTURING
Interventions on new or replaced buildings
Interventions aimed at transforming buildings through works aimed at replacing or eliminating the constitutive elements of the buildings to improve their energy efficiency, their sanitary system, by inserting new eco-sustainable constructive elements and systems. The plan calls also for interventions of structural updating and partial demolition, through vertical thinning, of the number of floors exceeding the environmental characteristics. Within the historical center, all architectural restructuring is performed without any increase in volumes.

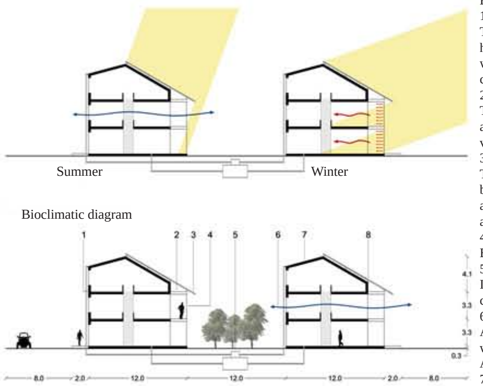
ARCHITECTURAL REPLACEMENT
Interventions on replaced and new buildings
Demolition of buildings that alter the environmental context, built in reinforced concrete, without eco-sustainable criteria, and replacement with new buildings,. The volumes of the new buildings must be in line with contemporary architecture, based therefore on modern construction methods, in terms of sustainability, technology and energy efficiency. Within the historical center the replacement of buildings is carried out with no increase in volumes.

Protection of the historical center

The project promotes restructuring and replacement interventions based on mechanisms of urban rewarding, offering compliant subjects the possibility of increasing the volumes of the new buildings up to 30%. Interventions of replacement and densification of the buildings must be accompanied by interventions of urban thinning, making buildings more compact and distant from the streets, in order to create space for green areas, improve roads and urban quality. Furthermore, all transformation work must have as its goal the reduction of consumption, incrementing energy and water efficiency in the buildings, through the use of passive and active construction systems, recycled and renewable materials.



Urban-architectural requalification and the densification of the city.



Neighborhood “Gneis Moos” Salisbourg - Austria   Solar neighborhood “Vauban” Fribourg - Germany

ENERGY AND WATER EFFICIENCY – PASSIVE SYSTEMS
1. EXTERIORS OF BUILDINGS
To reduce environmental impact, it is possible to use structures with wooden frames and claddings with high standards of thermal insulation, based on stratified elements. Furthermore buildings can be fitted with fiber cement panels, capable of creating an internal microclimate and a high transmittance level compared to traditional paneling.
2. SOLAR HOTHOUSE SYSTEMS
The creation of solar hothouse systems will contribute to the energy efficiency of the buildings causing a reduction in consumption and costs. These systems accumulate heat in wintertime and favor ventilation in the summer.
3. SOLAR SCREENING
The main facades of the buildings can be made with the so-called ‘double skin’ or brise soleil system, based on sheet metal panels placed in front of balconies. Panels can be regulated and serve to screen the apartments from the sun by filtering the light. Furthermore, photovoltaic panels, integrated in the architectural structures, can serve also as protection and canopies.
4. GLASS
Buildings can be fitted with triple glazed window panes with very high thermal insulating capacity.
5. RECLAIMING AND RECYCLING OF WATER
It is possible to install water reclamation systems that feed the water and gas system, through systems capable of transforming sewage into biogas to be used in kitchens.
6. VENTILATION
An excellent transversal ventilation of the interiors can be obtained through windows placed east and west with a direct passage through the area and therefore a cooling of the air due to air drafts.
ACTIVE SYSTEMS
7. THERMAL INSULATION
Buildings must be planned with a vast array of characteristics providing insulation. This is particularly important for protecting buildings from excessive heat during the summer and to reduce heating requirements during the winter.
8. PHOTOVOLTAIC SYSTEMS
Photovoltaic systems can be placed on the roofs and oriented towards the south, covering the roof almost entirely.

USE OF RECYCLED AND RENEWABLE MATERIALS
Materials must comply with the following characteristics: non-polluting origin, use of renewable and possibly natural raw materials, durability, ease of recycling and de-assembling, produced close to building site to cut transportation.

Abacus of the construction systems used for the urban-architectural requalification and the densification of the city.

Figure 24 – Urban-architectural renewal and densification: Abacus of pilot projects.

goods and services for society, not only through primary production but also, and more importantly, by recycling and replenishing primary resources (air, water, soil), through ecosystems and biodiversity conservation, through landscape protection, and by offering a chance for open-air recreational activities. This approach is also in line with the basic philosophy of the regional plan of Caserta as a *plan for the recreation of environmental quality.*

The preservation of rural areas includes those which currently risk urbanization, because they lie close, between or within the urban sprawl, as well as more extensive remote areas. Such areas have a dual function, serving as primary productive reserves and as a bridge between green areas. The plan calls therefore for the environmental restoration of abandoned agricultural areas, the protection and promotion of agriculturally more productive areas, and the promotion of local agriculture.

The area hubs (*poli comprensoriali*) in which the major public infrastructures are to be located,[10] are positioned in non built-up areas of the sprawl, in order to function as attractors for future construction. They are connected to the main urban centers of the integrated system both through the road network project (Fabian, Morandi, Piazzini, Ranzato, 2012; Fabian, Pellegrini, 2012) and the present-day main extra urban road (Asse di Supporto Villa Literno - Nola and SS 265 dei Ponti della Valle). Streets have a hierarchical structure: intermunicipal ones connect the *Poli comprensoriali* with scarce and general services; local streets are obviously part of the residential network. The plan also calls for the restoration and filling in of abandoned quarries to create infrastructures for sports and open-air recreational activities.

SECTION 2. INTEGRATED ASSESSMENT FOR URBAN TRANSFORMATION PROCESSES

The case-studies depicted above, albeit on different scales and treating specific issues, all relate to the rehabilitation and development of urban areas. In these cases it is necessary to plan a number of interventions, which, to be implemented, must be supported by appropriate regulatory mechanisms and accompanied by a financial feasibility study, as well as a study of their social and environmental impact.

In urban transformation processes, the complexity and structure of programs, the huge financial resources required and the qualified expertise required for their technical and economic management make it advisable, in many cases, to implement the initiative through the establishment of an urban transformation company with public-private capital.

According to Italian national legislation, municipalities can formally establish an inter-municipal body, which draws up projects, identifies intervention areas and proposes the transformation program, specifying the shares of capital stock assigned to public and private partners. The selection of the private participants (lenders, contractors or their associations, individuals who are able to provide services for the feasibility, sale and management of the program) is done through public procedures.

Thus, the urban transformation company is sponsored by the municipalities, also with the participation of the regional authority and/or other public/private agencies. Its objectives are to acquire real estate, carry out projects, manage the structures or sell them.

In order to determine the financial feasibility of the projects, a timeline chart is usually drawn up to assess the costs and revenues to be used in the financial analysis.

In general, conducting a financial analysis is a technique for evaluating financial costs and revenues related to the implementation of one or more options (including the so-called “zero alternative,” i.e. non-intervention) in order to establish the return on the investment to be realized and identify the options for maximizing profits, i.e. the difference between revenues and costs. It must also be borne in mind that revenues and costs do not occur at the same time, but are spread out over many years. For this reason, they are discounted at present value, at a determined rate, and the difference will provide the net present value (NPV) of each option being evaluated.

The financial analysis of a plan/program/project consists of an evaluation of investments and subsequent revenues for all operators, bodies and enterprises (public and/or private) involved in planning and/or implementation of a measure. It is conducted with reference to market prices (actual and/or expected). Thus, the result of the evaluation is expressed in monetary terms and can highlight the utility of the various operators gained from participating in planning, implementation and/or management of the proposed actions.

In order to accept an option, the NPV must be positive and if several alternatives are present, the one with the highest NPV is preferable. The internal rate of return (IRR) of each option, defined at the discounted present rate for which NPV is 0 (zero), must also be taken into account.

Financial analysis does not take into account whether after the realization of a given option, some social sectors will receive advantages (benefits) or others will suffer disadvantages (costs). The first will have a willingness to pay for the benefits, whereas the second will have a certain willingness

10. The *Poli* combine public infrastructures of the size prescribed by current legislation and commercial areas: high-school buildings for 3,000 students, day-hospital (3.4 beds / 1,000 inhabitants); open-air sports center and sports arena with 5,000 seats; music-hall with 2,000 seats; library for books and visual media for 700 users; market with 1,200 stands; urban parks totaling 146,000 m^2; commercial areas for a total of 91,500 m^2.

to accept compensation for the loss. Hence, a certain option will be desirable if the benefits exceed the costs, in this case too, discounted at the present value.

Cost benefit analysis (CBA) is a technique that takes into account the fact that while not all costs and benefits are financial, many can be adequately translated into monetary terms. Thus, it tries to consider all the gains and losses of all the members of society affected by a plan/program/project. CBA has the advantage of expressing on a single (monetary) evaluation scale the impacts of the various alternatives. In this case, the difference discounted at present value between costs and benefits provides for each alternative its "economic" net present value (NPV) (Figure 25).

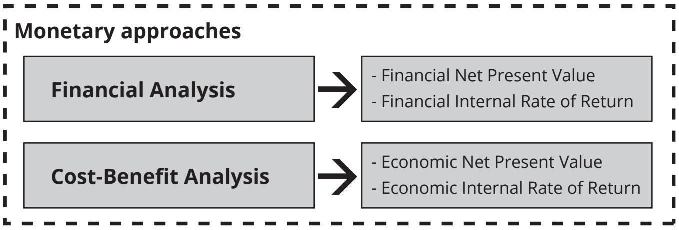


Figure 25 – Financial and economic analysis.

CBA however, cannot take into account impacts that cannot be transformed into monetary terms. For this reason, multi-criteria analysis (MCA) has been developed; MCA takes into account both monetary and intangible impacts, expressing them in quantitative and qualitative terms, viz. on cardinal or ordinal evaluation scales.

In the case of urban transformation options, the possibility of using MCA is based on a preliminary "impact analysis," that is the prediction of the effects of each alternative option from all relevant perspectives (economic, social, natural-environmental) and according to a specific period. These impacts can be transformed into monetary amounts or can be expressed in other evaluation scales, even using adimensional indexes. Thus, a multicriteria approach permits a systematic construction of impact matrices and the transformation of qualitative-quantitative data to compare alternative options. However, each evaluation method has its specific features, particularly with reference to:

- how the problem is structured (objectives and adopted criteria and their interrelations);
- how the available information is used (quantitative, qualitative, fuzzy indicators);
- how the results are aggregated (mathematical procedures);
- the possible participation and involvement of local communities in decisional processes.

It should be noted that it is not always possible to maximize all objectives simultaneously and that often the maximization of an objective implies the minimization of others; through MCA it is possible to recognize existing conflicts and search for more satisfying solutions. Thus, it is essentially an "integrated" evaluative approach, which takes into account different options involving impacts in various sectors and, at the same time, involves many different perspectives in the decisional processes.

Within this perspective, "integrated evaluations can be defined as an interdisciplinary approach able to combine, interpret and communicate knowledge starting from different scientific disciplines so that the cause-effect chain can be evaluated synoptically considering that it is possible to: a) obtain an added value with respect to evaluations based on one single discipline; b) supply decision-makers with useful information" (Rotmans and Dowlatabadi, 1995).

Especially in the field of territorial and urban planning, evaluation implies the need to operate in the framework of integrated assessment, conceived as a procedure needed to achieve an informed capacity to evaluate different courses of action with regard to environmental, social and economic issues. Integrated assessment is a methodological approach that benefits from the synergy of a variety of fields of knowledge and from different sources within society. Such evaluation methodologies allow social cost-benefit analysis to incorporate different aspects referring both to impact assessment and to local community participation in the decision-making process, while integrating subjective and objective components, tangible and intangible values, "hard" and "soft" data (i.e. coming from scientific knowledge and lay knowledge). Integrated assessment, conceived as a "learning process," helps take into account uncertainty, risk and complexity in the decision-making process, to which a broad range of expertise can contribute.

Therefore, integrated evaluations can be defined as structured processes that allow complex issues to be addressed using knowledge from different disciplines and elaborated by subjects involved in the decisions. It is a multidisciplinary approach in which different dimensions of value can come into conflict and any social decision will distribute positive and negative consequences among various groups over time and space. Indeed, integrated evaluations do not consider only the impacts of the alternative solutions but are open to broad public participation, in order to gain further information for the evaluation, facilitate the decision-making process and better ensure the desired results (Castells and Munda, 1999; Golub, 1997).

Participation becomes essential not only to examine and assess the effects of choices at the social, ethical, political, economic, environmental, etc., level, but also to legitimate and make all choices acceptable to the community. Within this context, good use can be made of "social multicriteria evaluations" (Munda, 2008), which have the following features:

- inter/multi-disciplinarity, since they integrate a plurality of

scientific approaches;
- participation, because they take into account new knowledge through citizen involvement;
- transparency, which ensures ethical and responsible approaches;
- coherence, to ensure that the desired results truly follow from the premises.

Social multicriteria evaluations adopt a cyclic evaluative approach which adapts evaluation elements on the basis of continuous feedback, obtained at various stages through consultation among stakeholders (Nijkamp et al., 1990).

In particular, in urban transformation processes, a very useful integration is that between multi-criteria analysis (MCA) and problem structuring methods (PSMs); these are methods providing a useful support for the information used to deal with a variety of non-structured problems and situations, going beyond traditional approaches and espousing communicative conceptions of planning (Rosenhead, 1996; Rosenhead and Mingers, 2001).

In particular, PSMs are useful for dealing with:
- multiple actors;
- multiple points of view;
- incommensurable or conflicting interests;
- significant intangible values;
- uncertainty.

In these situations, through PSM it is possible to represent a problem so that participants can clarify their positions and focus on one or more aspects potentially capable of creating consensus. Through PSMs it is possible to graphically represent the complexity of issues at hand, to explore solutions, compare alternatives, and take into account uncertainty, in terms of "possibilities" and "scenarios." PSMs are based on explicit modeling of cause-effect relations and their technical simplicity allows them to be used in "facilitated groups" and workshops.

Moreover, it should be noted that nowadays "hard" values – tangible, material and monetary values – are dominant, and "soft" values – intangible, immaterial and non-monetary values – are often ignored. Acknowledging both tangible and intangible values is the basis for collective decision-making processes, including the development and definition of goals, sharing of knowledge, negotiation and compromise, problem-setting and problem-solving, attention to issues of justice and equity (Sinclair et al., 2009). This means helping stakeholders and communities clarify values, become more adaptive and pro-active, respond to change, set personal and collective goals, and participate in the planning and designing of decision-making processes. An integrated evaluation approach can go beyond spatial and hierarchical limits to consider the different components, clarify weights, recognize different priorities and define appropriate strategies while also allowing for social participation and a dynamic dialogue among different experts (Lee, 2006).

Integrated assessment can become a "key tool" in supporting the decision-making process especially when uncertainty, complexity and values of different social groups are many, differentiated and conflicting. Integrated evaluations not only consider the input of data expressing the impacts of different solutions but they require broad public participation in order to offer more information for the evaluation process itself and, in addition, to make decision-making processes and their results more acceptable (Munda, 2008).

In this light, integrated spatial assessment (ISA) (Cerreta and De Toro, 2010) can be useful in decision-making as a tool that allows one to perform technical and political evaluations and deal with complex value systems in conflicting and changing contexts. Since ISA consists in the integration of multi-criteria analysis (MCA), multi-group analysis (MGA) and geographic information systems (GIS), it can become extremely fruitful in urban transformation, where the role of local agents, their relations and objectives may be considered a structuring element for the process of information construction in a spatial and dynamic evaluative model (Figure 26).

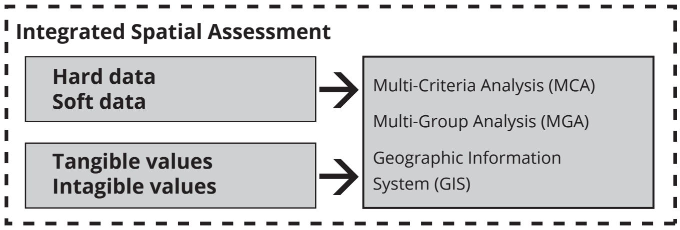


Figure 26 – Integration of tools.

The proposed approach may help communities clarify values, be more adaptive and pro-active, respond to change, set personal and communal goals, and participate in planning decision-making processes. At the same time, the application of spatial tools, such as GIS, is a useful support to identify territorial references and link values and planning choices with reference to:
1. the spatial characteristics of options proposed;
2. the temporal modification of data following the implementation of options;
3. the expressed preferences of local agents;
4. the analysis of conflict among the various stakeholders;
5. the evaluation of various options in order to obtain a priority list.

From this perspective, ISA can be a useful tool for decision-making, including technical and political evaluations, when dealing with complex value systems, in a conflicting and changing reality. It corresponds to a decision-making process that allows for the complexity of human decisions within a variable environment, in which collective knowledge and

learning assume a significant role, and offers the possibility to explore the transformation strategy definition in a spatial planning field according to sustainable and complex values.
Indeed, in decision-making processes relative to projects and plans, evaluation can help recognize values, interests and needs, explore the different aspects influencing decisions, and making the final choices. Evaluation can integrate approaches, methods and models that respond to the different needs of the decision-making process and helps take into account different goals and multidimensional values, in order to take into consideration the nature of the stakes and identify preferences and priorities. Consequently, evaluation becomes a tool for stimulating the identification of innovative solutions, and the evaluation activity takes on a significant role in urban and non-urban transformation processes, while integrating economic, ecological and socio-cultural assessment.

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Effects of the realization of a new tram-train system for the regeneration of urban areas. The case of the metropolitan area of Brescia

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Abstract

The present article aims to propose the possible application of a new transport system (tram-train) for the western metropolitan area of Brescia, in compliance with the new national guidelines (issued in April 2013), as an integration to the recently activated automatic light-rail line. The proposed system would upgrade an existing regional railway (the Brescia-Iseo-Edolo line), which at the moment is poorly used and would be an opportunity to redevelop the built-up areas to the west of Brescia, characterized by either residential or disused industrial zones.

Along the line being studied, new stops will be introduced with the aim of improving accessibility to the residential districts and city services.

Different kinds of tram-train systems are analysed here, highlighting the most important technical problems deriving from their application to the Brescia reality and providing a summary estimate of realization/operating costs.

1. Overview of the tram-train system

The tram-train system (TT), conceived in Germany[1] more than 50 years ago, has experienced a significant development in the last decade in Europe (Mantovani, 2011)[2], overcoming many technical and regulatory problems.

The main objective of this kind of transport system is to use light tram-like vehicles on existing poorly used/disused railways, if necessary connecting railways to urban tram lines, in order to create an integrated, flexible and adaptable system that is also able to guarantee low environmental impact (in terms of pollution) thanks to the use of electric light rolling stock.

Italy is characterized by a significant number of poorly used railways, which represent an extremely valuable infrastructure heritage as they are located in urban/metropolitan areas and have favourable features, such as limited slopes, wide radiuses of curvature and their own infrastructure.

In the past, these particular features have often been underestimated and existing facilities have been converted to car parks or used to widen road sections, without considering that reuse of such facilities would have made it possible to avoid considerable economic costs and environmental impact (in terms of land use) for the realization of brand new transport facilities.

The main goals of a TT system can translate into tangible advantages for users and transport companies:

- elimination of the so-called "passengers break-bulks": interoperability on both the railway and tramline network allows direct links between central and suburban zones, offering advantages to travellers in terms of time saving and comfort;
- improvement of accessibility: along a TT line, new tram stops can be realized to offer a more capillary service;
- economic advantages from a realization point of view: the renewal of existing railway facilities makes it possible to reduce initial investment costs;
- economic advantages from a management point of view: the TT system is characterized by flexible operating conditions.

TT systems are especially suitable for metropolitan areas (where there is no interruption between major and minor urban centres) often characterized by considerable mobility problems relating to the management of public transport, such as the critical balance between transport offer/demand and low levels of comfort. As a consequence, individual travel patterns are encouraged, causing congestion phenomena and negative environmental impact in urban centres.

1. The tram-train (TT) system was conceived in the German city of Karlsruhe. Since the post-WWII period the city has shown great sensitivity towards environmental problems and a series of traffic analyses have been carried out in order to exploit the existing but poorly used (or disused) regional railway networks.
The first example of a TT vehicle dates back to 1957, when the local railway line Albtalbahn was re-configured by installing ordinary gauge rails and was connected to the urban tramline, creating a continuous itinerary to the historical city centre. Another similar redevelopment project was undertaken only later, in the second half of the 70s, when a railway line, poorly used only for freight traffic was restored, linking the northern part of the region.
A significant step in TT system development was reached in 1992, when a new kind of service, based on the use of both the tramline rails and the regularly used national railway network (Deutsche Bahn - DB), was implemented.

2. It is not easy to outline a complete state of the art concerning the existing TT systems in Europe, as it is an ever-changing scenario, characterized by different countries that refer to different sets of national laws. In 2002 only two TT systems were already present in Europe: in Karlsruhe (including the Heilbronn T system) and in Saarbrücken. Two other TT systems were under development and 57 new systems were the subject of feasibility studies (Mantovani, 2011). In 2012 (after 10 years) in Europe a total number of 12 TT systems were present, even if not all of them could be considered "strict" TT systems, such as, for example, the one implemented in Zwickau.

2. Regulatory aspects and national guidelines

The regulatory framework concerning rail traffic on the National Rail Infrastructure (NRI) for "light transport" are RFI Provisions 01/2003 "Provisions concerning the regulatory and technical requirements for rolling stock" and 30/2007 "Modification and integration to provision 01/2003 concerning the regulatory and technical requirements for rolling stock".

Current regulations allow for the circulation of TT vehicles on the NRI, though some criticalities emerge, namely:

- the wheel-rail coupling;
- the gauges;
- the kind of power supply;
- the vehicle-platform interface;
- accessibility;
- safety issues.

Recently (April 2013), a work group including various organization representatives (ANFS, ASSTRA, Confindustria, RFI, UNIFER) elaborated the applicable national guidelines for tram-train systems (Molinaro, 2013). The national guidelines aim to provide the essential requirements for the safe circulation of TT vehicles.

The guidelines apply to TT systems and provide technical requirements in compliance with the applicable general legal framework. It should be noted that TT systems "must guarantee a level of safety at least equal to the existing rail/tramways systems, as specified in Legislative Decree no. 162/2007 and Presidential Decree no. 753/1980 [...]. Safety analysis must be carried out in compliance with European Community regulation (EC) no. 352/2009 and standard IEC EN 50126".

The initial section of the guidelines reports the definition of a TT system, which is "a transport system able to integrate railway lines and tramway lines (including high speed tramlines) through the use of vehicles which are specially designed to mainly circulate on tramlines, but also on railway facilities without causing passengers modal change and linking rural territories to urban areas. Such systems can be implemented following consecutive steps, starting from the extension of a tramline service to a disused railway facility and then realizing the actual sharing of different facilities and vehicles".

Therefore, the ultimate definition of a TT system, according to the guidelines, can include TT vehicles, tramway or railway facilities, trams and/or trains.

The guidelines identify three kinds of TT services:

- Tram-train type 1 (TT1): if the railway facility is exclusively used by tram-train vehicles;
- Tram-train type 2 (TT2): if the railway facility is used either by railway vehicles or tramway vehicles running in different time windows;
- Tram-train type 3 (TT3): if the railway facility is used both by railway vehicles and tramway vehicles running in a mixed way.

For each kind of TT system, the guidelines provide the technical requirements concerning the operating phase, the facility, the tramline and the TT vehicle.

The guidelines also provide information for verifying the feasibility of a TT system:

- Annex A - Aspects to consider during the preliminary design phase: the kind of system, kind of railway/tramway, existing tram features;
- Annex B - Aspects to consider during the design phase: expected transport demand/offer features, partners involved, existing facility features and relative programmed interventions, circulation regime and cruise control devices on the tramway/railway facilities, main trams/trains/TT vehicles technical specifications, check of the compatibility between TT vehicles and existing facilities.

3. Technical features and criticalities

The common origin of trams and trains offers important advantages from a technical and operating conditions point of view. However, the shared use of a single facility generates some criticalities.

▪ ***The wheel-rail coupling***

Permanent tramways and railways are based on the same operating principles, but differ in terms of rail geometry and type of switches. The problems deriving from the presence of different kinds of superstructures can be overcome by realizing a particular wheel section, able to adapt to the tramway and railway rails and switches (Alessandrini, 2005).

▪ ***The gauge***

There should be similarity between the tramway and railway gauges to avoid incompatibility problems. If both the tramway and railway have the same gauge or if the tramway is not present (and this is the most frequent situation), the TT system can be implemented without particular gauge problems. On the contrary, if the gauges differ, the technical solution should be evaluated taking into consideration the entity of the difference (Rizzetto, 2009).

In the case of significant differences between the two gauges, a third rail could be introduced in order to allow the circulation of either standard or reduced gauge vehicles.

In the case of slight differences between the two gauges and where a third rail cannot be introduced, it is possible to provide vehicles with variable gauge devices[3].

▪ ***The kind of power supply***

A TT system usually exploits existing facilities, i.e. railways or tramways characterized by different kinds of power supply. Over time this compatibility problem has been solved by re-

3. From a technical point of view, this solution is feasible but quite expensive and in contrast with the principle of economic convenience on which a TT system is based.

alizing vehicles able to adapt to different supplies, such as hybrids or multi-voltage vehicles (Dillig, 2003).

▪ ***Vehicle-platform interface and accessibility***

The original kind of facility exploited by the TT system can be characterized by different vehicle-platform interfaces, as the facility reflects original tramway or railway building standards. As a consequence, there could be two main problems relating to geometry (Novales, Bugarin, 2011): the height of the platform compared to the floor of the vehicle and the gap between the platform edge and the vehicle door.
If the original facility is a railway (without existing/planned urban tramlines) the problem can be solved by purchasing TT vehicles able to fit properly with the platform. On the contrary, when it is not possible to use special TT vehicles or when an urban tramline is present, adaptation work is unavoidable. The extent of work can vary considerably and can generate different costs. A possible solution (even if very expensive and more obtrusive) could be to double the rails and separate the platforms at the station, so that one platform is dedicated exclusively to the train stop and the other to the tram stop. Another solution could consist in aligning the tramway and railway stops linking two platforms at different heights.
Instead, in order to reduce the gap between platform edges and vehicle doors it is possible to provide vehicles with a movable step (paying particular attention to the prevention of malfunctioning) or to realize track bundles at stations so that narrower vehicles can better approach the platform edge.

▪ ***Issues relating to safety***

In the case of railway facilities used both by railway vehicles and tramway vehicles running in a mixed way, collision between trams and trains could occur with serious consequences because of the different kinds of masses and structural types of the vehicles involved, characterized by boxes with different levels of resistance to compression.
This problem can be dealt with by adopting either active or passive safety approaches. In terms of structural resistance to compression, TT vehicles, which are conceived to be light vehicles, will not be as safe as trains. Therefore, the lower level of safety which characterizes TT vehicles compared to trains should be compensated through the introduction of active safety measures, which consist in reducing the likelihood of crashes or malfunctioning through the use of devices, systems or equipment following preventive strategies.

4. The case of Brescia

4.1 The metropolitan area of Brescia

Brescia is a metropolitan city, with about half a million inhabitants and is located in the focal point of a linear metropolitan system (Busi, Pezzagno eds, 2011) called the “Po Valley LiMeS”[4]. The metropolitan area of Brescia requires high-quality transport systems (Maternini, 2000) and the recent activation of an automatic light-rail line (March 2013) goes in this direction, ensuring a high-performance connection between the northern and south-eastern parts of the city.
A possible light-rail line extension was initially provided for in the south-western part of the city, placing the terminus at the exhibition centre to obtain a sort of “backward T”, but the considerable realization costs spent for the first part of the light-rail line deferred the extension project.
The TT system project proposal (which this article focuses on) concerns the western part of the metropolitan area (the same that is the focus of the abandoned light-rail line extension project), which at the moment is covered by a rural railway service (the Brescia-Iseo-Edolo line). This line links the city of Brescia with the Camonica Valley and is characterized by a single track and standard gauge and is not electrified. The line is managed by the company TreNord Spa; it is poorly used but has great potential as its layout runs close to important residential districts and some disused industrial areas, which could be subject to urban regeneration processes, thanks also to the activation of a TT service.
The section of the Brescia-Iseo-Edolo line that is the focus of this redevelopment proposal is located between Brescia central station and Castegnato station and is about 10 km long (Maternini, Riccardi, 2010).
The proposed TT solution envisages 8 stops (of which 4 are existing railway stops), namely:

▪ **Brescia FS (km 0+000) – existing stop**

The Brescia-Iseo-Edolo line has its own terminus on the western platform of Brescia central station from where it is possible to interchange with other railway services (belonging to the national network) or with the urban automatic light-rail line (its stop is located just a few metres from the central station). The location of the terminus at Brescia central station also makes it possible to reach Brescia historical centre in 15 minutes, either on foot or using other urban bus lines.

▪ **Quartiere Primo Maggio (Milan Compartment) (km 1+100) – new stop**

The Primo Maggio district lies south of the Brescia-Iseo-Edolo line, with a population of about 3,000. The new stop would also serve the area just north of the line, where there is a

4. The concept of “Linear Metropolitan System” (or “LiMeS”) has been introduced by the 2007 PRIN national research. “From the metropolitan city to the metropolitan corridor: the case of the Po Valley corridor”, coordinated by Prof. Roberto Busi and funded by the MIUR Ministry. The Po Valley LiMeS, in the north of Italy, consists in a long narrow urban area, which goes from Turin to Trieste and is part of the European Corridor V which crosses Europe from west to east. It presents particular features which makes the Po Valley the main linear metropolitan system in Europe, comparable with the most important LiMeS located in North America, China and Japan.

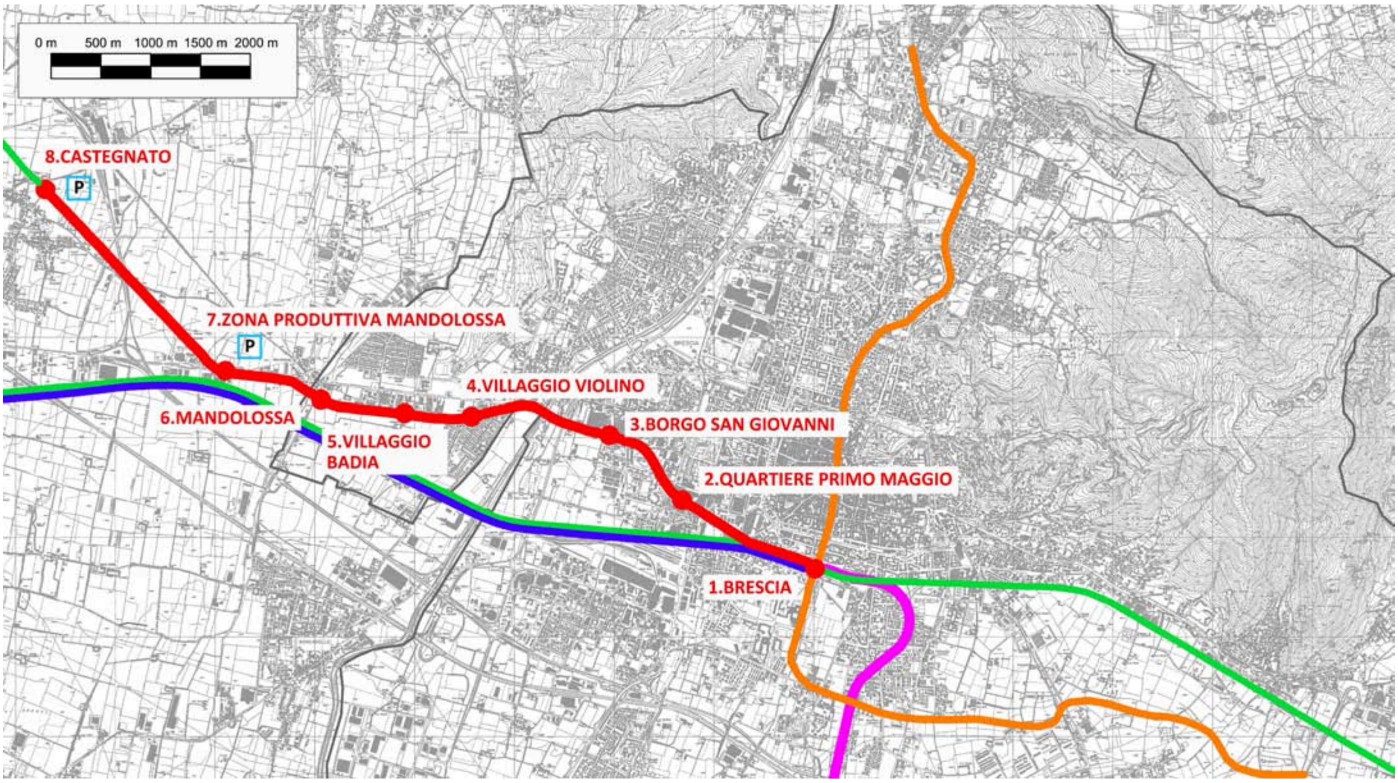

Figure 1 – The Brescia - Castegnato line section that is the subject of redevelopment (red) and the automatic light-rail line of Brescia (orange).

disused industrial zone which will be the subject of urban regeneration, leading to the realization of about 157,000 m^2 of floor space (61,000 m^2 have already been or are about to be built). From this district, with the present bus network, it takes about 6 minutes to reach Brescia central station and the maximum bus frequency (in rush hour) is 12'. The proposed TT system would have the same frequency, but it would take only 1'15" to reach Brescia station.

▪ Borgo S. Giovanni (Fiumicello district) (km 2+500) - existing stop

The Fiumicello district is located above the Brescia-Iseo-Edolo line, around Borgo S. Giovanni station, and has about 7,000 inhabitants.

At the moment a disused industrial area in the district is being redeveloped and a new residential block is under completion. Therefore, thanks to the realization of a TT service, the upgrading of the existing railway stop, which is at the focal point of the district, would make it possible to satisfy present and future transport demands.

From this district, with the present bus network, it takes about 9 minutes to reach Brescia central station and the maximum bus frequency (in rush hour) is 12'. The proposed TT system would have the same frequency, but it would take only 3'15" to reach Brescia station.

▪ Villaggio Violino (km 4+000) – new stop

The Villaggio Violino district is bordered by the Brescia-Iseo-Edolo railway to the north and by the Milan-Venice railway to the south. The district dates back to the 50s and was realized by the so-called "Cooperativa La Famiglia" owned by Father Marcolini. At the moment the district has about 4,000 inhabitants and is served by 2 urban bus lines. The new TT stop would be located close to "S. Anna" shopping centre.

From this district, with the present bus network, it takes about 26 or 35 minutes (depending on the bus line) to reach Brescia central station and the average waiting time (in rush hour) is 7'30" or 10'. With the proposed TT system there would be an average waiting time of 6' and it would take 5'15" to reach Brescia station.

▪ Villaggio Badia (km 4+600) – new stop

The Villaggio Badia district is located north of the Brescia-Iseo-Edolo railway and has about 3,500 inhabitants

At the moment the district is served by 1 urban bus line. The new TT stop could be placed near the disused level crossing in Via Colombaie, so that not only Villaggio Badia, but also the Villaggio Violino district would be served.

From this district, with the present bus network, it takes about 24 minutes to reach Brescia central station and the average waiting time (in rush hour) is 10'. With the proposed TT system, with an average waiting time of 6', it would take only 6'40" to reach Brescia station.

▪ Mandolossa (km 5+500) - existing stop

Mandolossa is located between Brescia South ring road and

the provincial road "SpBs11 (former SS11) Padana Superiore". It is crossed by the Brescia-Iseo-Edolo railway, where a stop already exists. It has a population of about 1,300 inhabitants and an urban bus line is present.
From this district, with the present bus network, it takes about 20 minutes to reach Brescia central station and the average waiting time (in rush hour) is about 10'. With the proposed TT system, with an average waiting time of 6', it would take about 8' to reach Brescia station.

▪ **Zona Produttiva Mandolossa (km 6+500) – new stop**
The hypothesis of realizing a new stop in the industrial estate of Mandolossa derives from the need to have an interchange car park where the rural bus lines can have their terminus (at the moment their terminus is at Brescia Central Station). With this solution, users would have to make a modal change, but would reach Brescia station more quickly as existing bus lines cover a highly congested itinerary, especially during rush hour.
The interchange car park could also serve commuters from the west and from the South ring road, linking the motorway toll booths.

▪ **Castegnato (km 9+000) – existing stop**
The TT line terminus would be at Castegnato station. This station would serve Castegnato town, with 8,000 inhabitants. Thanks to a new interchange car park, this stop would easily serve users from the other neighbouring Franciacorta towns and also commuters using their own private vehicles from the provincial road SpBS510 Sebina Orientale.
The new stops have been positioned taking into account not only the geometric layout of the line, but also by assessing the amount of space required for lay-bys and platform adaptation, aiming to reduce on-line train crossing as much as possible.
The realization of a TT service in the western metropolitan area of Brescia aims to improve accessibility to the city, provide an interchange between private and collective transport modes, reduce travel time and improve travel comfort.
The main advantages of TT service implementation consist in its economic convenience[5] and its moderate environmental impact.

4.2 Design alternatives

4.2.1 Tram-train type 3: mixed circulation of tram and trains between Brescia and Castegnato

A first design alternative consists in introducing a light tram-like transport service running on the existing railway line between Brescia and Castegnato with a mixed circulation of trams and trains to create the so-called TT3 system.
This hypothesis generates some criticalities, mainly relating to safety and the management of traffic and level crossings.

4.2.2 Tram-train type 1: exclusive circulation of trams between Brescia and Castegnato. Railway terminus at Castegnato station

Under this alternative, the railway terminus would be located at Castegnato station (instead of Brescia central station), isolating the link through the exclusive circulation of tram-like vehicles. This kind of solution would be characterized by reduced safety problems and favourable operating conditions, but would be disadvantageous to commuters from the Camonica Valley and Lake Iseo: as a matter of fact, commuters would experience modal change delays in reaching the city of Brescia, therefore, the modal interchange should be studied thoroughly.

4.2.3 Tram-train type 1: exclusive circulation of trams between Brescia and Castegnato. Train circulation deviated to the Milan-Venice railway at Castegnato Station

Under this alternative, the TT system could run exclusively on the existing facility between Castegnato and Brescia, while the regional railway service (Brescia-Iseo-Edolo regional line) could exploit the existing facility up to Castegnato station and then be deviated to the Milan-Brescia railway line for the last part of the itinerary.
The forthcoming HS/HC line will decrease the traffic on the old Milan-Brescia line; therefore the deviation of trains to this line would not cause relevant overloading problems. The deviation could be made between Castegnato and Mandolossa stations, where the two railway lines run parallel. The main limit of this configuration consists in the fact that regional trains from Brescia to Iseo would cross the opposite track on the Milan-Venice line, in order to join up with the Brescia-Iseo-Edolo line. Crossing could be done through a switch (causing potential safety problems) or through the realization of a flyover (with a consequent increase in costs).

4.2.4 Tram-train type 1: exclusive circulation of trams between Brescia and Iseo. Train circulation deviated to the Milan-Venice railway through the upgrading of the Bornato-Rovato Borgo line

Under this alternative, the new TT system could have its terminus at Iseo station. Trains going to Brescia could be deviated to the existing regional line Bornato-Rovato Borgo and

5. In order to implement a TT service only limited interventions are required on the infrastructure, such as for example the adaptation of existing platforms, the realization of new tram-like stops and the introduction of lay-bys for train crossing. Interchange parking at Castegnato and Mandolossa stations and a depot (for night-time vehicle parking and ordinary maintenance operations) should also be realized. The introduction of a TT service would lead to transport service optimization and the reduction of operating management costs thanks to the elimination of overlapping bus lines.

then deviated again onto the Milan-Brescia line changing at the Rovato station.
The TT service between Iseo and Brescia would be characterized by high frequencies. This solution seems to be the most expensive, as it implies the purchase of new vehicles, the installation of a power supply for about 25 km and the almost complete upgrading of the Bornato-Rovato line, which at the moment is used only for freight.

4.3 System design

4.3.1 Estimate of the maximum peak-hour passenger flows

The introduction of a new rapid transport service such as a TT system, characterized by a dedicated permanent way, could bring to a modal split relating not only to existing collective means of transport but also individual ones, thanks to the possibility of saving travel time during peak hours.
The attraction of the new system mainly relies on its features: punctuality, operating speed and frequency are fundamental conditions for its success against other alternatives. Another essential feature is the high level of comfort on board, which should push users to choose collective systems instead of passenger cars.
Existing urban bus lines, which overlap the new TT system (three in the western metropolitan area of Brescia), will be properly modified.
Brescia Mobilità Spa, Brescia's transport company, provided data concerning bus passenger flows. In particular, focusing on the bus stops situated close to the TT line, analysis of passengers transported by the three existing bus lines during the morning rush hour on a typical working day showed that a total of about 650 passengers/hour*direction could be diverted to the new TT service.
In addition to this flow, passengers from the existing Brescia-Iseo-Edolo regional railway (characterized, in the Castegnato-Brescia link, by 140 passenger/hour*direction) should be taken into consideration, reaching a total of about 800 passenger/hour*direction at peak times.
Alongside this, we should consider that a new potential flow of passengers could be generated by the ability of the TT system to attract new users, such as non-systematic users who would choose the new system because of its performances. Similarly, former passenger car users living by the stops or the interchange car park could find the new system more competitive than individual means of transport and then be diverted onto the TT system. It can be estimated that this component would increase the passenger flow calculated so far by 20%, to about 960 passenger/hour*direction.
If the terminus of the rural bus lines was set outside the city at the Zona Produttiva Mandolossa TT stop, it would be possible to further increase by 320 passenger/hour*direction the passenger flow estimated so far, reaching a total (for the TT3 system) of 1,280 passenger/hour*direction during rush hour.
This approximate estimate is based on the present situation. In the future, with easy interchanges between light-rail and TT system and after the regeneration of disused areas, considering also new residential loads, the estimated value could even increase.
Another future scenario, capable of increasing the estimated number of passengers transported, is represented by the extension of the TT system southwards towards Montichiari Airport.
Finally, the possible evolution of the initial TT3 system to a TT1 could bring to a total estimate of about 1,500 passenger/hour*direction.

4.3.2 Definition of the service

Definition of the service is based on the estimate of the maximum passenger load described in the previous paragraph.
The length of the vehicles is strongly related to the estimated number of passengers: in the Brescia-Castegnato link the selected vehicles are 35-40 m long and are able to carry up to 300 passengers.
Floor height will be selected depending on the platform layout: in the link in question, considering there is no tramline in Brescia, we do not recommend using completely depressed floor vehicles[6], as the platforms are mainly railway-like.
The minimum number of vehicles required refers to the worst operating conditions, i.e. to the peak hour of a typical school/working day. The number of vehicles able to satisfy transport demand can be estimated by analysing the service throughout the day, evaluating the time required to cover the complete itinerary of the line and then assessing where it is necessary to insert lay-bys.
For each link between two adjacent stops, as an initial approximation, the motion diagram is characterized by a trapezoidal shape and is composed of an initial acceleration phase[7], a constant motion phase and a final deceleration phase which equals the acceleration one, without considering the coasting phase, during which the vehicle moves thanks to its inertial force and progressively decelerates without using the braking system. Resistance to acceleration (which should be increasing rather than constant) was not considered, even if present, while the physical constraints to speed were taken into consideration.

6. The ideal solution would be to have vehicles with a floor 55 cm above the track surface. Doors should be numerous and wide, in order to make it easier to get on/off the TT vehicles.

7. Acceleration values for TT vehicles were set at 1.1 m/s^2 for speeds up to 40 km/h and at 0.5 m/s^2 for speeds up to the maximum permitted speed. The acceleration value for trains was set to 0.4 m/s^2 up to the steady-state speed value.

Figure 2 – The tram-train service in Kassel.
Source: http://railforthevalley.wordpress.com/

Stop duration time strictly depends on the kind of vehicle: in the case in question the stop lasts about 30 seconds. The stop at the terminus lasts about 4 minutes, considering the time the driver needs to reach the cabin in the opposite direction, the drivers' break time and any recovery of delays. The minimum lap time is therefore 2'016.8 seconds, corresponding to about 34 minutes. According to these assumptions, the commercial speed v_c and operating speed v_e are 44.44 km/h and 32.30 km/h, respectively.
Transport demand analysis led to the estimate of 1,280 passengers/hour*direction and it is plausible to allocate all of them to the section with the heaviest load. Assuming the TT vehicles' maximum capacity of 300 passengers, we can calculate the following amounts:

N of trains/h = (Maximum flow)/(Vehicles capacity) =
= (1'280 p/hd)/(300 p/veh) = 4.3 veh/h

Time separation between vehicles = (One hour)/(N of trains/h)=
= (3'600 s)/(4.3 veh/h) = 837.2 s

N of vehicles in line = (Lap duration)/(Time separation between vehicles)=
= (2'016.8 s)/(837,2 s) = 2.4

Rounding up the number of vehicles on the line, the minimum value is 3, with a frequency of about 11 minutes during rush hour. The effective time separation between vehicles is then re-calculated as follows:

Actual time separation between vehicles =
= (lap duration) / (rounded N of trains/h) = (2'016.8)/(3) = 672.2 s

In order to offer a regular frequency of vehicles, it should also be taken into consideration that the lap time duration should be a whole multiple of the interval between the different runs. A regular frequency is very important for users, especially when the interval between the different runs is more than every 5-6 minutes. Alongside this, timetables should be easy to remember for users. Therefore, under the hypothesis of setting the frequency to 12 minutes, the number of transits increases to 5 per hour. As a consequence, lap duration should be increased up to the smallest whole multiple of 12 minutes (corresponding to 720 seconds), i.e. 36 minutes, corresponding to 2'160 s. The difference between this last lap duration and the one previously calculated (144 seconds) can be used to increase the duration of the terminus stop or to recover any slight delays along the links. So, the actual capacity of the system described above is slightly higher than the estimated one at 1,500 passenger/hour*direction. During off-peak time windows the interval between transits can be increased.
Once the number of vehicles, frequency and the travel times are known, it is possible to realize the service motion diagram. In addition to the hypothesis described above, another constraint is represented by the need to make vehicles meet and cross at the existing Borgo S. Giovanni station (where a lay-by is already present) and at two other stops. "Odd" TT vehicles (running in the direction Castegnato-Brescia) cover the course in 12.8 minutes, considering maximum speed/acceleration/deceleration values and stops lasting 30 seconds. Instead, "even" vehicles (running in the direction Brescia-Castegnato) cover the same distance in 15.8 minutes, considering longer stops at stations (45 seconds instead of 30 seconds). The stop at the line terminus is 4.4 minutes (both at Castegnato and Brescia stations), therefore the whole course duration is of 34 minutes.
The regular railway service, whose circulating trains cover the whole distance in 7.5 minutes, means it is necessary to introduce 2 other lay-bys (at the Villaggio Violino and the Zona Produttiva Mandolossa stops) allowing a single train transit every 12 minutes or a couple of trains (running in opposite directions) every 36 minutes. Once the TT system is in operation, the ordinary train timetable will inevitably be subject to change.
It is also necessary to consider the availability of reserve TT vehicles, both to promptly substitute them of necessary and to better manage ordinary vehicle maintenance operations

without affecting the service. The number of reserve TT vehicles depends on many factors, such as their initial number, their maintenance requirements, etc. In the proposed system, it is assumed that maintenance operations are carried out on one vehicle at a time. In addition to this, as an 'active reserve' another TT vehicle would be necessary (corresponding to 15% of the fleet). Only an accurate analysis of the rolling stock and of operating conditions will lead to the final decision to purchase just one reserve vehicle, reducing investment costs and assuming a reasonable level of risk (corresponding to two vehicles out of order at the same time).

5. Some project characteristics

The preliminary design of a TT transport system, such as the one in the case study, implies the analysis of some fundamental elements, namely: the need to renew the existing facility, the power supply adaptation, accessibility to the service (in particular platform-vehicle interface and track pedestrian crossings at stations) and level crossings. The present document did not take into consideration the issues relating to safety and the signalling systems.

▪ ***Lay-bys***

Under the TT3 hypothesis, the service analysis highlighted the need to have four lay-bys located at four stops along the TT line: Borgo S. Giovanni, Villaggio Violino, Mandolossa and Zona Produttiva Mandolossa. Borgo S. Giovanni station does not require the realization of a lay-by[8] as it already exists (a three-track bundle is present) while new lay-bys should be realized at the other stops. TT vehicles are intended to use the deviated rails segments when a train is present at the station, in order to limit delays to the ordinary railway service.
The evolution of the initial TT system configuration from a TT3 to a TT1 could reduce the number of lay-bys from 4 to 2.

▪ ***Platforms***

The project foresees the realization of four new stops and the adaptation of existing ones.
Platforms are 80m long, corresponding to two coupled TT vehicles, in order to make it easy to get on/off the vehicles safely.
In order to increase accessibility, where a lay-by is not necessary, the platform should be realized on the side characterized by the highest passenger inflows.
The platform height[9], in compliance with railway standards, will be set at 55 cm at every stop. As a matter of fact, the present platforms are only 35 cm above the track surface and do not facilitate boarding operations.
On the contrary, there could be problems with the distance between the longitudinal side of the vehicles and the platform edges, as reported in figure 3. As a matter of fact, depending on the kind of vehicles circulating on the line, doors are placed at different distances from the platform edge and the distance is particularly considerable for TT vehicles (29.25 cm). In order to tackle this safety problem, a possible solution could be the use of movable steps.

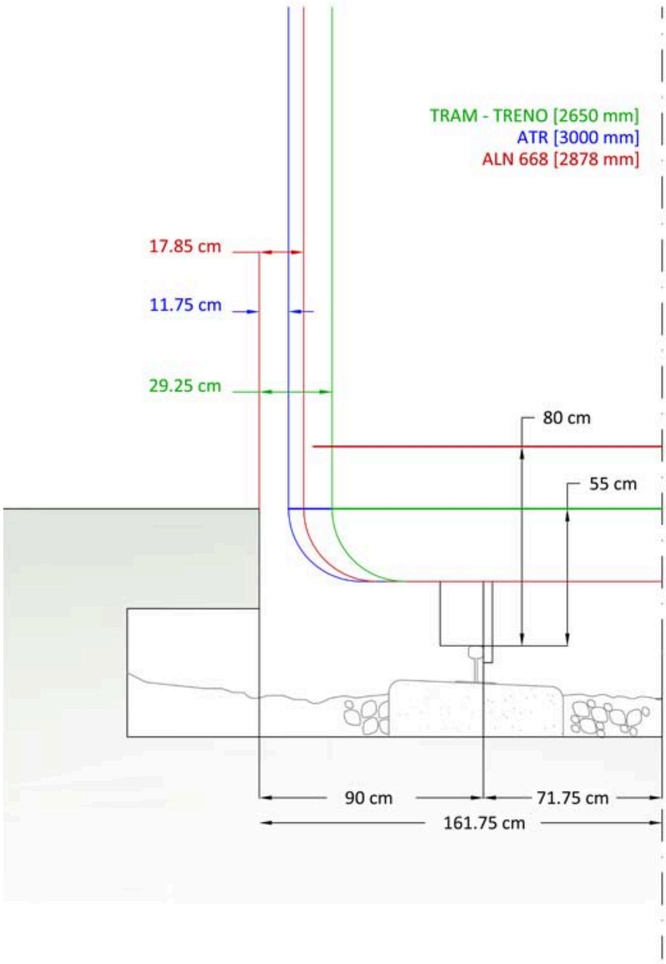

Figure 3 – Distances between the longitudinal side of the vehicles and the platform edge per type of circulating vehicle.

▪ ***Power supply***

Providing the line with an electrical power supply represents an important evolution of the existing facility and could increase line potential: as a matter of fact, the power supply can improve the overall performances of the system, such

8. Double-tracks are realized using deviators characterized by a radius of 170 m, in compliance with railway standards. The length of the deviators is about 30 m each, to which a useful length of 80 m is added (as the minimum length for the second track), reaching a total length of 140 m.

9. Alongside this, recently introduced trains circulating on the Brescia-Iseo-Edolo railway (ATR) are characterized by a floor that is 55cm high; therefore, platforms should be adapted in order to allow on-the-edge boarding operations. There are also more dated trains (ALn 668) still circulating on the line, which have a floor height of 80 cm which are likely to be out of use by the start-up of the TT system.
The selected TT vehicles are 55cm high; therefore they are compatible with the new platforms.

as acceleration, commercial speed, the possibility to partially recover energy during the braking phase, reduction of noise and pollutant gas emission and economic advantages during the operating phase of the service.

The only disadvantage consists in high initial investment costs, which do not vary depending on mileage (on the contrary, diesel-powered vehicles are characterized by operating costs which are proportional to mileage).

The choice of whether or not to electrify the line or keep the existing facility depends on economic consideration: to provide electricity to the line is justified only if a given mileage is reached during the steady-state service. According to the estimated passenger flow, the frequencies and the overall performances of the TT system that are the subject of the present project, electrification of the line should be more than justified.

If a 750V DC voltage tramway was installed, there would be a higher compatibility with any electrified lines within the urban area. Instead, if a 3kV DC railway voltage power supply was installed, it would be possible to limit potential drops along both the feeder and the contact power line, reducing the number of electricity substations. The rural context would allow higher voltages than the urban one and the potential future extension of the Castegnato-Brescia line to Montichiari Airport, exploiting the existing 3kV railway facility, would ensure compatibility of the rolling stock.

▪ ***Depot***

The depot will be located east of Castegnato station. The building will have three terminal tracks to house the whole TT vehicle fleet and a workshop for ordinary maintenance work will be realized. For extraordinary interventions the existing depot/workshop near Iseo station will be used and vehicles will be pulled by diesel-powered locomotives (as the Brescia-Iseo-Edolo railway from Castegnato to Edolo is not electrified).

▪ ***Level crossings***

There are 9 level crossings along the existing railway between Brescia and Castegnato. With the introduction of the new TT service, the level crossings could be managed based on different scenarios, depending on the kind of TT system.

A possible solution (for TT1 and TT3 systems) could be the realization of underpasses[10], in order to eliminate interferences with motorized traffic, even if this kind of intervention would require a more detailed analysis of the overall dimensions.

- Under the scenario of a mixed circulation of TT vehicles and trains, as it is not possible to use level crossings with gates for trains and with traffic lights for TT vehicles at the same time (the law does not allow such heterogeneous solutions for safety reasons), the existing gates are kept all along the line. Therefore, in order not to excessively affect the circulation of motorized traffic, it is necessary to reduce gate timing. The TT system guidelines establish that, in the case of TT3 systems, gate timing at level crossings can be differentiated depending on the kind of approaching vehicle and maximum speed or braking systems. In order to do that, automatic identification systems can also be used. As regards the line that is the subject of study, an automatic identification system could theoretically be introduced, considering that, at the same time, the track open sign should be placed at a distance that allows rolling stock to stop safely in the event of gate malfunctioning (in compliance with standard UNI 11117). In practice, the gate closure period would be too long because of the high frequency of vehicles, making the TT3 scenario unadvisable compared to a TT1 one.
- Under the scenario of the exclusive circulation of TT vehicles, level crossing management would be easier than in the previous alternative. According to standard UNI 8379, which defines binding transport system features, the TT1 system proposed for Brescia is treated as a rapid tramway. For this kind of service, standard UNI 8379 allows for level crossings with signals or level crossings with gates. The best configuration for Brescia would be the presence of crossings with signals, featuring traffic lights regulated on board by approaching vehicles. The "track closed" signal timing for motorized traffic would be about 30 seconds, for a total closure time of 5 minutes per hour.

5.1 Initial considerations about investment and operating costs

The most significant advantage of a TT system, from a realization point of view, consists in its economic convenience. An initial summary evaluation of the realization costs of the proposed solution for Brescia, expressed as the amount to be put out to tender (excluding VAT), excluding costs relating to control-command and signalling systems, safety devices and design costs, includes the following:

- civil work (realization of 4 new stations and redevelopment of 4 existing ones, realization of 1 underpass). Investment costs range from 3,500,000.00 € to 9,500,000.00 €;
- permanent way (realization of 3 90m-long lay-bys using UNI 50 rails, 2 s60/170/0, 12 switches for each lay-by). Total expenditure is 550,000.00 €, including ballasts, concrete sleepers, small parts and labour;
- electrification (for the whole line between Castegnato and Brescia, including 2 power substations). Investment costs are about 6,000,000.00 €;

10. Underpasses can be realized mainly in two ways: interrupting the service or maintaining operation of the service during the work. In the first case, for each underpass, a total expenditure of about 1,500,000.00 € (amount to be put out to tender); in the second case, in addition to the costs of the underpasses, the cost for Essen bridge technology application should also be considered (about 250,000.00 €).

▪ rolling stock (purchase of 4 vehicles). Total expenditure of 14,000,000.00 €;
▪ depot (depending on the selected technical solutions mentioned above). Expenditure ranging from 4,600,000.00 € to 6,100,000.00 €.

Thus final expenditure ranges from 28,650,000.00 € to 36,150,000.00 € (excluding VAT) for initial investment costs. Therefore, kilometric costs range from 3.2 to 4 million €.

It is important to highlight that the level of service offered by the newly designed TT system is comparable to the automatic light-rail system, but implies initial costs (in relation to kilometric costs) which are about 20 times lower.

Considering similar experiences, the estimate of annual operating costs is about 3,440,000.00 € -4,730,000.00 €,

Operating revenues can be estimated at 0.30 €/passenger, considering both ordinary and season ticket fares and setting the present TPL fare at 1.20 €/ticket. The estimated number of passengers per year varies between 1,200,000 and 2,500,000, therefore total revenue varies between 360,000.00 € and 750,000.00 €. In addition to the operating revenues described above, the savings deriving from the adaptation of the entire existing PT network should also be considered, namely: about 500,000.00 € could be saved by reducing overlapping urban bus lines; about 1,000,000.00 € by locating the terminus of rural bus lines outside the city at the Mandolossa TT stop. Finally, as a qualitative consideration, the introduction of a TT1 system (moving the terminus of the regional railway from Brescia to Castegnato) could bring further savings in terms of km covered by trains (about 120,000 km/year).

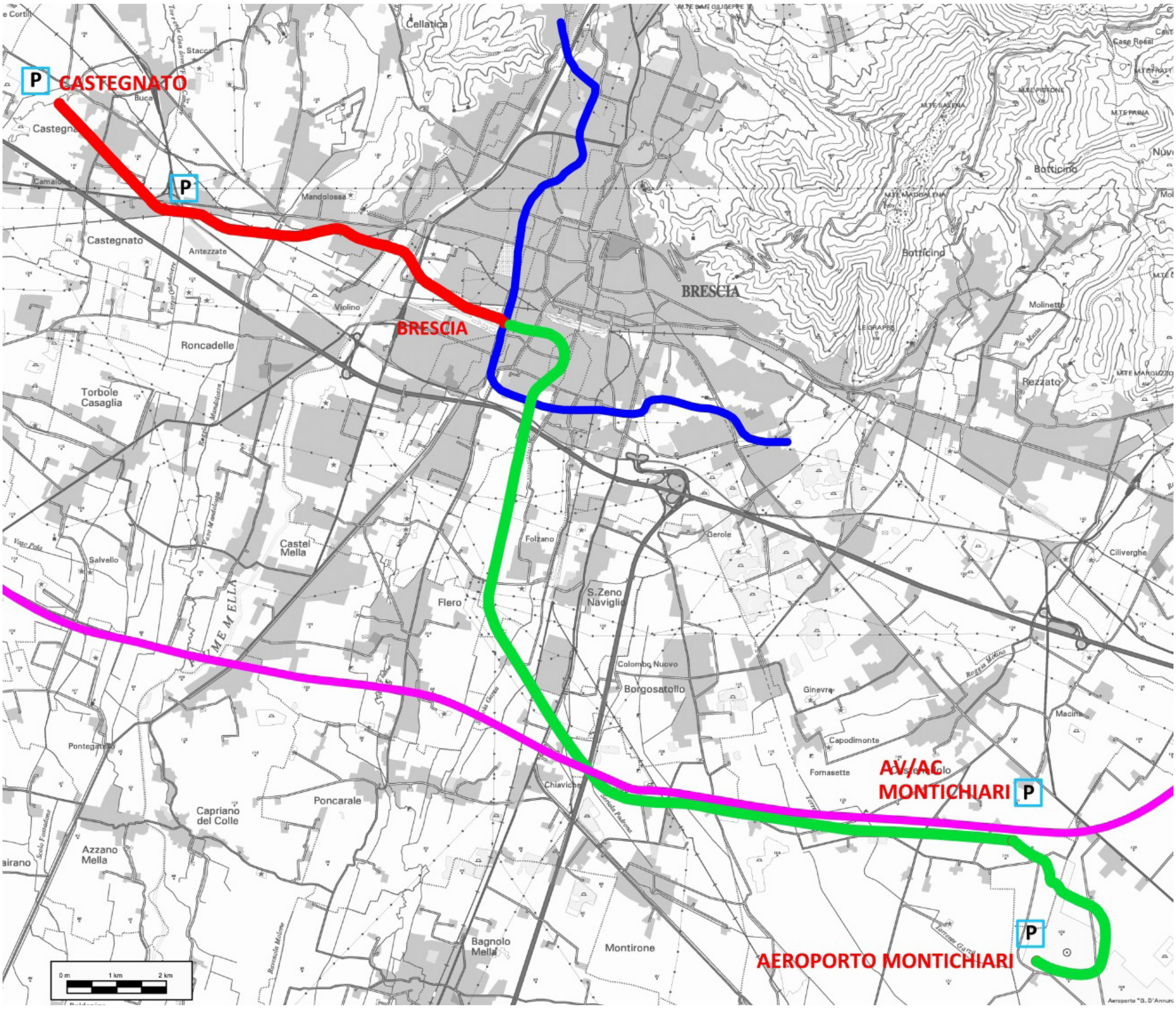

Figure 4 – The new Brescia - Castegnato TT line (red line) and its possible extension connecting Brescia and the High Speed/ High Capacity (HS/HC) Montichiari station (green line). The map also shows the new light-rail line (blue line) and the HS/HC line (magenta line).

6. Conclusions

The existing railway facility linking Brescia to Iseo and Edolo represents an important resource for the territory, which unfortunately, at the moment, is not sufficiently exploited. The recent guidelines on TT systems allow for the use of this line through the introduction of tram-like vehicles and by increasing the number of stops, such a system would provide a capillary service able to serve the western metropolitan area of the city of Brescia. In addition, after a necessary reorganization of the PTL network, the TT system would be well interconnected to the brand new automatic light-rail line (activated in March 2013), offering a high-quality integrated transport system, able to reduce the congestion problems of the area involved and improve service accessibility.
The TT solution which could be easily adapted to the Brescia reality is the TT1, which foresees the exclusive circulation of tram-like vehicles on the section of line between Brescia and Castegnato. This configuration would guarantee a maximum load of about 1,500 passengers/hour*direction in rush hour, reaching a total of 2,500,000 passengers per year. Other TT configurations, such as for example the TT3 solution, would guarantee a lower passenger load (about 1,200,000 per year).
A further development of the proposed system could be represented by the extension of the TT line from Brescia central station to Montichiari Airport where a new HS/HC station is planned, covering also the south-eastern area of the Province of Brescia (see figure 5). The extension proposal derives from the need to link the airport to the main cities in the north of Italy through a rapid, efficient and high-quality transport system such as the TT. The extension envisages the reuse of two existing (but poorly used) railway lines (namely, Brescia-Cremona to San Zeno Naviglio station and Brescia-Parma to Borgosatollo station) and the realization of a new permanent line adjacent to the HS/HC line and provincial road SP19 to the airport.
Finally, as already mentioned, during the design phase, particular attention should always be paid to analysis of accessibility to the stations, in particular for non-motorized users (especially vulnerable road users), in order to increase the likelihood of success and development of any new transport system.

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The cycling as a driver of a renewed design and use of public space within the neighborhoods

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Keywords: energy consumption, GHG emissions, cycling, road network, public space inside the neighbourhoods.

Abstract

A great contribution both to the energy consumption and to the air pollution results from road transport and mainly from travels in urban areas. The great number of trips occurring into the urban areas is certainly due to the increase of people in the cities, which will increase in the future representing thus a large proportion of the world population. Therefore, it is most influential the reference of the urbanization model and related transport model. In fact, for different historical periods, the shape of cities was depending on transportation technologies. The massive use of the cars has induced the extension of the urban areas in all directions without a prevalent priority, it has encouraged the private motorized mobility with respect to the widespread accessibility and it has allowed the separation of urban functions. As a consequence a reduced quality of life, social segregation - especially for people with a low level of self-sufficiency, and a reduced sense of community of residents are occurring. This led to a progressive impoverishment of the neighbourhoods that instead represent places of interaction for the individual well-being, community cohesion and urban vitality.

The study area is the 13th District (Ostia) of Rome – Italy, where it has been carried out a design laboratory in the frame of an European project"VillemiZero". This area has been urbanized after 1960 and it is representative of low-density settlements separated by agricultural enclaves. Infact this District has a population density of 13.6 inhabitants per hectare, one of the lowest of Rome. The collective transport can not support these density so low that instead are supported by private motorized transport.

A plan that encourages a higher urban density and mixed land use can have significant benefits in terms of provision of basic urban services that would allow a reduction in car use and as a consequent of GHG emissions and traffic congestion, increasing at the same time, the efficiency of the public transport and slow mobility. However, it is difficult to act on the density in urban areas already built. As a consequence we can act on the transportation modes used on the distance of proximity or short haul

According to these conception a reduction of use of the car and, consequently, of the traffic congestion and GHG emissions , can be achieved by increasing the component of slow mobility for travel within and among close neighbourhoods can be achieved through the increase of slow mobility for travels occurring within and among neighbourhoods. Finally, this paper aims to highlight the role of cycling as an important carrier for a renewed layout and use of public space inside of neighbourhoods.

Transport technology, urban morphology, GHGs emissions and energy consumption

Actual transport system has a very important role for the internal market and quality of citizens's life. If it is sustainable and effective then it can be helpful for economic growth and employment. Global, European and national contextes show that mobility has become increasingly necessary: between 1990 and 2007 the EU-27 road transport is increased by 29% and the car ownership, in the same time, is increased by 34% (EEA, 2010).

This transport model is accountable for 23% of energy consumed in Europe, and about three quarters of which depends on road transport (IPCC, 2007). It is estimated that energy consumption in this sector will increase around 80% for 2030. (IPCC, 2007). In this sector, the energy consumed originates of 96% from oil and its products (IPCC, 2007, EC, 2011; Lerch, 2011). A very strong dependence on oil that may also have important consequences on the resource supply and mobility of citizens for the next decades (EC, 2011; U.S. Joint Forces Command, 2010). Furthermore this high use of energy from fossil fuels produces large amounts of greenhouse gases and other emissions harmful to human health and the environment (U.S. EPA, 2010). Consequently, the transport system represents a significant and growing source of greenhouse gas (GHG) emissions. The European Commission shows that in this sector we need a reduction of at least 60% of these emissions compared to 1990 levels. By 2030, the objective of the transport sector is a reduction in GHG emissions by 20% compared to 2008 levels. Having regard to the considerable increase of GHG emissions in this sector over the past 20 years, it This data would be 8% above 1990 levels (EC, 2011).

This reduction could take place through gradual removal of vehicles powered by fossil fuels from the cities (EC, 2011). In fact, in the urban areas great part of energy consumption and air pollution is given from road transport. The important role of the road transport is certainly due to the fact that cities are becoming the places where a large proportion of the world population is focused on, and it will continue to focus on in the future (UN Population Division, 2007). At the same time it is of great importance to take in consideration the pattern of urbanization and the related transport model. In fact, for different historical periods, the shape of cities was depending on transportation technologies. The compact city of the 18th century owed their compactness at the prevalent pedestrian mobility (Glaeser & Kahn, 2003). In the 19th century the increase of use of the omnibus and tramways induced an urban development towards a less dense settlements, away from the city centre but distributed along the public transport lines (Glaeser & Kahn, 2003; Greene, 2004). Later, in the 20th century, two phases of urbanization occurred. In detail, the second one resulted in a greater growth and change than in the past , and it was characterised by the urban sprawl, which was began in the late 50's (Insolera, 1993; Antrop, 2004; Antrop, 2000a). The majority of new urbanized areas are characterized by low densities (Salvati et al, 2012), a reduction of the natural and semi-natural areas and a high fragmentation (EEA, 2011; Antrop, 2004; Cappuccitti, 2006). The widespread use of private cars has considerably contributed to the success of this urban model and it has represented the beginning of a new era of mobility, shape of public space and land use (Antrop, 2004; Rusk, 1999; Glaeser & Kahn , 2003). The massive use of the cars has a more pronounced effect on the shape of the city and the layout of public space with respect to the other transportation modes, because it eliminates almost totally the walking on. Moreover, the prevalent use of the car has induced the extension of the urban areas in all directions without a prevalent priority, it has encouraged the private motorized mobility with respect to the widespread accessibility and it has allowed the separation of functions. According to the ISFORT survey (2011), in the cities of central Italy, the share of proximity journeys lower of 2 km were just about 24.9% of the total, while for the short-haul journeys having a distance included between 3 and 5 km they were 22.9% of the total (Table 1).

In Municipalities with more than 250,000 inhabitants (i.e. Rome) in 2011, the proximity journeys were 31.1% and those of short-haul 25.8% (Table 2).

Therefore it is clear that even among proximity and short-range movements predominate the private motorized mobility. As a consequence, a reduced quality of life, social segregation – especially for people with a low level of self-sufficiency, and a reduced sense of community of residents are occurring (UN-HABITAT,2009; Appleyard,1981). Furthermore, the road network lost all hierarchical differentiations, standardizing itself on a model focused on movement and parking of motor vehicles, consequently reducing the degree of accessibility for the slow mobility. This led to a progressive impoverishment of the neighbourhoods that instead represent places of interaction for the individual well-being, community cohesion and urban vitality (Jacobs, 1961; Castells, 1997; Butler & Robson, 2003; Karsten, 2003; Danyluk & Ley, 2007; Raffestin, 1984).

Aim of paper

According to these analyses, we can think that a reduction of the car use is possible. This reduction could allow the reduction of the GHG emissions and traffic congestion. Moreover, it can be achieved the increase of slow mobility for travels occurring within and among neighbourhoods. Finally, this paper aims to highlight the role of cycling as an important carrier for a renewed layout and use of public space inside of neighbourhoods, in a way that neighbourhoods are more friendly and able to endure at the different needs of people.

Road Network as urban "vascular system"

Several studies highlighted four characteristics influencing the increase or reduction of the component of cycling mobility and walking: 1) functional aspects related to the structure of the settlement, 2) safety, 3) pleasure and 4) destination (Pikora, 2003). If we refer to the movement of proximity and short-haul, in order to give greater strength to walking and cycling mobility and, consequently, encouraging the public

Table 1 – Radius of mobility (journeys subdivided on the base of the path length - percentage value) (ISFORT, 2011).

	Prossimity (up to 2 km)	Short-haul (3-5 km)	Local (6-10 km)	Mid distance (11-50 km)	Long distance (more than 50 km)
Central Italy	24.90%	22.9%	22.08.00	26.3%	3.10%

Table 2 – Radius of mobility related to the demographic width of the cities (ISFORT, 2011).

Inhabitant number	Proximity (up to 2 km)	Short-haul (3-5 km)	Local (6-10 km)	Mid distance (11-50 km)	Long distance (more than 50 km)
Up to 5.000	21.7	15.5	22.1	37.0	3.7
From 5.001 to 20.000	7.4	20.1	21.1	28.2	3.3
From 20.001 to 50.000	32.4	23.3	20.6	20.5	3.2
From 50.001 to 250.000	31.7	27.2	20.6	18.2	2.3
Above 250.000	31.1	25.8	23.1	18.0	2.0

transport, it becomes crucial to give new and greater importance to public space of the neighbourhoods (Jacobs, 1961; Wellman, 1996; Castells, 1997). In fact, local dimensions allows to meet all the daily necessities of residents without the use of motor vehicles, seeking also relationships of greater proximity and effectiveness. The theme of accessibility can be treated considering both resources and residents distributions (Hansen, 1959; Horner, 2004; Krizek, 2005; Kwan et al., 2003), but it is equally important to consider the urban tissue characteristics, other than structures of the public space and road network. As in an organic body, the cardiovascular system distributes energy and materials to the cells, a road network (which is the major component of the public space) distributes energy, materials, and people in different places (Samaniego & Moses, 2008). If the space required for these transfers is not effective, the movements and relationships will not be effective (Samaniego & Moses, 2008). Analysing and working about the network space that connects people and places is thus a significant starting point to improve accessibility.

According to Allometry and Metabolic Scaling Theory (MST) in biology (Banavar et al.,1999; Brown et al.,2004; West et al.,1997) the characteristics of vascular networks determine, in an organism, its volume (Banavar et al.,1999; West et al.,1997), the velocity of the flows of energy and materials, growth (Moses et at.,2008; West et al.,2001), the duration of life (West & Brown, 2005) and other key features of the functioning of organisms (Brown & West,2000). Furthermore, Samaniego and Moses (2008) shows similarities existing among cities and organisms regarding metabolism, size of the system, network size, density and scale of prediction. The road network is equaled to the vascular system of organisms. This distributes energy to the cells as well as the road network distributes materials, people and energy in different urban places. As a consequence, to reconfigure the vehicular space can have a positive impact on the characteristics (i.e. social, economical and environmental ones) of the entire system. Samaniego and Moses (2008) points out that according to the MTS, the networks distributing energy are characterized by hierarchical branching. Similarly, urban road networks should distribute cars and people in the city through a hierarchical structure (Samaniego & Moses, 2008). The hierarchy of the parties is one of the network's characteristics, making thus it more effective. If characteristics, such as continuity, capillarity and recognizable hierarchy, are not fully included in a planning of the road network then this network will be low efficiency, with more energy consumption and harmful emissions. In addition, the economy decline is linked to the reduction of quality and accessibility of streetscapes (Hamilton-Ballie, 2008). The road network has lost all hierarchical rank mainly in the neighbourhoods and it is standardised towards a model that allows for a greater car-based mobility, but at the same time, it has reduced its accessibility. Thus searching for a high level of accessibility for the road network can be a starting point for reconnecting the broken linkages and increasing the overall connectivity. This systemic reconnection can help to ameliorate the well-being of communities and individuals.

Study area

The study area is the 13th District (Ostia) of Rome – Italy, where it has been carried out a design laboratory in the frame of an European project"VillemiZero". This is area has been urbanized after 1960 and it is representative of low-density settlements separated by agricultural enclaves (Figure 1). The 13th District covers an area of 15,064.27 hectares and it has a population density of 13.6 inhabitants per hectare, one of the lowest of Rome. It is connected to the city centre by an urban railway line, which is not adequate to sustain actual transport demand, favouring thus the use of private cars. In fact, data regarding to vehicles on the road show high levels of car ownership in Rome (Figs 2 and 3) that, proportionally, are typical of the 13th district too. The public space is largely vehicle space, without any continuity in walking routes and bicycle routes and spaces for public relationships are almost absent. Inside the 13th District is not traceable neither a well-defined structure of the public spaces system nor a widespread distribution of public services and commercial.

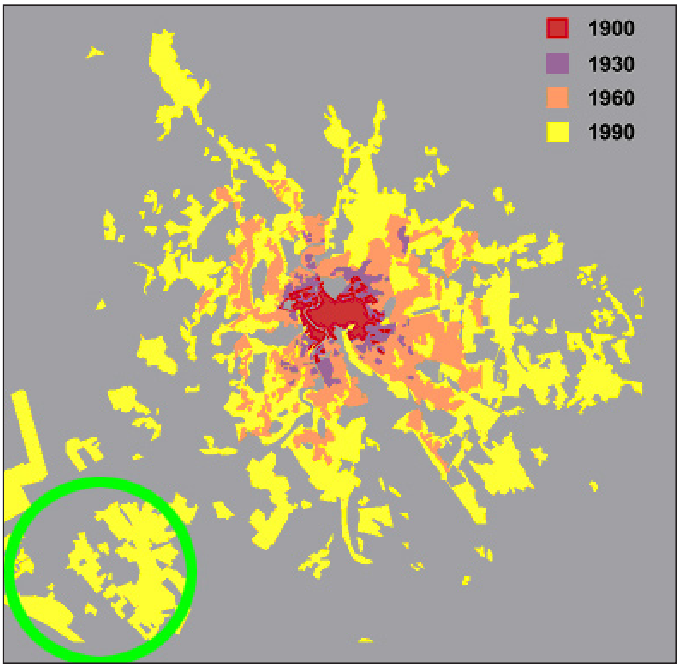

Figure 1 – Rome, urban growth between 1900 and 1990. Localization of the study area.

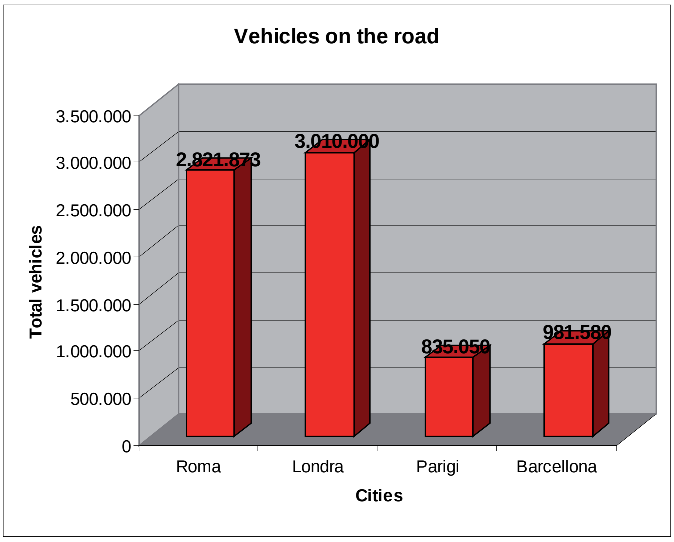

Figure 2 – Vehicles on the road; Source: Roma Capitale, 2011.

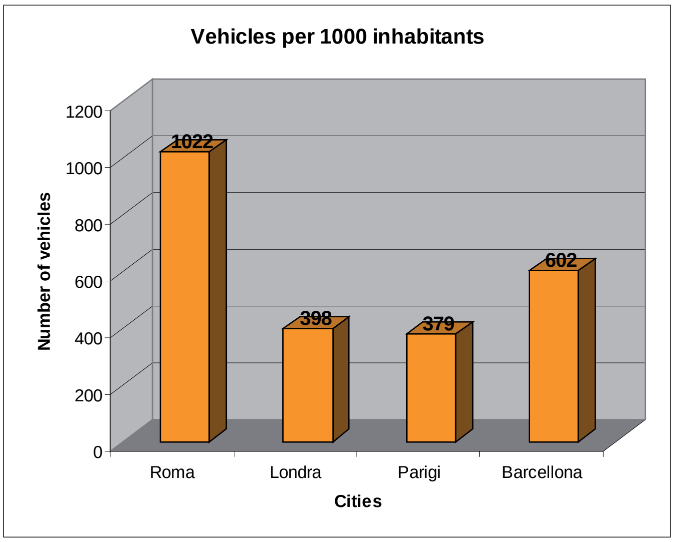

Figure 3 – Vehicles per 1000 inhabitants; Source: Roma Capitale, 2011.

Results and Discussions

The city of Rome has a road network of 8,752 kilometers inside the GRA (GRA), of which only a very small part is classified and belonging as main road (Table 3).

Table 3 – Existing road classification.

Existing road classification	
Main road	Highways
	High speed urban roads
	Inter-district roads
	District roads
	Inter-zonal roads
Local street	Local streets

The absence of capillarity and recognizability is confirmed by analysis of the road sections: technique (Figure 4) and perceptual analysis (Figures 5a, 5b, 5c). In relation to different uses of the road, the design of the spaces does not change, with great predominance to the needs of motorized vehicles. In this way, functional relationships among slow mobility, motorized mobility and social relationships needs are invariant, regardless of the different uses and functions of the urban space. On the other hand, these functional relationships are certainly different in the main streets and in local ones occurring as residential function. The main streets support high speeds, so they are used for movements of great magnitude. For these reasons, they have great dimension and width of roads. The difference between the speeds of the different transportation modalities is evident, therefore, it should prevail the flows separation. The local streets cover shorter distances, the width of road is reduced and the speeds are lower. Consequently, it should prevail the rule of space sharing among various traffic modalities . The reduction of traffic and speed levels is the better condition for increasing of the roads comfort and for sharing of the space (Harkey et al., 1998; Pikora et al., 2003). Furthermore, the reduction of the speeds makes possible a progressive diminution of the space required for the motorized vehicles' movement. This space could be used to give immediacy and continuity to the pedestrian and bicycle network (Burden et al., 1999; Pikota, 2003).In the frame of the pattern of movements, the main road represents the first level of the network, characterised by a reduced capillarity respect to the next levels and it can be constituted from different road types (these are also characterized by a certain hierarchy), which are recognizable among them and designed in accord to the needs, in order to accommodate the high speed traffic (protecting the near neighbourhoods) and the routes of public transport.

The traffic model of the road network inside the main routes, proper to the neighbourhoods, represents, instead, the secondary level. The latter is constituted by different levels with more and more capillarities and it is characterized by a less invasive and fast vehicular traffic, prevalence of slow mobility, more accessible spaces, a design of the road space more difficult to be used for the motorized vehicles, and liveable for the people.

This classification, however, has no value if it is not part of the road space design. A fundamental criteria for getting a resilient urban mobility system is that the road space have to influence the choice of the transportation modality (DfT, 2007). A capillary road hierarchy is characterised by a design that highlights roads with different uses and needs, their binding, and recognisable each to other.

The importance of a capillary road hierarchy is especially noticeable if the data of night accidents are analysed. In Rome, the 40% of all deaths occurred between 9 pm and 6 am, although the number of trips is much lower than during the day (Roma Capitale, 2011). These data show that in absence of a recognisable hierarchical network the speed limits are dictated by vehicle numbers on the road instead by the road shape. Moreover, the extensive use of the road signs does not ameliorate the safety on the roads. During the day, in the time frame of the systematic trips (home-school/work) there are less serious accidents, although these occur with great frequency. In fact, the circulating vehicles are numerous, the space available is less, as a consequence the speed is reduced and the gravity of accidents too.

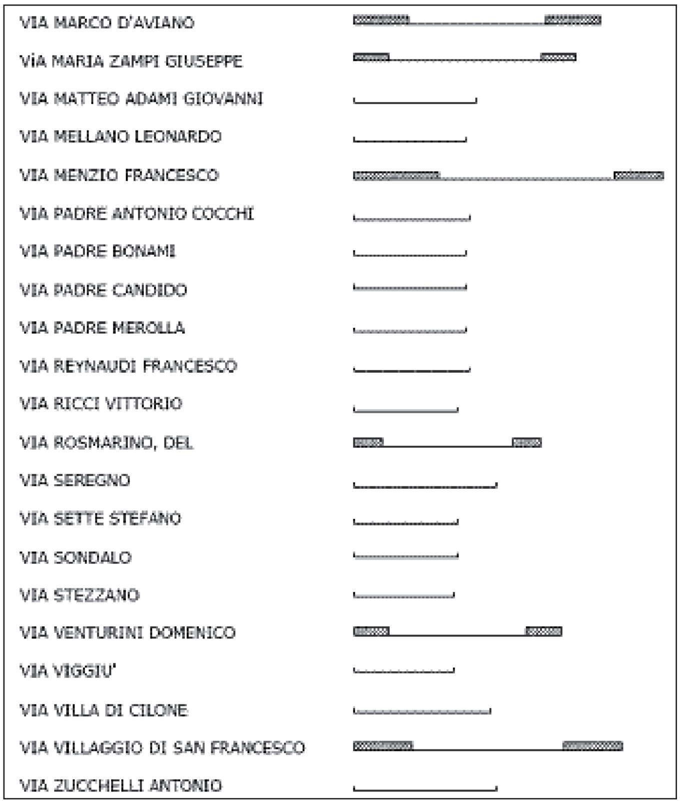

Figure 4 – Road sections of some local streets.

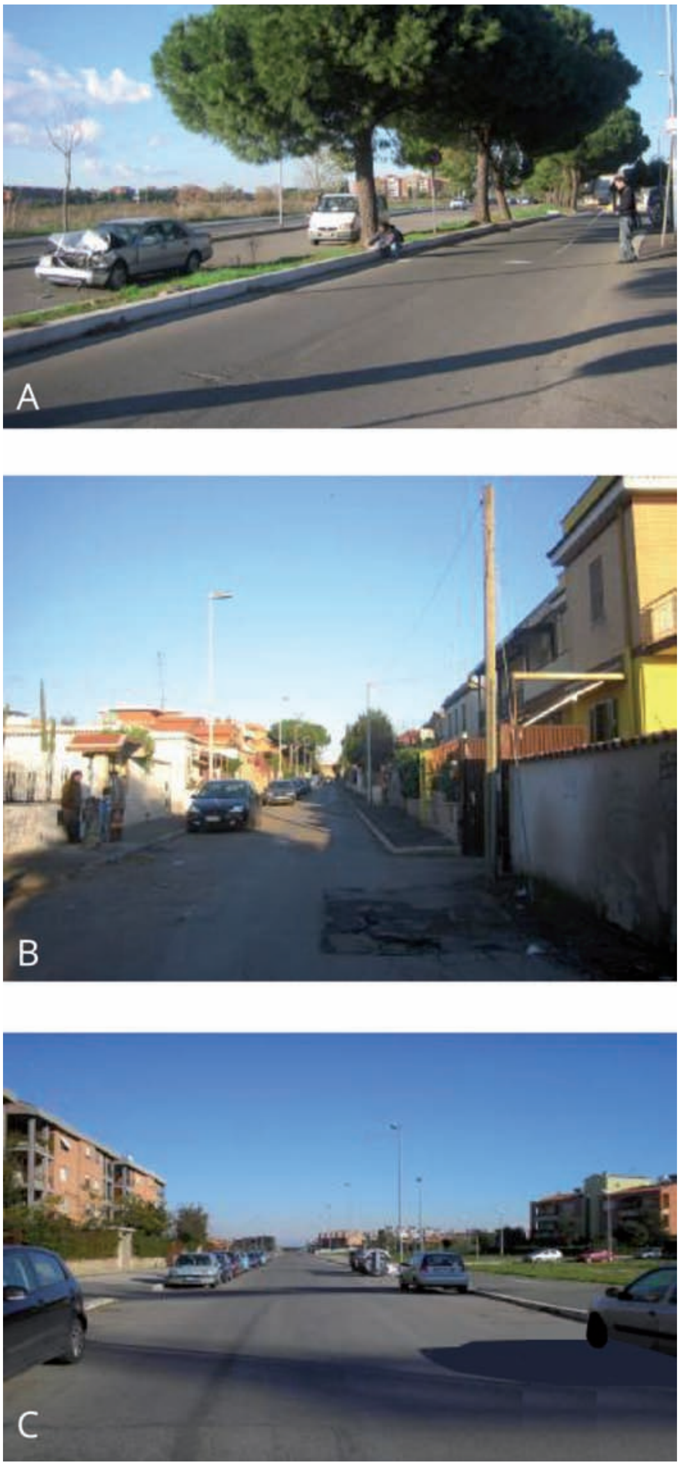

Figure 5 – A) Scrolling road; B) Interzonal road; C) Local street.

Generally, the design of the road should be aimed at ensuring the necessary space to all transportation modalities, but giving much more attention modalities with greater autonomy, low fuel consumption and emissions and low operational and management costs (Table 4).

Table 4 – Hierarchy of users of road space.

1	Pedestrians (spaces for moving and socialization/meeting)
2	Cyclists (spaces for moving and for parking)
3	Collective public transport
4	Service vehicles (Emergency vehicles, vehicles for waste collection, etc.)
5	Other transport modes (private cars, motorcycles, car-sharing, car-pooling, taxis, etc..)

This hierarchy should serve as a general remark and, on the basis of road section, traffic flows, existing services and equipment on the road, it should be planned urban spaces according to this hierarchy. Considering both road classification and different typologies of road users, the spaces for different traffic modes will be certainly different, ensuring that the design of the road space will be different and, therefore, recognizable. Under these conditions, the road space will have a higher level of attractiveness for pedestrians and cyclists. Consequently, the use of public transport will increase. In fact, a road network for the slow mobility will become most connected, permeable and continues. The latter encourages the pedestrian and cycling mobilities (Burden et al., 1999; Pikora, 2003), leading to a better distribution of motorized traffic throughout the road network (DfT, 2007), reducing the risk of accidents (York et al., 2007; DfT, 2007) and also resulting in a globally reduction of the urban pollution (Hawthorne, 1989). The increased travel by bike, as well as obviously those on foot, and with the public transport allows significant savings in greenhouse gas emissions. In fact, even if neither cycling nor the public transport are free from the production of carbon, these modes of transport produce approximately the 13.5 % of the emissions resulting from individual motorized transport (ECF, 2011).

In an interesting study, the ECF (2011) has calculated the impact of the production stages, maintenance, operation and fuel production for four different modes of transport: bicycle, assisted bicycles (*pedelec*), private car and bus. This represents a data relevant to allow assessment of the ability of reducing GHG emissions (Table 5).

The plan carried out on the territory of the 13th Districts of Rome has led to a classification of all roads in the District neighborhoods and reduce the percentage of travel by motorized vehicles on the distance of proximity or short haul. This reduction can contribute significantly to the reduction of energy consumption and GHG emissions thereby increasing the overall quality of the urban environment. Further changes that such interventions can bring concerns the revitalization of the local economy and social relations of proximity (Appleyard, 1981).

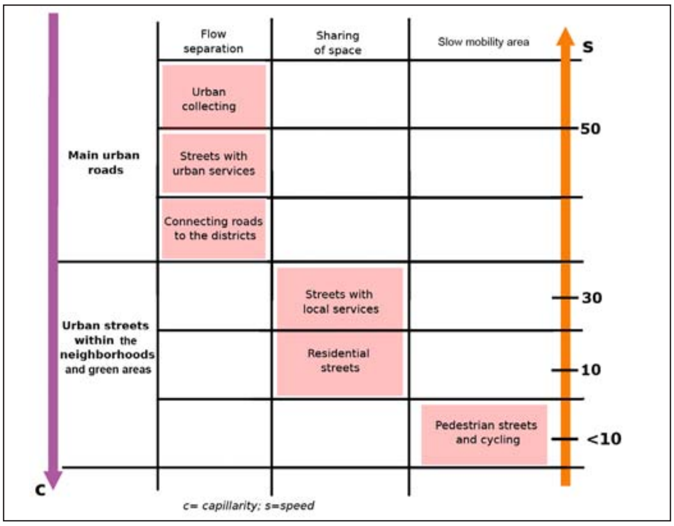

Figure 6 – Traffic pattern.

Table 5 – GhG emissions for the four different transport modes.

	Production and Maintenance phase	Operation and fuel production phase	Total
Bicycle	5 grams CO2e/km	16 grams CO2e/km	21 grams CO2e/km
Pedelec	16 grams CO2e/km	6 grams CO2e/km	22 grams CO2e/km
Car	42 g CO2e/km	229g CO2e/ passenger-kilometre	271g CO2e/passenger-kilometre
Bus	6g CO2e/ passenger-kilometre	95g CO2e/ passenger-kilometre	101g CO2e/passenger-kilometre

formulated according to the diagram shown in Figure 6. Although there are no central places (Colarossi, 2008; Cerasoli, 2008) it was possible to identify a continuous network, capillary and recognizable both on the cycling mobility (Figure 7). Among the four characteristics that influence the increase or reduction of the component cycling and pedestrian, we have chosen to work on the functional feature, related to the structure of the settlement, safety and pleasure. In relation to the destination and hence to the dislocation of trade places, services and equipment to carry out daily life was not proposed any intervention because such proposals are not just about the sphere of spatial planning but also other relevant areas such as economic and social.

We have planned continuos networks for walking and cycling trips. So local services and equipment will be reached, however, in a more comfortable way and safe even if placed at a longer distance. These paths can be useful also as paths of adduction to public transport.

The main objective was to increase the accessibility inside the

Through actions that affecting layout and use of public space, without changing the density, with the aim of a change in the modal split in relation to the movement of proximity and short-range, in existing neighborhoods, it is possible a reduction of use of the car, the traffic congestion and, consequently, of the GHG emissions. Increases, at the same time, the efficiency of other modes of transport: collective public transport and slow mobility.

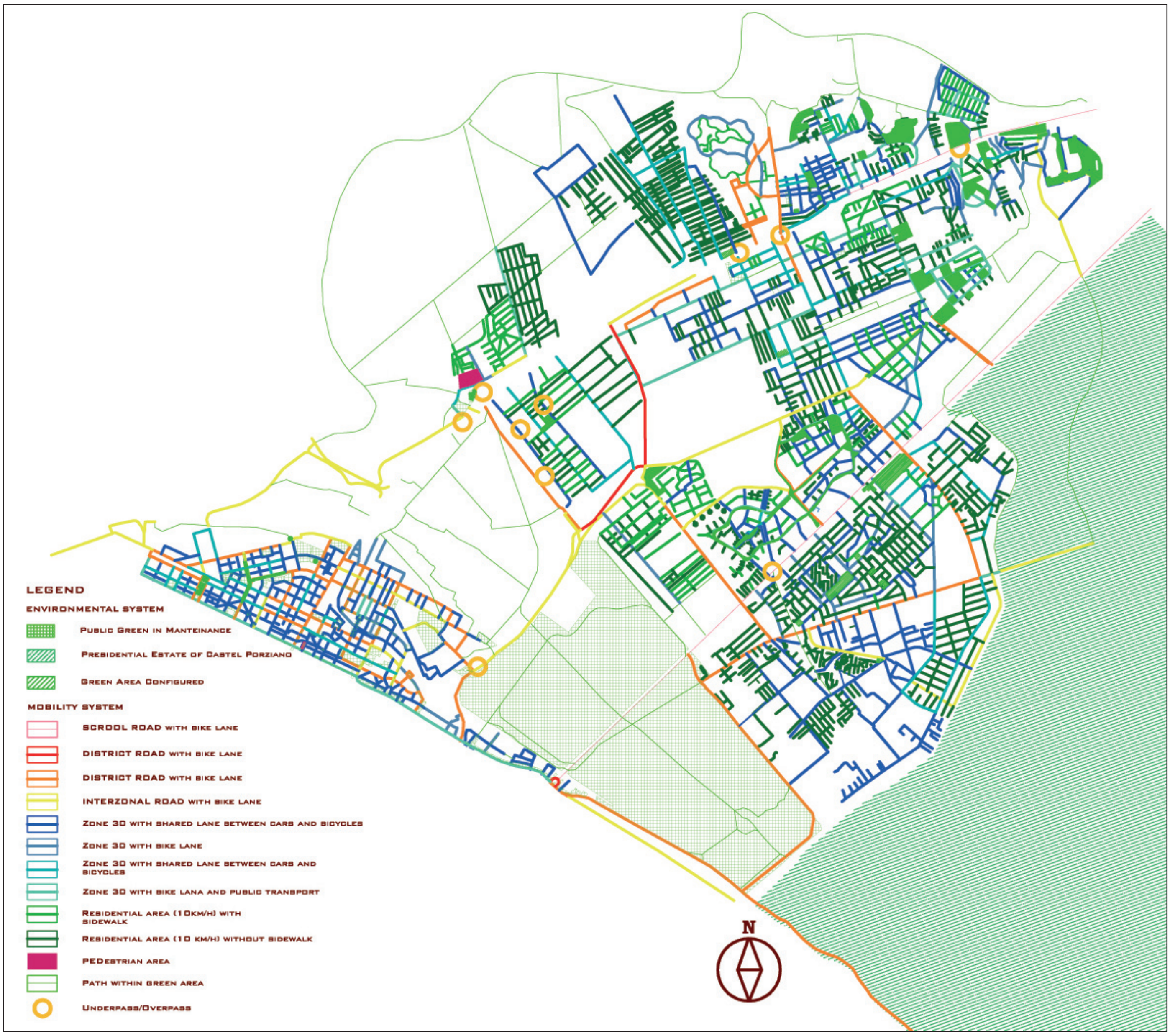

Figure 7 – Cycle network.

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Energy integration for performance intensity public urban spaces[1]

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Keywords: renewable energies, open spaces, integration suitability, performance intensity.

Abstract

The paper reports some results from the National Research Project 2008 on systemic integration of technologies for renewable sources in the built environment, where the team from the Second University of Naples has studied the context of public open space in a consolidated city. The group has worked on preparing complex protocols for environmental reading of the townscape. According to international scientific literature on the subject, we proposed the definition of the features of the intensity performance spaces for the meta-design of innovative solutions. These solutions are characterized by multi-functionality and adaptability to variable context conditions. Features regarding energy autonomy and the requirements of integration suitability for renewable energy technologies are here studied. The relationship between requirements and strategies for the integration of PV components together with their applicability and potential compatibility in urban open spaces are discussed.

1. Systems to analyze urban open spaces

The evolution of the urban asset, in constant and chaotic increase has lead to reconsider the role of open spaces through updated interpretation codes, by aggregating fulcrums of public and social life organized according to new reactive models thanks to information technology. In order to identify indications for the sustainable design of equipment for such places, it is advisable to read them in semantic, energetic and environmental terms in order to guide the redevelopment considering the complexity of the present aspects.
By referring to the National Research Project on systemic integration of technologies for the production of energy from renewable sources in the built environment, coordinated by G. Scudo of the Politecnico di Milano, one has a more thorough understanding of the topic. The local unit of the Second University of Naples, led by S. Rinaldi, has studied the application in urban spaces, by using a system of three adjoining squares as a case study. According to international scientific literature on environmental design, public space is read through the overlaying of levels which express data regarding physical, material and use, besides mapping of meteoclimate conditions.
Experiences from cities such as Berlin, New York and San Francisco have enabled the construction of a functional protocol for a GIS tool, which is the first part of his complex analysis methodology. In fact, the Berlin Digital Environmental Atlas 08.06 (Edition 2008) reports the solar Energy potentials on roofs and facade surfaces of the town in the chapter dedicated to solar Energy. Whereas, online solar maps of New York City (NYC Solar Map, by City University of New York, CUNY) and San Francisco are interactive tools that evaluate the solar energy potential for every building whose address is typed. Furthermore solar existing panel plants are reported with their energy production, allowing to asses environmental benefits, savings, costs, incentives and revenues for the investments in this sector. Thus, it is impossible to obtain data for open space surfaces in these cases, although the implementation seems quite feasible.
By using shared spaces in our towns according ones everchanging needs, different groups of people produce a variety of phenomena: mixed, temporary, representation, conflict or pacification uses, which derive from direct or indirect appropriation.
The necessity of a methodological and survey approach is nowadays acknowledged, in order to obtain appropriate design solutions. To find vocations and priorities of the case study places, on the basis of tests carried out according to the protocol and thus reported in the context conditions in GIS, our team has worked towards obtaining a map of the users' needs, in reference to habits and timeframes. In fact, social and technological changes affect the way and time people use public open spaces. To identify flows and patterns of use, we studied the different dynamics on a daily, monthly and yearly survey of the area.

1. This work is the result of collaboration between two authors: Renata Valente has written paragraphs from 1 to 3, Luigi Foglia has written paragraph 4.

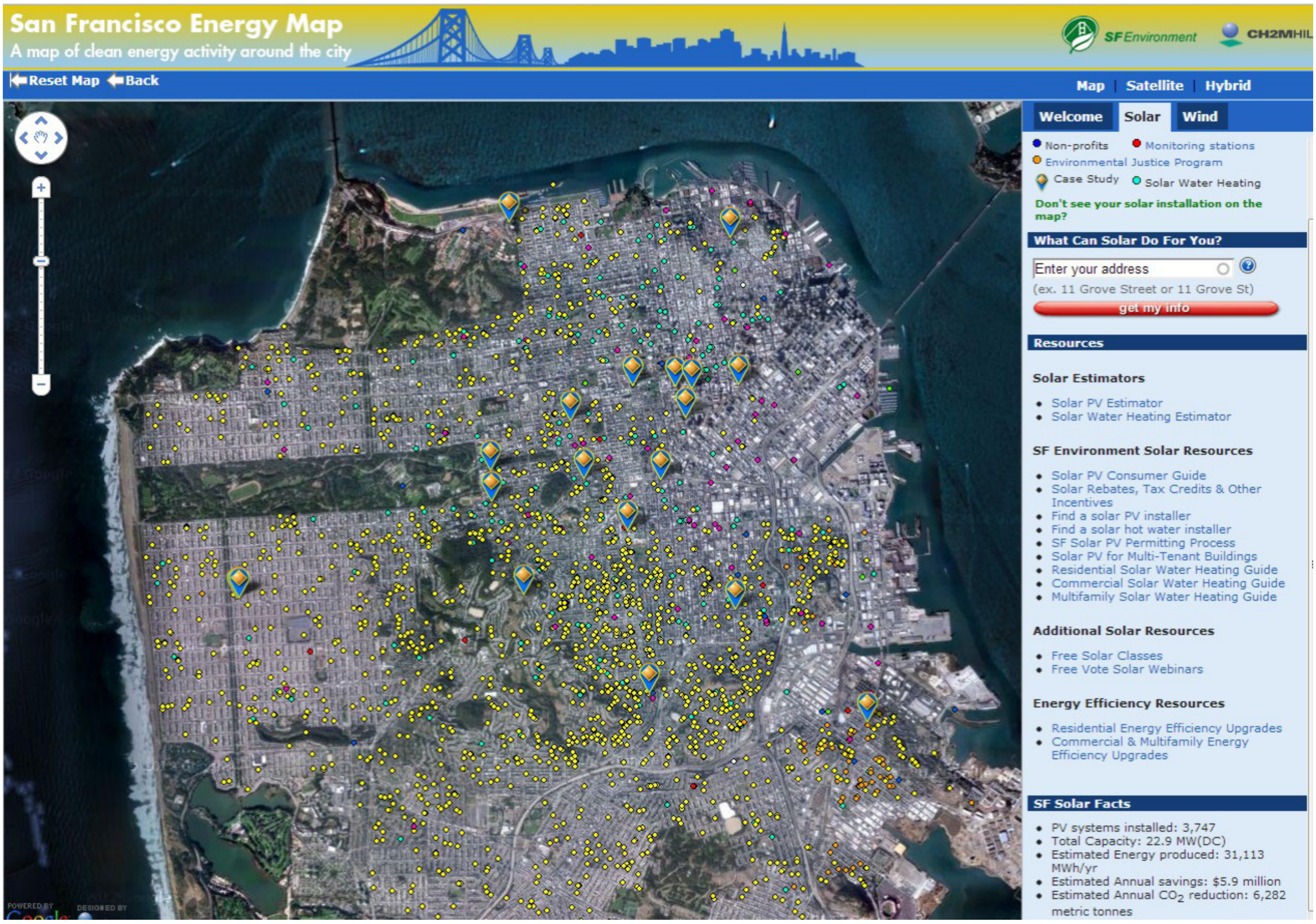


Figure 1 – San Francisco Energy Map. Solar Installations: municipal, residential, schools/libraries, commercial, non-profit organizations, monitoring stations, Environmental Justice Program, case studies, solar water heating (from http://sfenergymap.org).

2. Spaces with performance intensity and energy autonomy

Design ideas that govern the various configurations over time and the method of transformation are necessary to meet the needs dictated by continuously changing scenarios, in order to avoid dysfunctional conditions. To provide customizable, intelligent and responsive small buildings, it is possible to use lightweight construction systems that become dynamic from the original static shape. These artifacts should absorb even chaotic layering of service equipment in open spaces by canceling it, in those situations where operating on the frontiers of existing buildings has not been possible. The described strategies are aimed at creating spaces characterized by four main aspects:

a) possible integration of new required equipments in existing volumes and surfaces, enhanced by assimilating functionality and raising the possibility of use;
b) transformability of the same physical equipment;
c) dynamism of these spatial configurations, powered only by energy from renewable sources;
d) performativity, that is predisposition both to provide a direct benefit and to produce new participatory relationship between users and place. This attributes value in terms of relationships to the outcomes of the induced interventions.

The development of this approach aims to give shape to places rich in perceptual stimuli and interacting potential, that may become basic elements of contemporary urbanity, generating new social cross-identifications. We have defined such places as characterized by "performance intensity", which means they are furnished with extensible quality and potential, related to innovative use. To look for guidelines for these projects is necessary to define a framework of requirements related both to needs classes already identified in the scientific literature for open spaces and to associated to new parameters.
There aren't, however, enough appropriate case studies presenting all the performances required. So we have referred to features of the projects chosen each time as showing one of the aspects related to our goal. Then we have extrapolated and aggregated these features to shape a sort of identikit. This procedure gave rise to a list of characters organized by families. The first of them is related to space (including the characteristics of flexibility and integration), the second to

use (including the usability and the intensity of use), the third to sustainability (examining options for energy independence and reversibility), the fourth to comfort (concerning environmental objective and subjective perceptual aspects) and the last responsiveness (where we include characters related to computerization, sensitivity and interactivity of the proposed equipment) (Foglia, Valente 2011).

Here we discuss the character of energy autonomy for new urban spaces, starting with the discussion on the uses that require electrical potential, exploited for functions that we have distinguished in first and second utility. In the first group we include, in fact, the lighting system, the s.o.s. call points, info points, environmental control units. In the second group, we list services such as wifi and Information Technologies, social and advertising communication and safety and traffic control devices automation, charging of the various computing devices, recharging of electric vehicles, sound and visual art installations. The energy soul of new equipment for performance intensity spaces with integrated renewable energy technologies induces opportunities for scenarios that were unthinkable in the past.

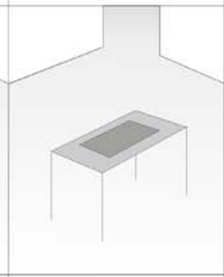
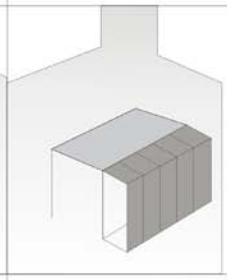
3. Suitability to integration of components for micro-landscape design

Once we have assessed the dynamic and variable nature of the projects to propose, the energy requirement for these transformations leads to explore the possibilities and integration modalities of technologies for the production from renewable sources. These technologies include among the obvious benefits also the chance to not imply physical landline connection works with the urban electric network, favoring the conditions of pavement maintenance.

The requirements for the suitability to integration of PV elements in the built environment have been studied by framing the importance of the management aspects in relation to the maintainability of the integrated systems linked to their durability and reliability over time. This work is included in the Project Guide of the IEA (International Energy Agency) for the application of photovoltaic technologies to so-called Non Building structures (IEA, 2011), already commented in a previous publication (Foglia, L., Valente, R., 2011a.)

To critically study in deep the mentioned requirements, we

Table 1 – Relationship between requirements and strategies for the integration of PV components: the case of coverings in urban open spaces (elaborated by author from the contents of A. Bosco, S. Rinaldi, "Tecnologie di Integrazione," in *Fotovoltaico e Riqualificazione Edilizia*, edited by A. Bosco e A. Scognamiglio (ENEA, 2005): 196).

implementation procedures		overlap	partial replacement	total replacement	addition of technical or spatial elements
classes of requirements	requirements				
technological suitability to integration	constructive compatibility	•	•••	•••	•
	static compatibility	•••	••	•••	•
	materials compatibility	••	•••	•••	•
morphological suitability to integration	chromatic variation	•	•	•	••
	variation of graine	•	•	•	••
	variation of texture	•	•	•	••
bioclimatical suitability to integration	heat recovery/dispersion	•	•	•	••
	control of solar radiation	•	•	•	••

• *low criticality*
•• *medium criticality*
••• *high criticality*

component: ***covering***

refer to a 2005 text (A. Bosco, S. Rinaldi, 2005) where authors identified other three classes of requirements, considered as specific definitions of the category of needs. These classes were: the technological suitability to integration, to which compatibility of construction, static and materials refer; the morphological suitability to integration, to which the changes in color, grain and texture are attributed and the bioclimatic suitability to integration with the requirements of recovery and heat dissipation, and control of solar radiation. In the same text the authors distinguished four integration strategies: overlapping, total substitution, partial substitution and addition.

Such a summary table of the relationship between strategies and integration requirements, can be constructed also for each of the categories of components of urban open spaces we have already proposed (Valente 2010). These are: coatings, quints, roofing and tectonic, excluding that relating to objects. We propose here table 1, where, unlike what happens in the reference work, more conditions of low criticality of the application appear, specifying that the bioclimatic suitability to integration regards the possibility of conditioning the microclimate next to the considered element.

This way it is possible to study the relationships between space components, needs systems, energy requirements and performance of any selected technologies, reporting on the steadily improved performances from applied research, as described in the following section. In addition, the passage from the conception of open spaces as passive energy systems (terminals of the power grid) to complex active systems (with inflows and outflows) leads to rethink the relationships between space and energy in the direction of dematerialization. By creating self-sustaining hub (connected or off grid) to supply the needs in every place, the energy management dependent from small locations rather than large power plants might be safer, although more complex. In the interim, the gradual replacement of traditional lighting elements with PV technology models (if not be eliminated through the integration of light in architectural elements) may be preceded by the connection of the current ones with plants on roofs or walls of bus shelters, kiosks and parking lots.

Figure 2 – Ameglia (La Spezia, Italy). One of three prototypes of stand-alone photovoltaic shelter made in 2004, as part of the Italian German PVACCEPT research project funded by the European Commission. This project is based on the integration in the architectural historic environment and landscape (photo R. Valente).

Figure 3 – Ameglia (La Spezia, Italy). Detail of photovoltaic trellis wiring. Five 2.40 m x 0.30 m module strips for each pergola facing south / east at an angle of 30 ° above the horizon, support the semi-transparent thin film with a pattern of 10% of holes which produce up to 240 Wp (photo R. Valente).

4. Applicability and potential compatibility of the PV technologies with urban open spaces

This is a study to identify analytical criteria concerning the applicability of the photovoltaic technologies for the performance model of urban open spaces, aimed towards energy autonomy. These technologies are both currently in production and/or in experimentation.

Therefore we would like to identify and connect the performing aspects (linked with the energy production) with the peculiar characteristics of the urban open spaces. This connection must be carried out according to the principles of both the potential compatibility and the maximum integration and non-interference with the uses. Therefore, the elaboration of an operational methodology which aims at reading/systematizing data and knowledge, is required. This model supports the design choices considering the possibility of integrating PV technologies for the energy autonomy and the peculiar characteristics of the new spatial evolutionary structures.

Main PV systems available on the market and in experiments (table 2) can be classified, establishing relationships among the data concerning the technology of reference (photovoltaic generation, basic technology, cells) and the applications prevailing on the different supporting typologies. In order to obtain an adequate implementation, both the market and the research offer different application solutions for each specific technology. The different typologies of support and treatment of the cells and modules can influence both the

Table 2 – Categorization of the main PV systems available both on the market and in experiments.

PV generations	Basik technologies	PV cells typologies	Prevailing applications on supporting typologies
First	Crystalline silicon	Monocrystalline silicon	- Rigid solar panels
		Polycrystalline silicon	- Rigid solar panels
Second	Thin film solar cells (TFSC)	Cadmium telluride (CdDe)	- Thin films solar cells on flexible substrates - Printed thin films solar cells on flexible substrates - Laminated thin films *cut-to-size*
		Arsenurio di gallio (GaAs)	- Thin films solar cells on flexible substrates
		Copper indium gallium selenide (CIS or CIGS)	- Thin films solar cells on flexible substrates - Thin films printed/preforated on flexible substrates
		Amorphous silicon (a-Si)	- Thni films solar cells on flexible substrates - Preforated thin films on flexible substrates
Third	Nanocrystalline silicon	Nanocrystalline silicon	- Paints - Gels
	Quantum Dots	Nanocrystalline silicon	- Nanocrystalline silicon thin film
	Multijunction	Multijunction	- Thin films solar cells on substrates
	Beam splitting	Concentrated PV cells	- Rigid solar panels integrated with optical lens
	Superlattices	Multijunction	- Thin films solar cells on substrates
	Microcells	Spherical micro solar cells (Sphelar)	- Semitransparent thin film on flexible substrates
	Organic	Hybrid (DSSCs)	- Thin films solar cells on flexible substrates
		Organic (OPV)	- Thin films solar cells on flexible substrates - Flexible PV textiles - Printed on substrates
		Dye sensitized	- Transparent and semitransparent thin films on flexible substrates
		Multiuse pigments	- Transparent and semitransparent thin films on flexible substrates

aesthetic result of the module in terms of design flexibility and the production efficiency.
The Final 2005 Report of the "PVACCEPT" European research, coordinated by the Faculty of Architecture/Design (Udk University of Berlin), shows a datum underestimated up to now. Some factors related not only to the components but especially to the cells and the production modules can directly influence the photovoltaic acceptability within the urban contexts, often damaging the actual energy performances.
The experimentations, aimed at increasing the values of design flexibility in terms of clearness and "customization" of the modules in a thin CIS film, dot printed and/or silkscreened structure, actually highlight a decrease that is proportional to the treatment of the surfaces (averagely to be estimated around 20%) of the performances of an untreated module.
In the next step of the research, the relationships among the uses noticed in the urban open spaces, the related energy requirements and their spatial implications – in terms of possible locations of the interventions and occupation of the surfaces – are analyzed concerning the prevailing applicable PV technologies. In the analytical model (table 3) we refer to the basic and spontaneous uses (Gehl 1996) in the urban open

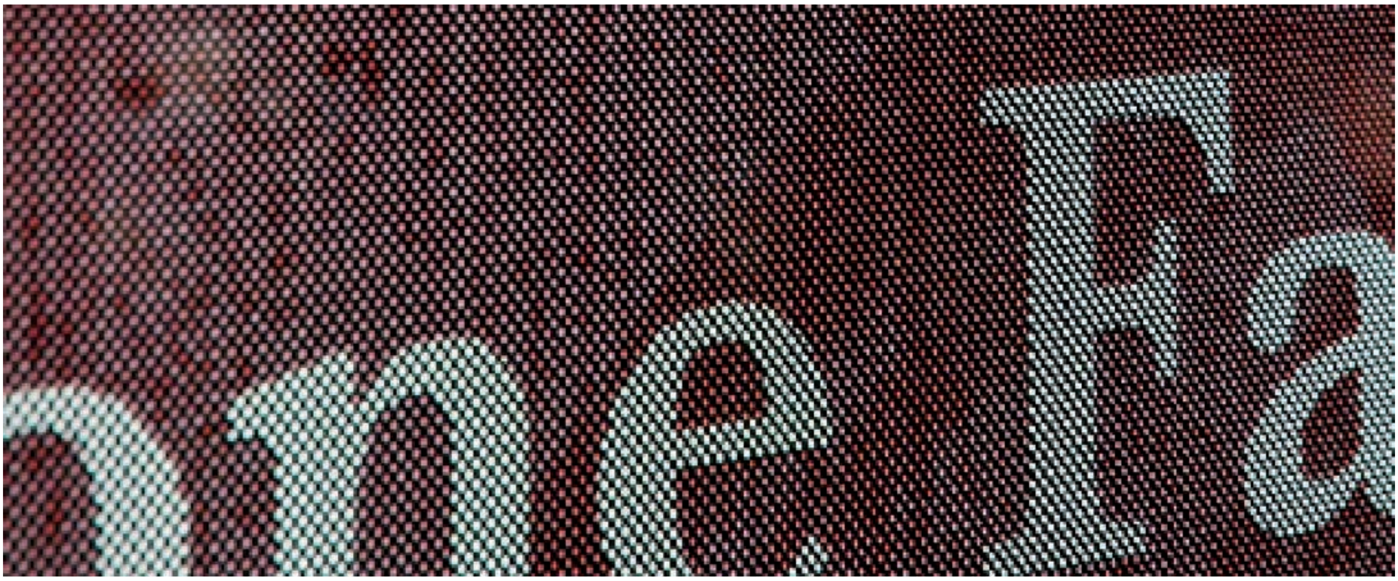


Figure 4 – Printed and perforated thin Film PV module CIS. Demo Object produced by Würth Solar and tested on La Spezia Castle according to the research program PVACCEPT.

Table 3 – PV technologies for autonomous performance intensity spaces. Relations between noticed uses, energy needs and space involvements.

Prevailing uses RUE 06 Emilia Romagna	**Connected prevailing needs**	**Approximate energy needs** IEA Report 2002 Task 7	**Applicable PV technologies**	**Required productive surface (1 kWp)** AREA Science Park/CETA 2005	**Connected *micro-landscape design* components** Valente 2010
Waiting	- Seat/psycho-physic comfort - Shelter/environmental comfort - Illumination/visual comfort - Recognisability	- Average (500 - 1000 W)	Crystalline silicon	Low (<10 m2)	- Shelters - Objects - Tectonics
			Thin film	Average (10-15 m2)	
			Nanocrystalline	High (>15 m2)	
			Quantum dots	Average (10-15 m2)	
			Microcells	Low (<10 m2)	
			Organic	High (>15 m2)	
Socalization	- Seat/psycho-physic comfort - Leisure/psycho-physic comfort - Shelter/environmental comfort - Illumination/visual comfort - Acoustic comfort/acoustic barriers	- Hight (1000 - 10000 W)	Thin film	High (>15 m2)	- Coverings - Wings - Shelters - Tectonics
			Nanocrystalline	Average (10-15 m2)	
			Quantum dots	High (>15 m2)	
			Multijunction	Average (10-15 m2)	
			Beam Splitting	Low (<10 m2)	
			Superlattices	Low (<10 m2)	
			Microcells	Average (10-15 m2)	
			Organic	High (>15 m2)	
Transit	- Illumination/visual comfort - Paths recognisability/stream - Usability/signage - Safety/equipment - Acoustic comfort/acoustic barriers	- Low (0 - 500 W)	Crystalline silicon	Low (<10 m2)	- Coverings - Wings - Shelters - Tectonics
			Thin film	Low (<10 m2)	
			Nanocrystalline	Low (<10 m2)	
			Quantum dots	Low (<10 m2)	
			Multijunction	Low (<10 m2)	
			Superlattices	Low (<10 m2)	
			Microcells	Low (<10 m2)	
			Organic	Average (10-15 m2)	

spaces as classified in the Building Urban Rule (RUE 2006) of the municipalities in the Region Emilia Romagna (Italy): *Waiting, Socialization, Transit, Recreation, Events, Representation, Relax, Trade, Filter* and *Technical Management*. Considering the different typologies of the prevailing uses identified, those concerning *Waiting, Socialization* and *Transit* are analyzed. Such a selection has been made in order to offer a minimum-example scenery of the features of functional/needing compatibility (*Waiting, Socialization*) and diversification (*Transit*) shown by the widest and the most implementable records. The specific uses are linked with the connected prevailing needs, mediated by the studies related to the open spaces (Dessì, 2007) and the outdoor environmental comfort (ITACA Protocol, 2004). The uses and the connected needs find spatial explanation in the elements of micro-landscape design composing the urban open space (Valente, 2010). At the same time this can show the usable surfaces for the implant of the productive PV technologies and then indicate the location of the interventions.
Subsequently, the related energy requirements are analyzed, illustrated by the Tables of "Guide of Design" elaborated by IEA (International Energy Agency) for the application of the photovoltaic technologies to the non-building design (Foglia, Valente, 2011). Ranges of values are distinct as follows:

Low energy requirement (0. 500 W);
Average energy requirement (500. 1.000 W);
High energy requirement (1.000. 10.000 W).

In addition to this, the attention is focused on the applicable PV technologies, analyzed on the basis of the extension of the surface necessary to produce a kWp. Such data – found in the 2005 *report "The photovoltaic technology, state of the art and potentiality of its use in the production processes"* made by CETA (Centre of Theoretical and Applied Ecology) and by Science Park AREA – are classified according to dimensional ranges:

Surface of a reduced production (< 10 m2);
Surface of an average production (10-15 m2);
Surface of a high production (> 15 m2).

In the last section (table 4), the layout of a synthesis model is introduced, aiming at the intersection of the data related to the performing aspects of the PV technologies, declined on the basis of the applicability and potential compatibility, with the specific features of autonomous performance intensity spaces. Here, four production technologies have been analyzed, selected on the basis of the three photovoltaic generations of affiliation and on the basis of the diversification of the proposed technological approaches. The systematization of data is organized in a hierarchical structure, according to macro-categories. In the "passport" category, different technologies are filed on the basis of the status of the development process (in production, in experimentation). It has been chosen not to limit the records to the actual market supply, but to extend it to the most recent experimentation in progress, in order to give a wide reference that is both a support and a stimulus to the designer. In the "typology" category, the photovoltaic generation of affiliation and the specific typology of the module are considered, according to the indications given by the GSE: rigid, flexible and special. In the "production" category, the potential production is analyzed according to the parameters of the surface of the production required, the (specific, non-specific) orientation and the productive skills according to the different ways of (direct,

Table 4 – Relations between PV technologies and autonomous performance intensity spaces features.

PV technologies	Passport		Typologies		Energy production				Applicability				SIPA
	Developer, year	Status	Generations	PV Modules	Performance	Required productive surface (1 kWp)	Orentation	Solar radiation	*Micro-landscape design* components	Potential Integration	Customization	Cautions/ interaction users	Potential compatibility
Crystalline silicon Monocrystalline *_Sharp*	Sharp, 1981	In production	First	Rigid Solar Panel	18%	Low (<10 m2)	Specific	Direct	Shelters Objects	Partial	No	Yes	- Wide usability - Uses - Energy self-sufficiency - Reversibility - IT
Amorphous silicon thin film (aSi) on substrate*_Sharp*	Sharp, 2006	In production	Second	Flexible substrates	9%	High (>15 m2)	Nonspecific	Direct Diffuse	Coverings Wings Shelters Objects	Total	Yes	No	- Flexibility - Integration - Wide usability - Uses - Energy self-sufficiency - Reversibility - Environmental Comfort - Psycho-physic Comfort - IT
Spherical microsolar cells_Sphelar	Kyosemi Corporation, 2010	In testing	Third	Flexible substrates	19%	Average (10-15 m2)	Nonspecific	Direct	Coverings Wings Shelters Objects Tectonics	Total	Yes	No	- Flexibility - Integration - Wide usability - Uses - Energy self-sufficiency - Reversibility - Environmental Comfort - Psycho-physic Comfort - IT - Sensibility - Interactivity
Nanocrystalline silicon paint_ *Photon Inside*	CNR Bologna, 2006	In testing In production	Third	Special	6-8%	High (>15 m2)	Nonspecific	Direct Diffuse	Coverings Wings Shelters Objects Tectonics	Total	Yes	No	- Flexibility - Integration - Wide usability - Uses - Energy self-sufficiency - Reversibility - Environmental Comfort - Psycho-physic Comfort - IT - Sensibility

diffused) solar radiation. Concerning the "applicability" category, this analysis considers as descriptive parameters the applicability of the PV technology within the micro-landscape design above defined and the features of (total, partial) potential integration, according to the indications given by the GSE. Moreover, this study considers the parameter of the "customization"– that is the design flexibility and the possibility to suit the PV module to the needs required by the specific application *in situ* - and the parameter of the "precautions of users' interaction", which describes the technological requirement for a safe use of the module.

The last category concerns the potential compatibility with the specific features (Foglia, Valente, 2011) of the *autonomous performance intensity spaces,* here called "SIPA". In this section, we show the potential suitability and the attitude of the solutions analyzed to be integrated in the interventions of rehabilitation for the new urban open spaces, according to the logics of compatibility and non-interference.

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Energy in Architecture
Climate responsive design and the wisdom of Traditional Architecture

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Keywords: sustainability, energy efficiency, climate responsive design

Abstract

Thou the European Commission defined a strategy necessary to achieve the goal of a competitive sustainable and safe energy for the European Countries, lifestyle of western societies led to an increase in the consumption of primary energy, a future of low carbon dioxide emissions is an effective solution to support both economic development and the international energy situation. In the last years we have witnessed an increase concern for environmental impacts of building and for the quality of internal environment, this led to the raise of interest in "green buildings" and in climate responsive design. In order not to have discomfort indoor, to reduce energy consumption, to minimize pollution, bioclimatic design should be considered. Climate responsive design is part of an environmental approach to building development called ecological sustainable design (ESD), based on the understanding of the climate parameters which may be influential in the design process, id est: temperature, humidity, wind, vegetation, light, related to the geographical position. Looking carefully at traditional architecture all these aspect, or at least most of these, can be recognized in the wisdom of traditional construction practice. Traditional architectural solutions, thanks tended to maximize the use of energy contributions, both in terms of solar radiation and of natural ventilation provided by the external environment, and at the same time, to ensure proper shielding of windows.

The problem of sustainability in architecture can be approached from different points of view. Often the problem of energy consumption is analyzed with reference to the ex-novo design, but it is important to shift the focus on to how to apply the principles of sustainability to existing buildings, that is, to turns the attention to the issue of upgrading the energy efficiency and improving the performance of the building. Brutally "sustainability has been defined as the extent to which progress and development should meet the need of the present without compromising the ability of future generations to meet their own needs" [1].

Such a definition leaves plenty of room for interpretation of the readers. Therefore, probably, must be detailed and specified. To begin with, the term sustainability can be applied to many fields.

To better define the subject is still necessary to understand the basic principles that make a building sustainable, explore the concept of climate responsive design, and then moving to

1. J. Steele, *Sustainable architecture: principles, paradigms, and case studies* (New York: McGraw-Hill Inc, 1997).

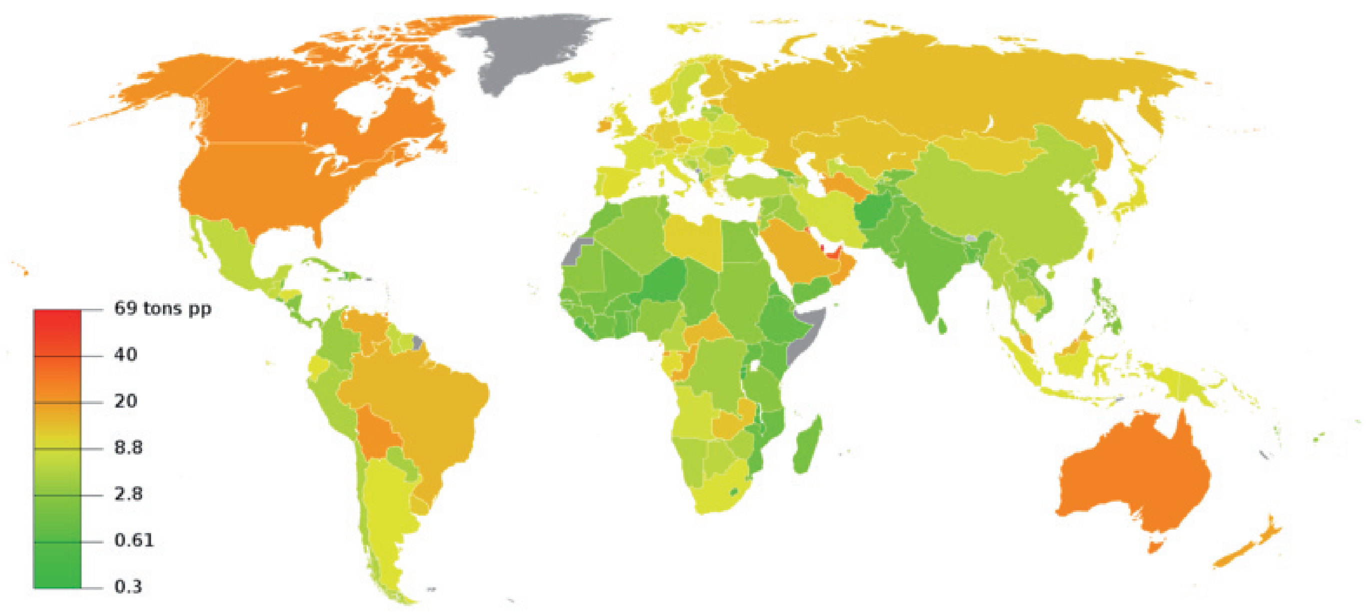


Figure 1 – CO_2 Emissions Distribution levels per Capita, World Population.

how these concepts can be applied to the present case.
"In Europe, 50% of material resources taken from nature are building-related, over 50% of national waste production comes from the building sector, and also 40% of energy consumption is building-related".[2 3] The European Commission defined a strategy necessary to achieve the goal of a competitive sustainable and safe energy for the European Countries, through a document that identifies priority actions for the next 10 years, by building an energy system more efficient, a market at competitive prices, energy supplies more secure, etc..
In addition, the International Energy Agency points out, in its report on the energetic perspectives, that the revolution hoped for a long time to respond to the issues related to climate change is actually a process already in progress.
A future of low carbon dioxide emissions is an effective solution to support both economic development and the international energy situation. In Italy, however, investment in low-carbon technology sector, despite a good growth rate, are unbalanced in favour of projects for power generation, while have almost zero shares for technological innovation. In our country it is necessary to identify policies and tools to enable a technology growth. The percentage composition of demand by source, confirms the specificity of Italy, in comparison with the average of the 27 countries of the European Union, concerning greater use of oil and gas, electricity import, small contribution of solid fuels 7% of primary energy consumption, and the non-use of nuclear power.

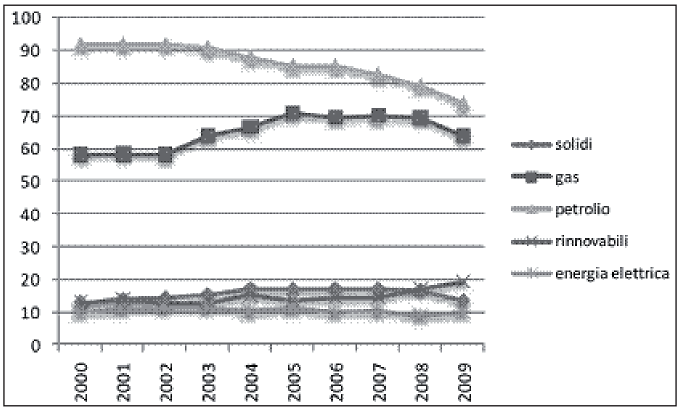


Figure 2 – Energy consumption by source. Years 2000-2009. Source: ENEA based on MSE data. Years 2000-2009. ENEA, "Rapporto Energia e Ambiente 2009".

2. D. Anink, C. Boonstra, J. Mak, *Handbook of sustainable building: an environmental preference method for selection of materials for use in construction and refurbishment* (UK: James and James, 1996).

3. M. AboulNaga, K. Al-Sallal, R. El Diasty, "The impact of city urban patterns on building energy consumption in hot climates: Al-Ain city as a case study," in *Proceedings of ISES Solar World Congress*, (S. Korea: Taejon 1997): 170–81.

The *Rapporto Energia e Ambiente* 2009 by ENEA on energy consumption in end-use sectors of energy shows:
- a small but significant decline in consumption in the transport sector (-1.8%);
- a variation of opposite sign in the Civil sector (+3.5%) related to climate variability (gas +5%, electricity to +3%, and renewable +9%);
- a significant drop in consumption of "industry (-20%) in agreement with the sharp drop in industrial production (-13.3%).

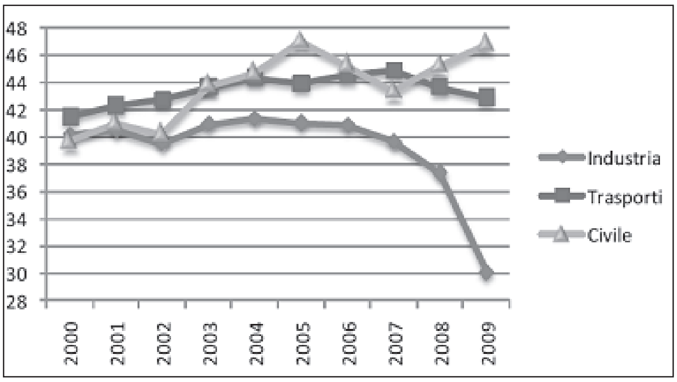


Figure 3 – Final energy consumption by sector. Source: ENEA on MSE data. ENEA, "Rapporto Energia e Ambiente2009".

As noted in the chart above, the domestic sector, unlike the others, in recent years has had a growing trend in terms of energy consumption. To act in the domestic sector is therefore important.
Furthermore, through simple measures, and the direct involvement of the population, it is possible to act on a large scale, a necessary condition to make the intervention effective. ENEA scenarios show how, in the domestic sector, a massive use of more efficient technologies will provide for reductions in fuel consumption by up to 12% already in the year 2020, about 4 Mtoe less than the evolving trend (according with the draft of the *Piano straordinario per l' Efficienza e il Risparmio Energetico*, of March 2010). In the long run the reduction compared to the reference scenario may further increase, up to 29% (of the sector consumption) in 2050. These results are obtained primarily through efficiency improvement of the Italian high-tech sector for air conditioning (winter and summer) and production of hot water.
Although in recent years progresses have been made in this direction, the scenarios show that there are still plenty of room for improvement.For example greater use of high-efficiency condensing boilers, high-performance heat pumps and air conditioners, may guarantee to reduce consumption by about 3 Mtoe within 2020. Energy use for domestic hot water and kitchen use, are more or less the same, while electricity use is growing fast, (mainly because of the standard comfort that has been changing, and an increasing consump-

tion of energy for summer cooling and dehumidification can be registered).

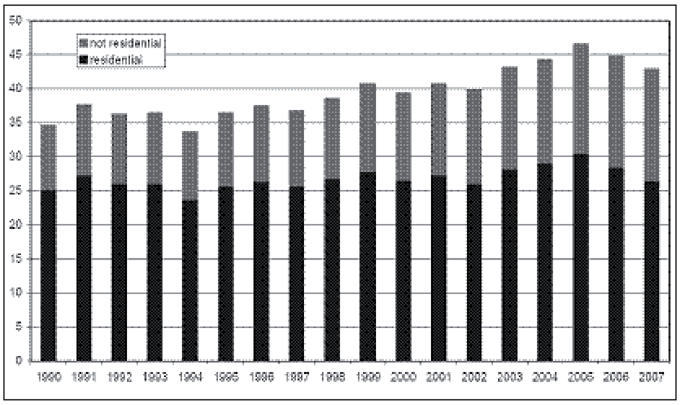


Figure 4 – Energy and use in Italian buildings since 1990. Grey: non residential, black: residential. Source: M. Zinzi, G. Fasano, M. Citterio, Impact, compliance and control of legislation in Italy, ENEA, Brussel Sptember, 2009.

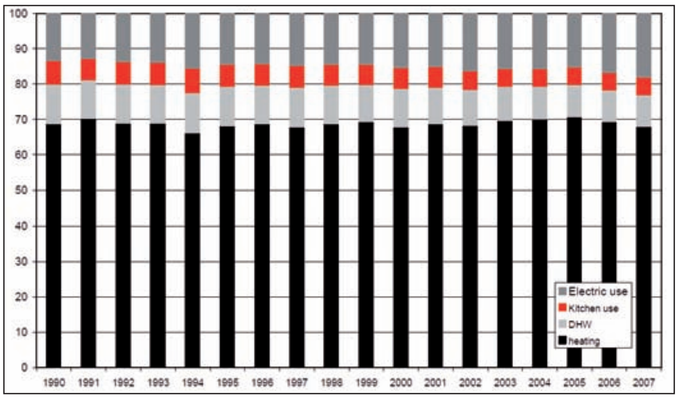
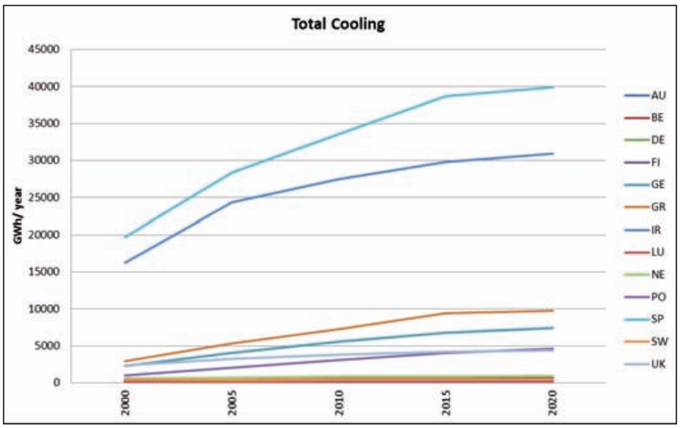


Figure 5 – Percentage Energy uses in residential sector per typology of Energy use. Source: Rapporto Energia e Ambiente ENEA 2008.

The lifestyle of western societies led to an increase in the consumption of primary energy needed to cool the buildings, with enormous impact on the environment. In particular, Mediterranean countries had a significant increase in energy consumption in summer due mainly to the use of air conditioners.

In Europe, Italy is leading both for the number of square meters provided that in the growth forecasts, followed by Spain. According to studies EECCAC[4] demand for summer cooling will become up to four times higher by 2020. To deal with this question common to many European countries, the European Community in 2005 launched the "Keep Cool" programme with the aim of illustrating the features and benefits of sustainable cooling systems, to propose regulatory changes and to encourage economic incentives.

While in the commercial sector the major saving's opportunities are offered by the improvement of energy management systems, in the residential sector, next to the update of heating/cooling systems, the crucial problem is the choice of a correct solution for the building envelope.



TOTAL COOLING - GWH/YEAR					
Country	Year				
	2000	2005	2010	2015	2020
AU	469	549	633	689	707
BE	274	422	559	681	708
DE	71	122	180	232	260
FI	206	210	229	242	246
FR	5010	8213	10954	13240	14071
GE	2286	4012	5542	6785	7415
GR	2909	5365	7269	9399	9734
IR	127	180	222	252	264
IT	16209	24336	27445	29795	30890
LU	11	18	23	27	29
NE	605	690	797	869	892
PO	1020	2049	3072	4039	4621
SP	19689	28333	33573	38719	39915
SW	391	378	403	421	425
UK	2359	3227	3826	4241	4401
TOTAL	51636	78104	94727	109631	114578

Figure 6 – Cooling only energy consumption by country and year.

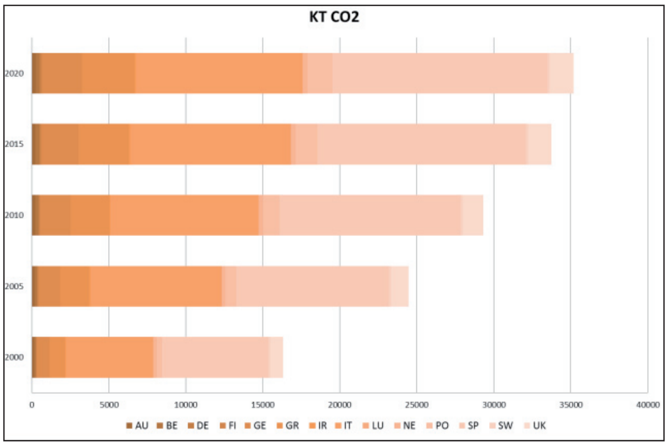
That's why this research work analyses how act cleaver to reduce consumption, taking into account the boundary conditions, i.e climatic conditions and regulatory framework.

EPIQR (energy performance, indoor environment quality and analysis of refurbishment cost) defines retrofit actions as those ones which upgrade and improve the building (or building element) to a higher standard than was originally planned for the apartment building.

Recently the main solution to gain the standards of comfort indoor has been the use of heating and cooling systems which led to the so called "universal climate"; it means that,

4. J. Adnot et al., *Energy Efficiency and Certification of Central Air Conditioners – Final report*, (2003): 16.

whatever the climate outside, it is possible to have always the same climate condition indoor (about 25°C and 50% of humidity) almost everywhere, without concern for place.



KT CO_2					
Country	Year				
	2000	2005	2010	2015	2020
AU	164	192	221	241	248
BE	96	148	196	238	248
DE	25	43	63	81	91
FI	72	73	80	85	86
FR	1754	2874	3834	4634	4925
GE	800	1404	1940	2375	2595
GR	1018	1878	2544	3289	3407
IR	44	63	78	88	93
IT	5673	8518	9606	10428	10812
LU	4	6	8	9	10
NE	212	242	279	304	312
PO	357	717	1075	1414	1618
SP	6891	9916	11751	13552	13970
SW	137	132	141	148	149
UK	826	1129	1339	1484	1540
TOTAL	18073	27335	33155	38370	40104

Figure 7 – Numerical results about CO2 emissions due to cooling in Europe.

But this way of design is absolutely improper from an energetic point of view, designers should respect the natural climate and should consider more the historically used strategies for environmental control, given a particular building function, design and context.
Thankfully in the last years we have witnessed an increase concern for environmental impacts of building and for the quality of internal environment, this has led to the raise of interest in "green buildings" and in climate responsive design.
In order not to have discomfort indoor, to reduce energy consumption, to minimize pollution, bioclimatic design should be considered.
Climate responsive design is part of an environmental approach to building development called ecological sustainable design (ESD), it is based on "the way buildings form and structure moderates the climates for human goods and well-being"[5]. The interaction between a building and the external environment depends mainly on the climate:

- cold climate requires a defensive strategy;
- buildings in warm climate, instead, have to filter the climate in a multitude of ways.

In order to optimize the relationship between the site, climate and building, climate responsive design requires both analytical and synthesis skills of the architects.
The main principle at the base of the climate responsive design is the understanding of the climate parameters which may be influential in the design process, id est: temperature, humidity, wind, vegetation, light, related to the geographical position.
As R. Hyde defines Climate Responsive Design in his book, it is possible to identify three main kind of condition:

- global condition (created by the dominant geographical features of land, sea, sun and air.);
- local condition (dependent on dominant features of water, topography, vegetation and built environment);
- site condition and building context (interaction of local condition and the building).

The problem is that the weather is quite difficult to predict, so designers have to use a "patter", a methodology, in order to design in an appropriate way.
The problem becomes to "adapt" design objectives with what the climate factor made necessary. Even if it may sound simple, the application of all these strategies is not!
There are a lot of parameters that need to be taken into consideration.
The first ones are site and building context, it means that it's necessary to understand the climate (micro and macroclimate) and the site potentiality, these led to the understanding of the building response to the climate (as it was in the vernacular architecture were climate, site and elements of the building generate the building form).
A strategy, which can be split in two levels, may be followed:
Level 1: relate the general building and the environmental control;
Level 2: analyse specific aspect of the building.
A really careful analysis of the site is important, the factors affected by the site are:

- temperatures, that can be modify by vegetation or topography;
- solar radiation, in fact shading from vegetation or other buildings can affect solar access to the building (= heating and light);
- airflow, modified by ground condition, with velocity grow-

5. R. Hyde, *Climate Responsive Design- A study of building in moderate and hot humid climate* (London: Spon Press, 2000).

ing with high, elevation and orientation are key factors;
- evaporative cooling, affected by topography and vegetation.

Another key aspect in the microclimate is the context, the rural one is represented by the prevalence of natural feature compared to the manmade, vegetation, proximity to ocean, sea, hills (that can provide shadows) are all aspects important in the design process, and are also aspects to consider in retrofitting actions.

In the suburban context, instead, the main issue can be the provision of airflow for ventilation, the higher density of the building, the less access to the building for the wind floe. In the urban context density of building is very high, this led to the so called *urban climate*, that has many different characteristic from the macroclimate of the area.

The fabric and spatial extent of urban context affects temperature, humidity, wind, and solar radiation, at the macroscale, but even at the microscale, land coverage, high of buildings, and orientation.

Microclimate produces the so called "microscale effects" for example the creation of shade in urban open spaces, provides the ideal environment for outside living, while the macroclimate produces "macroscale effects" one of the main effects is the so called "heat island" i.e. nocturnal elevation in temperatures as compared to the rural temperature.

The "island" extends both vertically and horizontally. To take advantage of the microclimate conditions careful considerations on orientation, airflow, environmental factor, is required, it means a careful site investigation.

Site investigation includes a collection of data on microclimate condition of the site, in order to use the data for an environmental analysis, and finally it led to conceive a climate responsive project. Looking carefully at traditional architecture all these aspect, or at least most of these, can be recognized in the wisdom of traditional construction practice.

Figure 8 – Palacio de la Ciudadela a Montevideo, Arch. Sichero 1958. Web site: http://www.skyscrapercity.com/

Geographically, Italy lies in the temperate zone. Because of the considerable length of the peninsula, there is a variation between the climate of the north, so close to the centre of Europe, and that of the south, surrounded by the Mediterranean sea.

The weather conditions in a particular region will affect the life, and thus the architecture, which is in many cases a mirror of the needs and priorities of the life of people.

Traditional local architectures, also known as vernacular architectures, differentiated by latitude, are an example of harmonizing buildings with nature its features. This also applies to the architecture of the Mediterranean region, which, as said before, is characterized by very specific climatic conditions, presenting sometimes humid summers, not very cold winters but rainy, thanks to the strong mitigating effect of the sea. The Mediterranean traditional architecture evolved to produce buildings that would be in harmony with the harsh climates of its various regions.

Figure 9 – Grid to natural ventilation on windows and doors. From T. Contri "Antoni Gaudì, l'Architetture – I protagonisti" La Biblioteca di repubblica – l'Espresso April 2007; p. 68.

To better understand the properties of modern building envelopes in the Mediterranean area is necessary, first, to analyse the properties of traditional enclosures. But which definitions can be given to the Mediterranean architecture? And which characteristics distinguish it?

Actually, building typologies are few and simple, as they have always complied with the territory according to simple paths of rationality and geometry. Architecture adapted to the uneven nature of the ground, repeating row houses in linear settlements along the sea coasts, or along main roads of the countryside, or expressed in isolated buildings that identify scenic viewpoints.

If you consider that the architectural culture has accepted the challenge of energy conservation as a driver of development and as a commitment to safeguarding the environment, we must not forget that Mediterranean architecture is, from this point of view, an effective model, tested for centuries to address these issues.

In fact, traditional architectural solutions, thanks to the aforementioned climate, tended to maximize the use of energy contributions, both in terms of solar radiation and of natural ventilation provided by the external environment, and at the same time, to ensure proper shielding of windows.

"While the traditional Mediterranean residences provided shelter from extreme climatic conditions with various methods without consuming a lot of energy, the mechanization and the internationalisation caused the rejection of the tried methods and the lack of knowledge of building physics stripped the building structure from its basic operations and they left the building in the mercy of climate."[6]

Solar radiation has always been regarded by humans as a principal source of energy, enough to significantly influence the traditional building techniques.

The Mediterranean architecture has been characterized, during different historical periods, by solutions that had a relatively high number of openings, simple or complex, sometimes large, but always with shading systems. Due to the geometry of the openings, properly shielded, the sun could hardly penetrate and affect the interior surfaces for a major fraction of the day during summer.

With a proper dimensioning of the openings of two important objectives are achieved in the design of the traditional shells: the onset of natural ventilation and, simultaneously, the filtering of solar radiation.

Open or semi-open structures, such as terraces, loggias, balconies and porches, have helped to enrich the Mediterranean architecture and complete architecturally the tradi-

6. Despina K. Serghides, "The Wisdom of Mediterranean Traditional Architecture versus Contemporary Architecture – The Energy Challenge," *The Open Construction and Building Technology Journal*, no. 4 (2010): 29–38.

tional building.

But vernacular architecture in the Mediterranean climate has features far more extensive and complex, some basic points are:

- The location of the building and its orientation, chosen in such a way as to guarantee the ability to operate a natural cooling provided by the cross ventilation of rooms.
- The presence of massive walls capable of providing significant inertial characteristics of the building envelope.
- The use of building materials with low thermal conductivity that can reduce the total amount of energy transmitted through the outside walls
- The optimization of the size and location of openings through side walls and roof, both with regard to heat transfer and day light;

Men have gradually learned that many aspects participate in the operation and function of the thermal regulating mechanism such as: topography, construction it means morphology, materials and even the layout and use of internal spaces.

Figure 10 – Trulli in Alberobello – Puglia (Italy) and a "dammuso" in Pantelleria (Italy).

Site was important too, the presence of vegetation, of water, or simply of other construction affects thermal performance of the building.

The more they learned that in hot regions ventilation is necessary for comfort and hygiene; even in warm summer days when the building interior is colder than the outdoor, that's why in traditional buildings a great deal of attention was given to ventilation especially to the pre-treatment of air.

Other architectural aspects and structural elements which exist in the old houses that reflect the traditional wisdom are solarium and the courtyard.

"In the countries of Mediterranean and the regions with hot climates, in which the sun is desirable in the winter while in the summertime the cooling and ventilation is necessary, the solarium and the courtyard are indispensable solar features of houses, unique elements of local architecture.

Both components, although outdoor, open spaces of building, they are focal elements around which the various activities of all other spaces, are composed and synthesised whether the house is found in the plains or in the mountains, in the village or in the city.

They form the heart of the dwelling spatially, socially and environmentally.

They are important architectural characteristics and they show the instinctive approach of passive solar design and planning that contributed in the climatic configuration of the Mediterranean house.

Their form evolved naturally from the climatic conditions, the needs of the family and the social structure of community. Always adjoining each other they act upon as transit spaces and connect and unite the exterior with the internal building layout.

They are extensions of the house outwards and simultaneously extensions of the exterior spaces indoors."[7]

So we can say that the elements and architectural features, which are now the basis of a sustainable design, such as solar greenhouses, ventilated facades, or massive wall systems, are essentially applications derived from the study of compositional aspects of vernacular architecture and its characters.

Through a process of trial and error our predecessors have found ways to cope with the extremes of climate. The influence of western cultures is, however, all pervading.

The trend towards an internationalized style of building could result in a reduction in the traditional solutions, which have served several cultures well for many centuries.

Certainly, the architecture of the Mediterranean provides an interesting and alternative points of analysis and evaluation of construction technology comparing the criteria of simplicity with those of more advanced technology, those based on tradition with those addressed in the trial, makes valid the principles of insulation and thermal inertia, giving the designer a variety of solutions rational, reliable and effective in the long run.

It seems evident that, for a correct design of a building, it is

7. *Ibid*.

not possible irrespective of an analysis of the climate and of evolutionary parameters of the buildings in that area.

"The selection of the appropriate design strategies, derived from a bioclimatic analysis, compatible with each other and other architectural aspects, could considerably reduce the cost of a building by minimizing, the mechanical means for cooling and heating".[8]

In particular those arrangements typical of Mediterranean houses (natural ventilation, thermal insulation, solar control) should be re-considered in building practice to reduce energy consumption for heating and cooling.

8. M. Santamouris, "Natural cooling techniques," in *Proceedings Conference workshop on Passive Cooling* (Ispra: Italy, 1990).

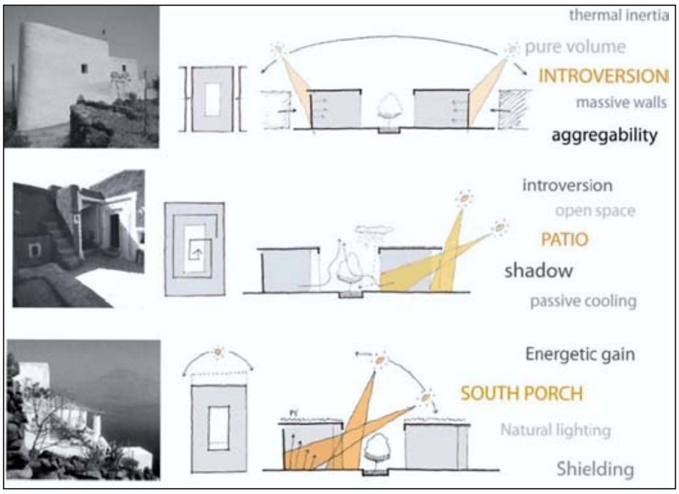


Figure 11 – MED in Italy - The Sustainable Mediterranean House, Tradizione Mediterranea, web site: http://www.medinitaly.eu/it/progetto_mediterranea.

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Energy aspects of urban planning. The urban heat island effect[1]

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Abstract

The research aims to analyze the tight relationship between the conformation of the city and the urban climate. The "heat island" phenomenon, typical of big urban centers, has a great impact on external temperatures, causing their increase compared to the surrounding rural areas. The study points out that the main factors responsible for such phenomenon are: the high percentage of built-up areas, the considerable presence of impermeable areas at the expense of the permeable ones, particularly green areas, the introduction of artificial heat in the atmosphere, generated by the combustion of hydrocarbon for transportations and domestic uses. Moreover a pivotal role is played by the urban canyons (which are generated by the geometrical configuration of the spaces among the buildings), the morphology of the urban tissue and the radiation properties (such as albedo and emissivity) of the surfaces. These considerations are confirmed by the results obtained in the experimentation conducted, in the city of Bari. Actually the results demonstrate that light color surfaces, with a higher level of albedo and wider green areas in some neighborhoods of Bari leads to a drop in temperatures of the external air, even of some degree days in the summertime.

The experimentation conducted outlines a guideline which considers the energy aspects of urban planning, thanks also to the possibility of realizing simulations by means of some particular software (suitable for the study of surfaces-vegetation-air interactions in the urban context) and to define different scenarios of project planning.

1. Introduction

It is recognize by several studies that the concentration of people and buildings in the city, in restricted portions of territory, causes a different characterization of the urban climate from that of the surrounding rural areas (figure 1). This generally concerns the diverse weather variables, especially the range of temperatures. It is the so-called *Urban Heat Island Effect* which depends on how the city is built, the materials employed, how the streets and buildings are arranged, as well as the level of heat generated by the combustion of hydrocarbon for the transportations and domestic uses. The geometry of streets and buildings, their shape and height (canyon effect) entrap the heat in the façade of the buildings and the streets, before releasing it in the atmosphere (figure 2).

The most evident effect of the "urban heat island" on temperatures appears during the night, since the green areas get cold rapidly, while the artificial elements remain warm longer.

The characteristics of the materials employed for the pavements, the façades and the shingles of the buildings, are decisive for the warming of urban areas. The albedo, which is the capacity of materials to reflect the sunlight (in shortwave) is particularly crucial, since it has a high impact on the energy balance and the conditions of thermal comfort. The thermo-hygrometric wellbeing depends both on objective (microclimate of the area) and subjective (physical, biological and psychological conditions of the inhabitants) features. But the most effective index to evaluate the thermal comfort is the PMV (Predicted Mean Vote) by P. O. Fanger external modified (Jendritzky, Maarouf, Staiger, 2001) which takes in consideration environmental parameters (temperature, humidity, air speed, radiation, MRT) as well as the metabolic activity and clothes.

During the last years, the consequences of the Urban Heat Island have been emphasized by the global warming, so that during the summer, in the cities, it is possible to reach very high temperatures, which can seriously affect the public health. For the first time in the world, citizens, entrepreneurs, administrators, are considering the environmental consequences of the choices that, till today, have followed only the criterion of the economical disposability.

The urban morphology, in terms of external microclimate, plays a pivotal role and it is important to specify that when we speak about urban morphology we mean the tridimensional shape of a body of buildings and the urban spaces defined by it.

The analytical evaluation of the microclimate of a urban fabric has been long since object of study of the urban microclimatology (Yoshino, 1975; Lowry, 1977; Oke, 2006) and it is a complex issue, since there are almost unlimited combinations of different climate contexts, urban geometries, climate variables and purposes of the projects.

1. This paper is the result of a work conducted by both the authors. In particular Francesco Selicato wrote the paragraph 1, 2.1 and 3, while Tiziana Cardinale paragraph 2.2.

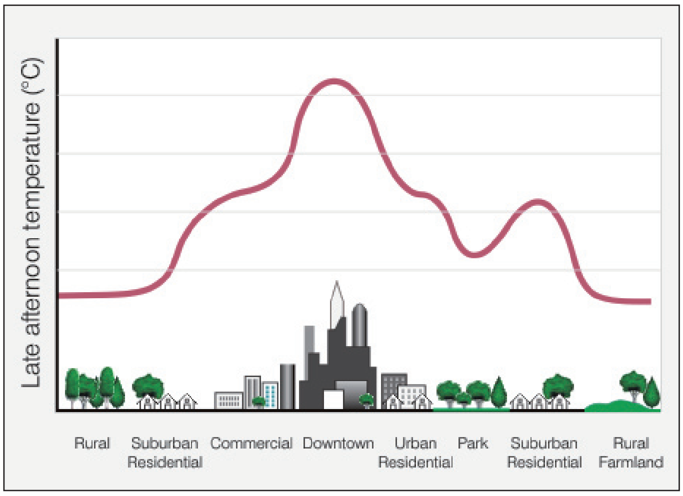


Figure 1a – The profile of the Urban Heat Island.

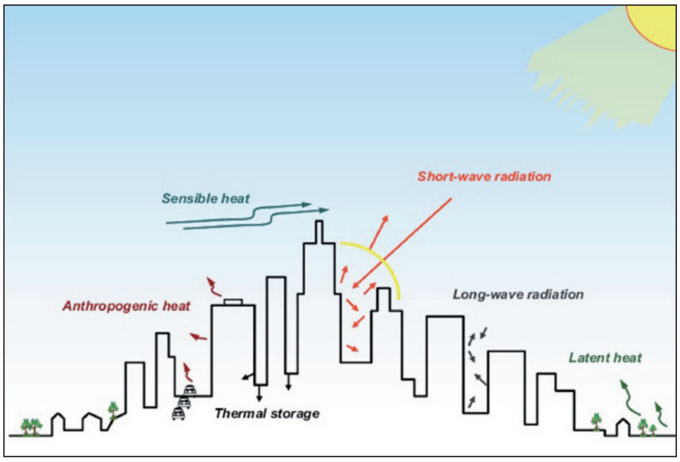


Figure 1b – Energy exchanges within the city.

The literature has identified a first classification, distinguishing the environment of the development of the heat island between rural and urban areas. Stewart (2007) and Oke (2006), two of the most expert in the field of the heat island phenomenon, explain that one-third of the studies produced during the last 30 years doesn't provide any qualitative or quantitative description of the sites, in order to distinguish them between rural or urban, while the other two-thirds focuses only on qualitative descriptions, without providing measurable criteria according to the environmental characteristics, such as the geometry of the area, exposure and shingles. The two researchers think that it is better to consider more technical and scientific models of the urban expansion and the different urban settlements with their morphology, taking account of thermal observations, as if it was possible to outline a sort of "energy signature" which does not focus only on a single building, but on blocks, districts, cities and regions.

2. An experimentation in the city of Bari

2.1 The importance of the phenomenon of the Urban Heat Island for the case study analyzed

The following work focuses, thanks also to the experimentation made by Bruse (2004) at the University of Mainz with the innovative ENVI-Met fluid dynamics software, on the identification of the heat island in the city of Bari, the climatic and morphological parameters which affect it and the requisites of thermal comfort in the surrounding environment. Therefore, the work at the beginning demonstrates the scientific basis of the phenomenon, then it considers the core issue of the identification and evaluation of the thermal comfort, and finally outlines a list of mitigation technologies and a guideline, in order to choose and evaluate proper solutions and procedures according to which develop the project planning, the recovery and restoration of the open-air areas.
Bari is characterized by a Mediterranean moderate worm climate, with a dry season in the summer. It is a typical example of the Italian East coast climate. Moreover, the sea, the lack of mountains and the East quadrant orientation are the three key elements which determine the peculiarities of the climate of Bari. In quantitative terms, the warming of the city of Bari is very high; actually, one and a half degree more can be registered during the spring and the summer, moreover the thermal amount of the daily-degrees is very high. Despite the mitigating effect of the sea, during the summer the intense warm days are increasing, reducing the number of pleasant days of the season.
The research starts with a comparison between the temperatures registered by the weather station of Bari-Airport and the weather station of Bari-city; the former is managed by the Italian Air Force and the latter by the Regional Agency for the Prevention and Protection of the Environment, ARPA-Puglia (figure 2). The data collected date back to 2010, since the weather station of ARPA provides validated data only for that year.
The first station is characterized by a rural zone, being located into an area with a very low presence of buildings, while the second station represents a urban zone, being located along the south seafront of Bari, in a highly built-up area.
It can be immediately noticed that the values of the variations of the temperature in the city are always positive compared with that of the airport, except for only three cases in which the values are null (Table1). The most remarkable variation can be noticed for the lowest temperatures with a ΔT of 2-3 °C, while for the medium and maximum temperatures the ΔT reaches 1-2 °C. The highest value of 3°C was registered during the summer period, in August (Figure 4). Also the maximum variations are greater for the lowest tem-

peratures, ΔT of 4-6 °C, while for the medium temperatures the variations fall to a ΔT of 2-3°C and to ΔT of 2-4 °C for the maximum temperatures. The results clearly show that the air warming is higher in the urban environment than in the rural environment, especially during the night, exactly when the lowest temperatures are registered. Therefore it can be confirmed that the phenomenon of the heat island becomes more relevant after the sunset.

Figure 2 – The location of the two weather stations of the city of Bari.

Table 1 – Monthly mean values of the lowest, medium and maximum temperatures at the Airport weather station, of the medium and maximum variations of these temperatures compared to that registered by the City weather station during 2010.

Month	Tmin (Aer) (°C)	Avarage ΔTmin (°C)	Max ΔTmin (°C)	Tmed (Aer) (°C)	Avarage ΔTmed (°C)	Max ΔTmed (°C)	Tmax (Aer.) (°C)	Avarage ΔT max (°C)	Max ΔT max (°C)
1	6	1	4	8	1	3	11	1	4
2	5	2	4	9	1	2	13	1	3
3	6	2	5	11	1	3	15	1	4
4	10	2	4	14	1	2	18	1	4
5	13	2	6	18	1	2	23	0	2
6	18	2	5	22	0	2	26	0	2
7	21	2	4	26	1	2	29	1	4
8	20	3	5	25	1	3	29	1	3
9	16	2	4	21	1	3	25	2	4
10	13	2	5	16	2	3	20	2	4
11	10	2	4	14	2	3	18	2	4
12	6	2	4	9	1	2	13	1	2

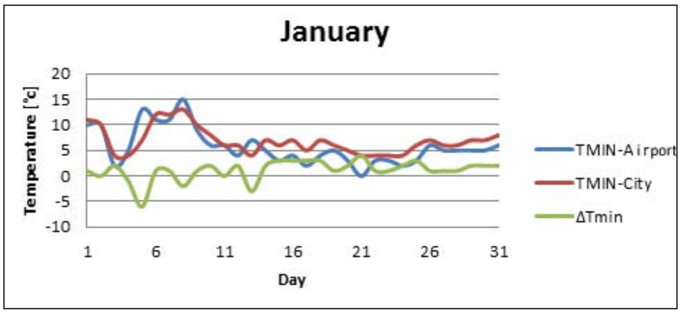


Figure 3 – Lowest temperatures in January registered by the weather stations of Bari City and Bari Airport and the differences between them.

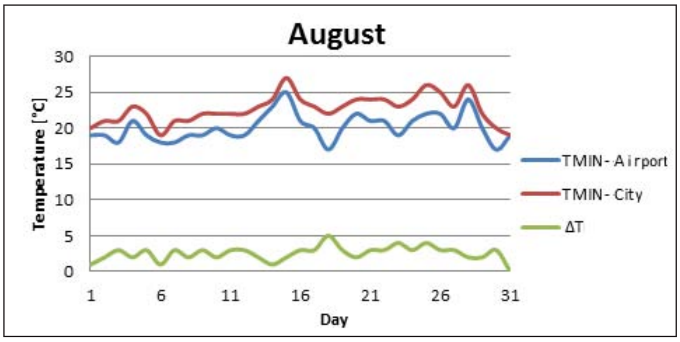


Figure 4 – Lowest temperatures in August, registered at the Weather station of Bari city and Bari airport, and the differences between them.

2.2 The influence of the urban shape in the identification of the heat island

The purpose of investigating the relationship between the heat island and the urban shape refers to the definition of the urban and morphological aspects which characterize the diverse parts of the city, aspects which correspond to different typologies of macro urban fabrics (Selicato).

After defining the classification, it was conducted a detailed simulation with the ENVI-Met software on some significant fabric-shape. The ENVI-Met software is based upon the Navier-Stokes equations and it is considered one of the most accurate in the simulation of the interactions surface-vegetation-air inside the urban environment.

The model allows to evaluate:

- The shortwave and long wave flows of radiation, considering the shading and the emissions of radiation from buildings and vegetation;
- The perspiration, the evaporation and the heat flow between the vegetation and the air, the temperatures of surfaces and walls for every point of the grid;
- The mixing of water and heat inside the soil system;
- The calculation of the bio meteorological parameters, like the mean radiant temperature and the PMV.

The software turned out to be particularly useful for other programs of energy simulation of dynamic type (Ecotect, Design Builder) in the field of the study of the urban micro climate. This is also demonstrated by the state-of the-art in relation to its application in the field of the determination of the heat island in different climatic situations. Lahme and Bruse (2003) conducted a comparative study between the simulation with the model and a campaign of experimental measures for a small park situated in the German city of Essen. Huttner et al. (2008) analyzed two scenarios for a residential district typical of many cities of Central Europe. Yu and Hien (2006) applied the model of heat island to an area characterized by a tropical climate (Singapore). Fahmya et al. (2010) as well focused on the micro climate in an area of mid-latitude (Cairo). Ali Toudert and Mayer (2007) analyzed the urban canyon in an area characterized by hot-dry subtropical climate (Ghardaia, Algeria) with different height-width relations (H/W) of the buildings and solar orientations.

The aim of the work is to evaluate the influence of certain parameters on the development of the heat island and on the wellbeing of the inhabitants of a urban area. Such as the percentage of the built-up areas, the vegetation and the impermeable grounds, the aspect ratio of the urban canyons, the type of urban fabric and the radiation properties (albedo, emissivity) of the surfaces.

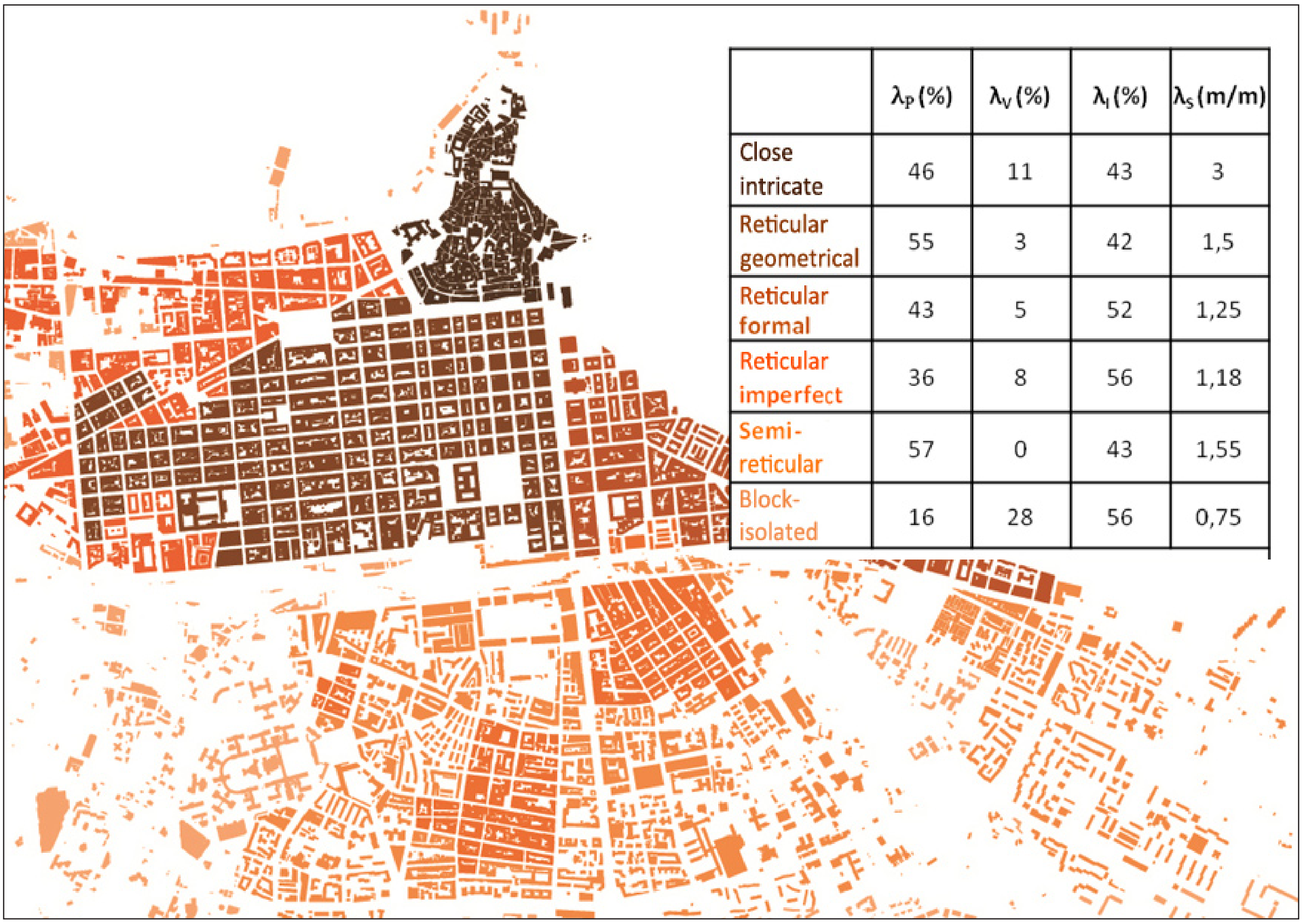
The calculation of the above parameters was realized for each different shape-fabric, in order to choose some areas to study (figure 8), and to find a correlation between urban shape and heat island (figure 5). All over the city there is a high presence of impermeable surfaces at the expense of the green ones. The plane area index, that is the ratio between the built-up plane area and the total plane area is around the 50%, except for the fabric divided in blocks, which is 16%. The aspect ratio (which is the ratio of the average height of the buildings to the width of the streets) is about 3 for the close intricate fabric, while it is about 0,75 for the fabric divided in blocks and 1,5 for the other kinds of shape-fabric.

Since the development of the phenomenon is very complicated we used, as previously said, the ENVI-Met software, but in a new and different way if compared to its employ in the previous studies. We created two files in which we collected all the data required for the simulation: a "Configuration" file and an "Input" file (Table 2).

The file "Input" includes all the geometrical descriptions and the location of the model. The values of the albedo for the asphalt road and pavements is 0.2 and 0.4, which correspond to almost black and dark gray, while for the façade of the buildings the value is 0.6, which represents a light-colored surfaces.

In the file "Configuration" are collected the meteorological data which, for the first simulation realized, correspond to the experimental data collected the 17th June 2010: the Initial Temperature Atmosphere of 23 °C registered at 6.00 AM, and the Wind Speed and Direction of 3.3 m/s and 45° relative to N clockwise (N-E).

in the areas protected from the direct sun radiation, while in the exposed areas the values reach +4, which corresponds to an intolerable heat (figure 7). These first quantitative analysis



	λ_P (%)	λ_V (%)	λ_I (%)	λ_S (m/m)
Close intricate	46	11	43	3
Reticular geometrical	55	3	42	1,5
Reticular formal	43	5	52	1,25
Reticular imperfect	36	8	56	1,18
Semi-reticular	57	0	43	1,55
Block-isolated	16	28	56	0,75

Figure 5 – Urban shape-fabric and morphological-climatic parameters for Bari city: [close intricate/reticular geometrical/reticular formal/reticular imperfect/semi-reticular/ block-divided]

λp= built-up plane area/total plane area

λv= vegetation plane area/ total plane area

λi= impermeable plane area/total plane area

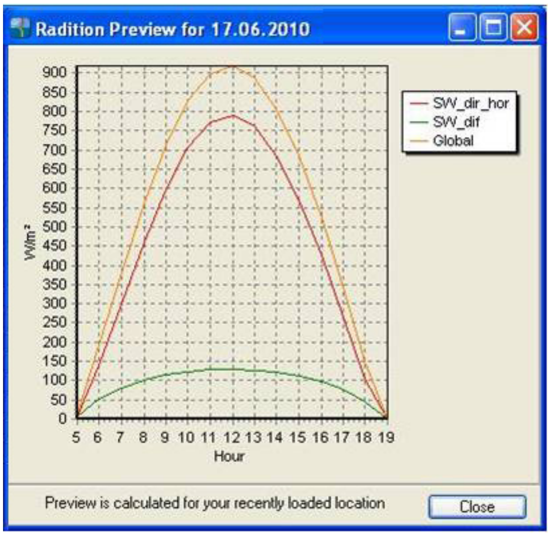
λs= aspect ratio of the urban canyons

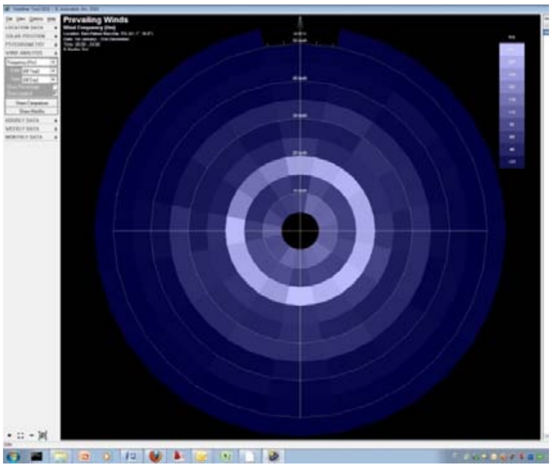
At the beginning, in order to understand the importance of the vegetation, the program ENVI-Met was employed for the microclimate forecast in a summer sunny day in the area of Piazza Garibaldi (figure 6), an urban area characterized by a high housing density with a public garden situated at the center of the urban square. The East sunny zones reach a temperature of 30°C, so that the high speed of the wind leads to a great quantity of warm air, with the following increase of the temperatures. The lowest temperatures, 27 °C, are registered inside the garden, because of the vegetation and also in the West zones, which are touched by a cooler air, thanks to the trees. The lower PMV values (between +1.5 and +2, which correspond to a tolerable heat) are registered only

shows that in order to increase the comfort, or better to say, in order to limit the discomfort during the warmest hours of the summer days it is essential to increase the areas protected from the direct sun radiation and covered by a dense vegetation. Therefore, the presence of different typologies of trees which produce a thick shading leads to the two above mentioned positive effects, contributing to a significant increase of the PMV.

Table 2 – File Input and File Configuration Solar Radiation and Wind Rose.

Altri Dati principali dell'INPUT file (Piazza Garibaldi.in)		
Surface of soils		
Code Name	Albedo	
Emissivity		
s Asphalt Road	0.20	0.90
p Pavement (Concrete)	0.40	0.90
Type of vegetation		
Code Name		
Parameter		
sk Tree 15 m very dense, distinct crown		
layer height, width, LAD, RAD		
Dati Principali del Configuration File (Piazza Garibaldi.cfg)		
MAIN-DATA --------------------------------		
Wind Speed in 10 m ab. Ground [m/s]	=3.3	
Wind Direction (0:N..90:E..180:S..270:W..)	=45	
Initial Temperature Atmosphere [K]	=296	
Specific Humidity in 2500 m [g Water/kg air]	=7	
Relative Humidity in 2m [%]	=60	
[TIMESTEPS] [BUILDING]__Building properties		
Inside Temperature [K]	=299	
Heat Transmission Walls [W/m²K]	=1.5	
Heat Transmission Roofs [W/m²K]	=3	
Albedo Walls	=0.6	
Albedo Roofs	=0.6	
[PMV]__Settings for PMV-Calculation		
Walking Speed (m/s)	=0.3	
Heattransfer resistance cloths	=0.5	





[in the table: Configuration file's Main data (Piazza Garibaldi); Other main INPUT file data (Piazza Garibaldi)].

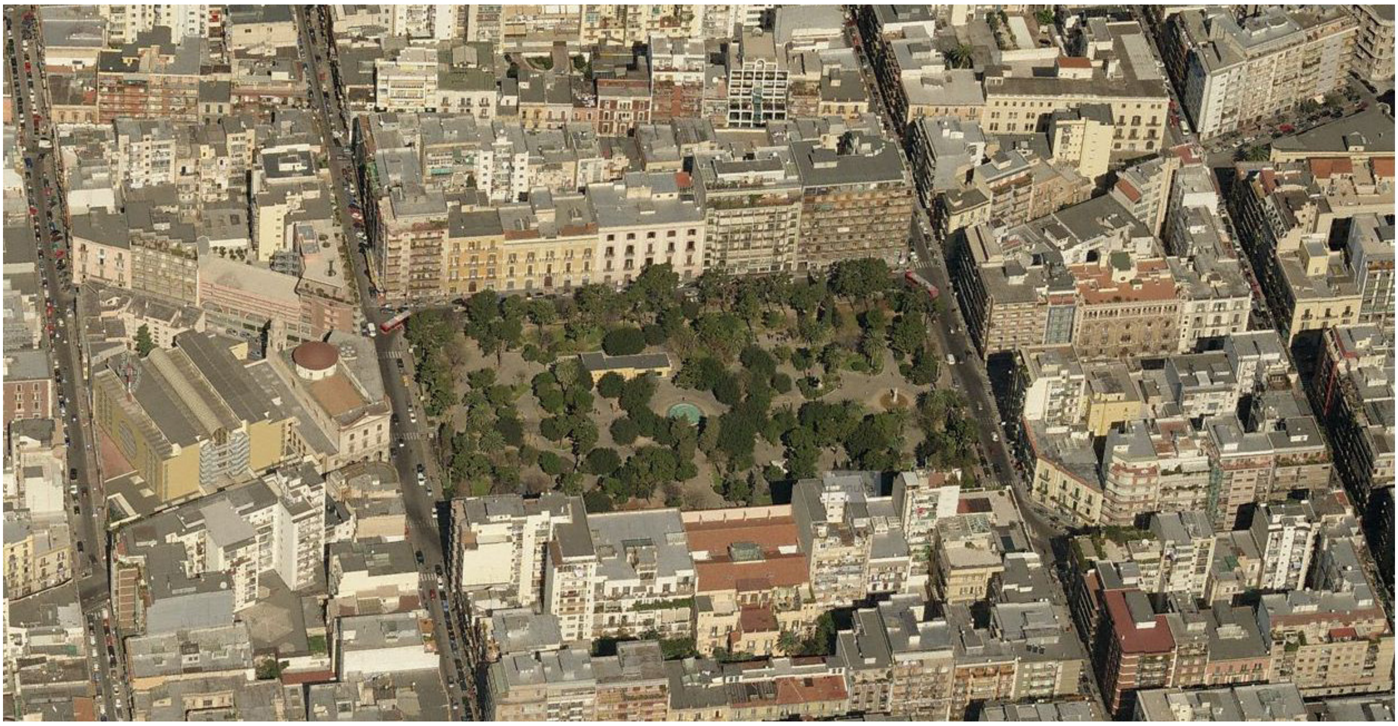


Figure 6 – The example simulation area in the city center of Bari: the garden of Piazza Garibaldi.

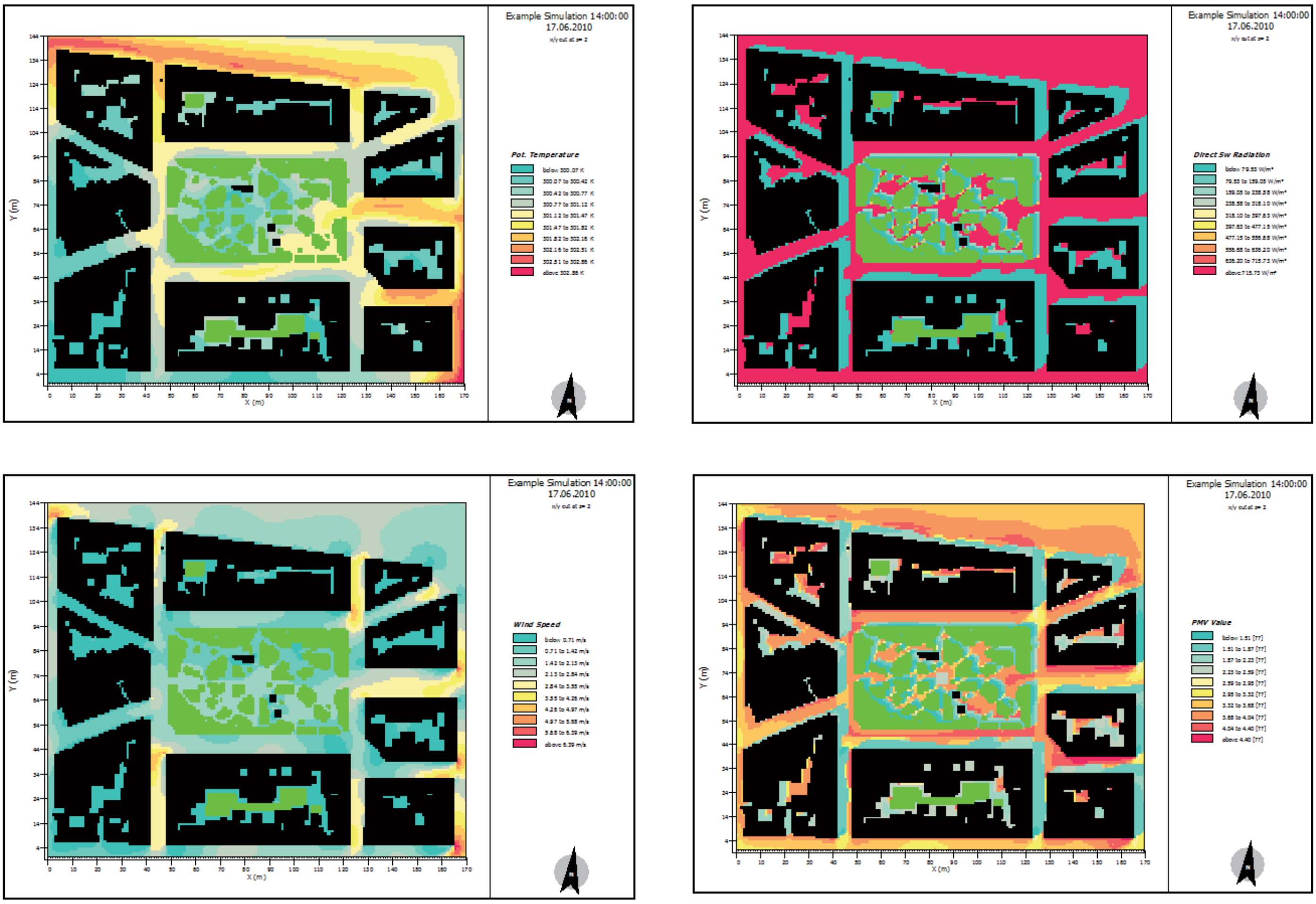


Figure 7 – Temperature, Direct Sun Radiation, Wind Speed, PMV Value at 2.00 PM in Piazza Garibaldi, Bari.

The values of the Aspect Ratio of the three selected areas (figure 8) are: 3, for the intricate and dense fabric of the Old Town; 1,5 for the reticular and geometrical fabric of the Murat area and finally 0,75 for the Japigia area, characterized by a fabric divided in blocks (figure 8).

The simulations are conducted in the same meteorological conditions of Piazza Garibaldi, but considering a lowest wind speed (0.5 m/s) and a random direction (North), since it appears from the wind rose that there isn't a predominant direction of the wind in the city of Bari. Actually, the absence of a predominant direction of the wind is a positive factor, because it facilitate the evaluation of the influence on the formation of the heat island and on the comfort for the individuals living in the urban space (1.2 m of height from the ground). It also provides a better evaluation of parameters such as the percentage of the built-up areas, of the vegetation and impermeable surfaces, the Aspect Ratio of the urban canyons, the type of urban fabrics and the radiation properties (albedo and emissivity) of the surfaces.

A first sequence of simulations is realized considering the current conditions of the quarters (Table 3). For the light-colored buildings the albedo of the façade and the roofs (for sure less influent on the wellbeing conditions of the inhabitants) is equal to 0.6. The albedo of the streets of the Old Town, paved with light-colored stones, is equal to 0.6 as well. While the albedo in Murat and Japigia quarters, with their streets (asphalt) and pavements (tiles), is around 0.4 and 0.6 (Figures 9, 10, 11, 12).

A second sequence of calculations analyzes the influence of the employ of surfaces with a lighter color (albedo 0.6) for streets and pavements of Japigia and Murat quarters (Figures 13, 14).

The first thing to notice is the higher illumination of the sun in the area of Japigia, because of the large space which separates each building, and because of the high percentage of impermeable surfaces and the unordered arrangement of the urban fabric. Therefore the temperatures in Japigia are higher, even of +3.3°C more, during the sunny hours. On the contrary, the reason for which the temperatures in the Old Town are higher than that of the Murat area, despite a less sunlight, is the higher value of the Aspect Ratio, which tends to compress the hot air in the urban canyons (the so called "thermal trap" effect). However, the warming effect in the Old Town is limited by the white color of the materials used for the buildings, which generates a high index of reflection. The Murat quarter in characterized by an east-west orientation

of its grid of buildings and by the presence of real urban canyons with an average street section of 14-15 meters, which causes the creation of strong flows of air. Actually, the cool North wind enter the urban grid without finding blocks or obstacles, and provokes a pleasant decrease of the temperatures. Even the trend of the PMV comfort index, which takes in consideration both the temperature and the sun radiation, follows the trend of the temperatures, reaching the highest values of discomfort during the midday hours.
During the hours in which the sunlight is minimal or null and doesn't affect the results, the lowest values of the temperature and PMV are registered in the area of Japigia, because of a larger air circulation in the wider spaces of the quarter and because of the cooling effect fostered by the evapotranspiration of the vegetation.
It is evident in the simulations with light-colored streets and with an albedo equal to 0.6 a cooling down and a decrease of the PMV, both in the Murat area and Japigia quarter. It is also clear that during the warmest days of the summer, between 12 pm and 2 pm, in the spaces more exposed to the sunlight, it would be better to choose "cold" surfaces with a high albedo (whose cost doesn't exceed that of the traditional surfaces), but always considering the dazzling effect that can be determined by the light surfaces. Therefore it is important to verify the time of exposure and durability to the sunlight of the paved surfaces and the related heat that they stored.
The combination light-colored surfaces with higher albedo and vegetations provides the best result, which can be quantified, taking Japigia as example, in a decrease of 4°C of the maximum temperature and a decrease of 1 for the maximum PMV. The green vegetation used to cover the pavements can considerably contribute to the increase of the thermal comfort, since it reduces the level of temperature and fosters the evaporative exchanges, benefiting both the sensory and living aspects.
This synergy is fundamental, since it discourages the use of the air-conditioning (with a consequent money saving). Actually, air-conditionings introduce a great quantity of energy in the atmosphere, equal to the total of the heat removed in the houses plus the electricity absorbed by the compressor of the refrigeration cycle, moreover they contribute to the increasing of air temperatures with a dangerous effect of positive feedback.

Figure 8 – Urban areas selected in the urban fabric of the city of Bari: the Old Town, Murat and Japigia areas.

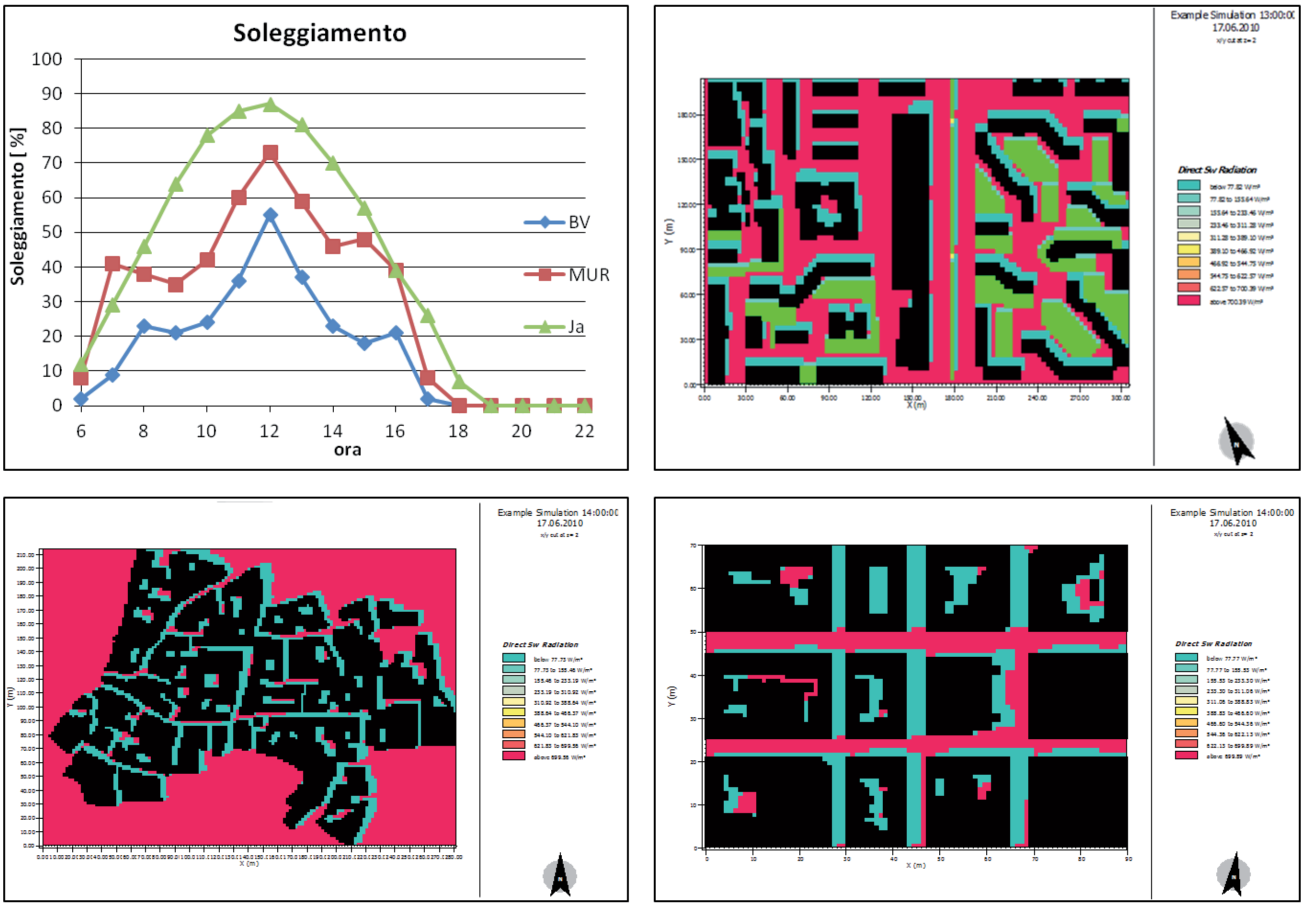


Figure 9 – Comparison of the direct solar light among the three shape-fabric at 14 o'clock.

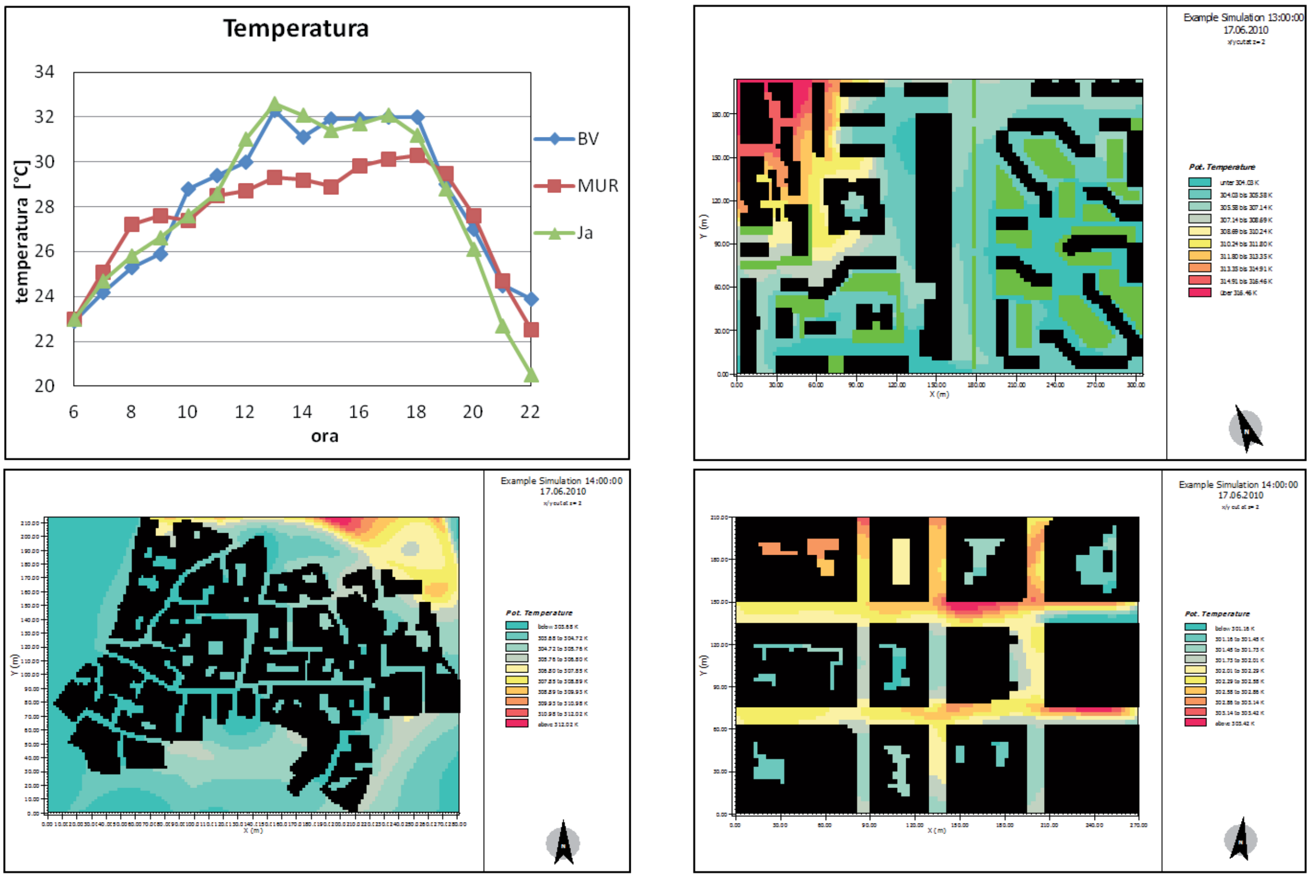


Figure 10 – Comparison of the temperatures among the three shape-fabric at 14 o'clock.

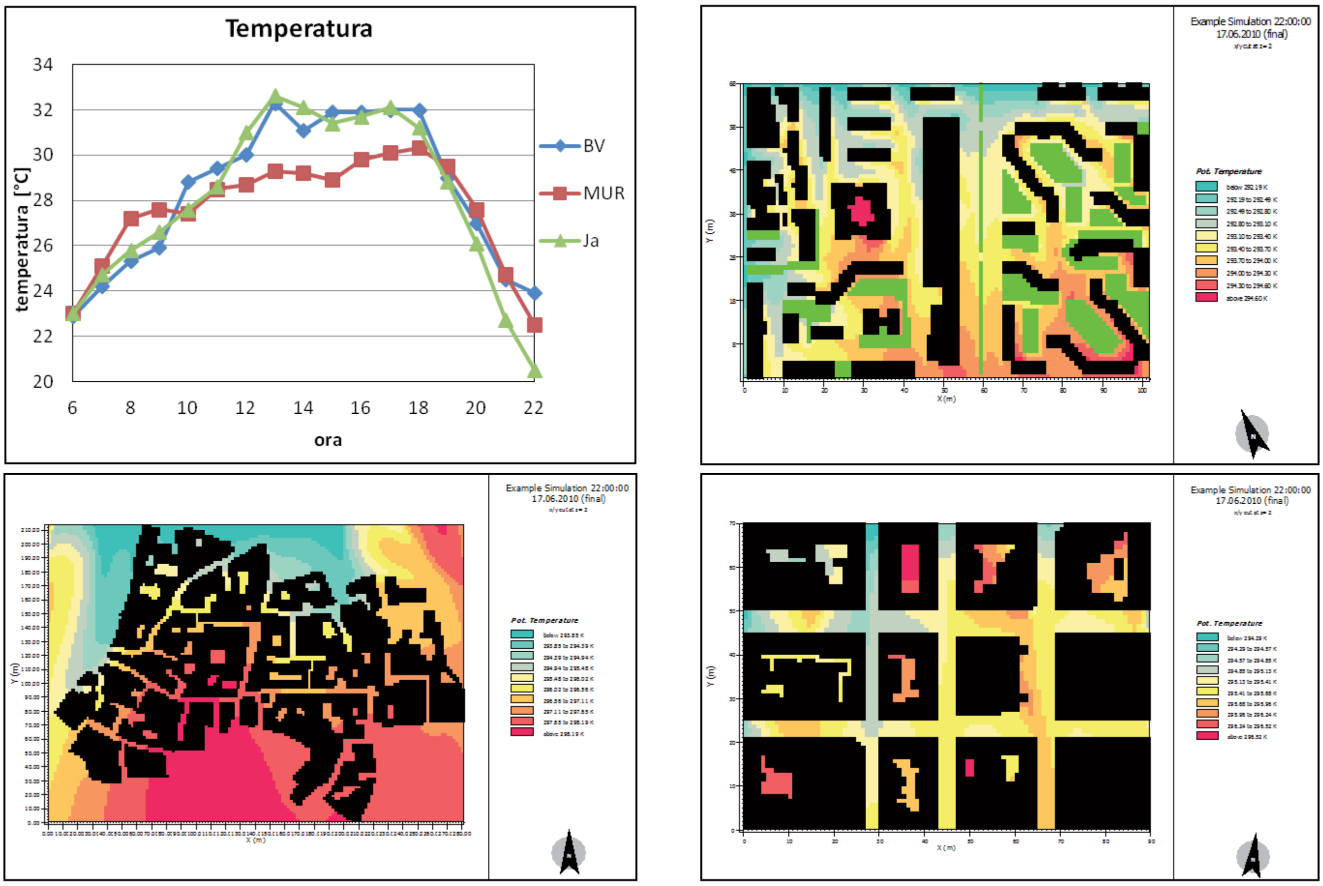


Figure 11 – Comparison of the temperatures among the three shape-fabric at 22 o' clock.

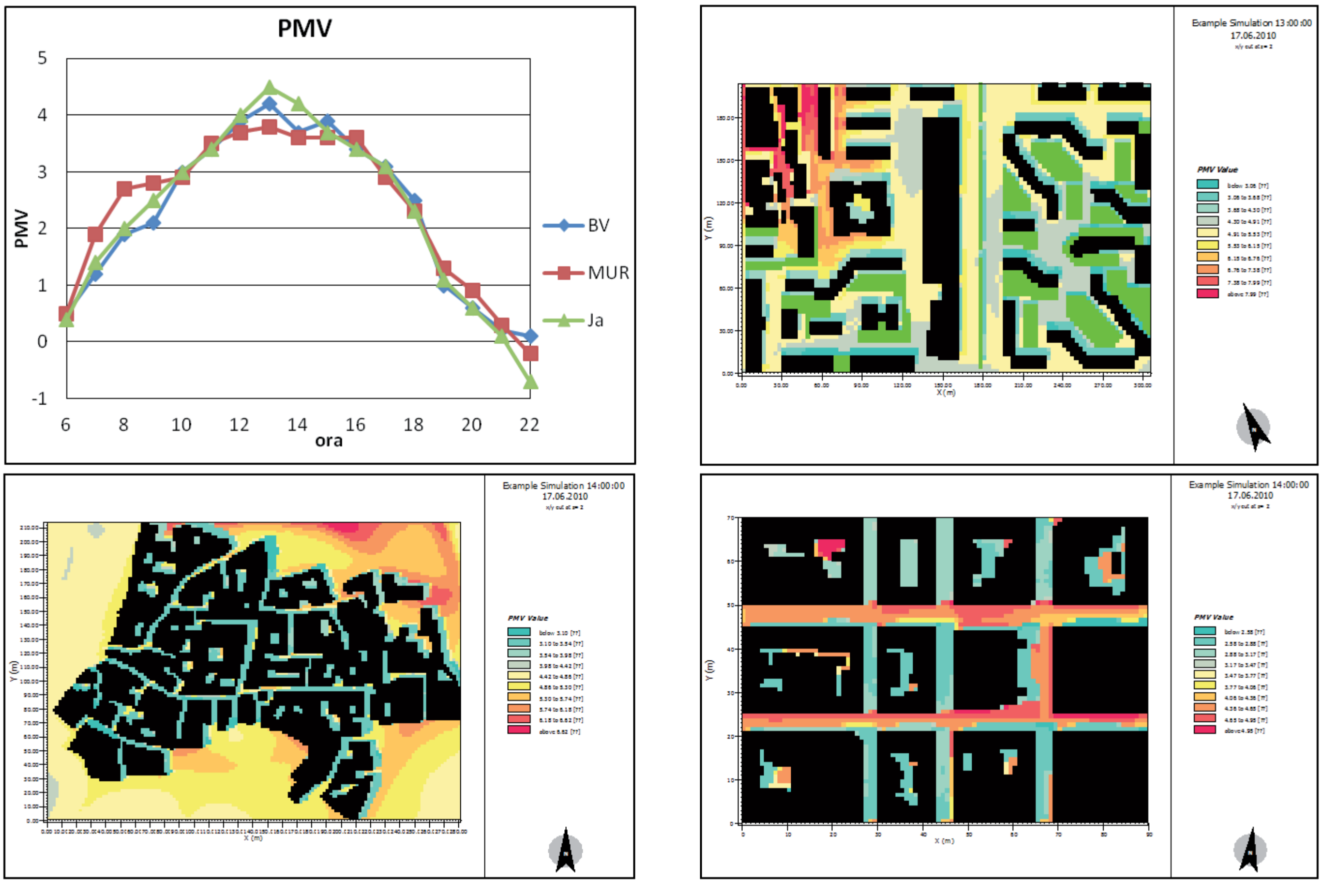


Figure 12 – Comparison of the PMV values in the three shape-fabric at 14 o'clock.

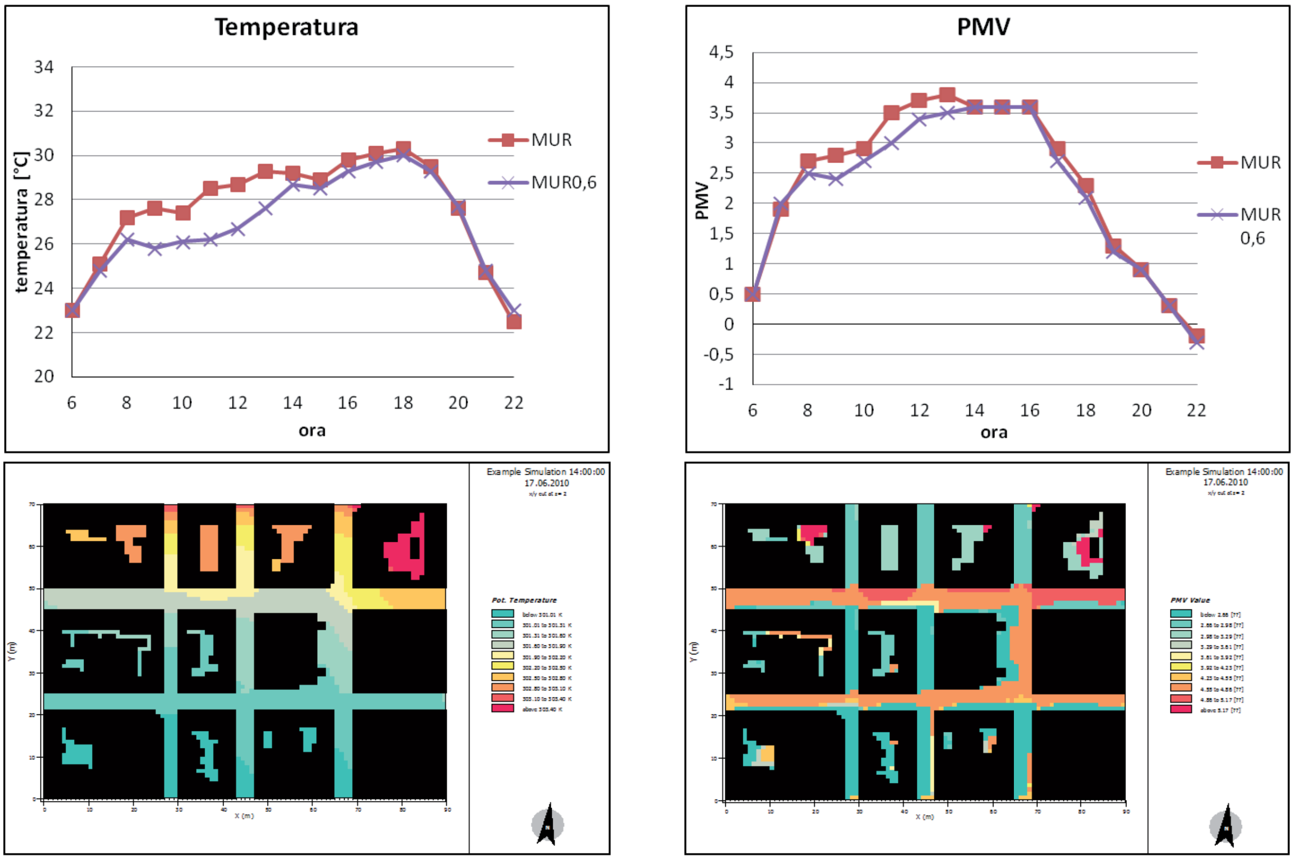


Figure 13 – Comparison of the temperatures and PMV values in current conditions (albedo: asphalt= 0,2 and pavements=0,4) and modified conditions (albedo: asphalt and pavements=0,6) for the Murat quarter.

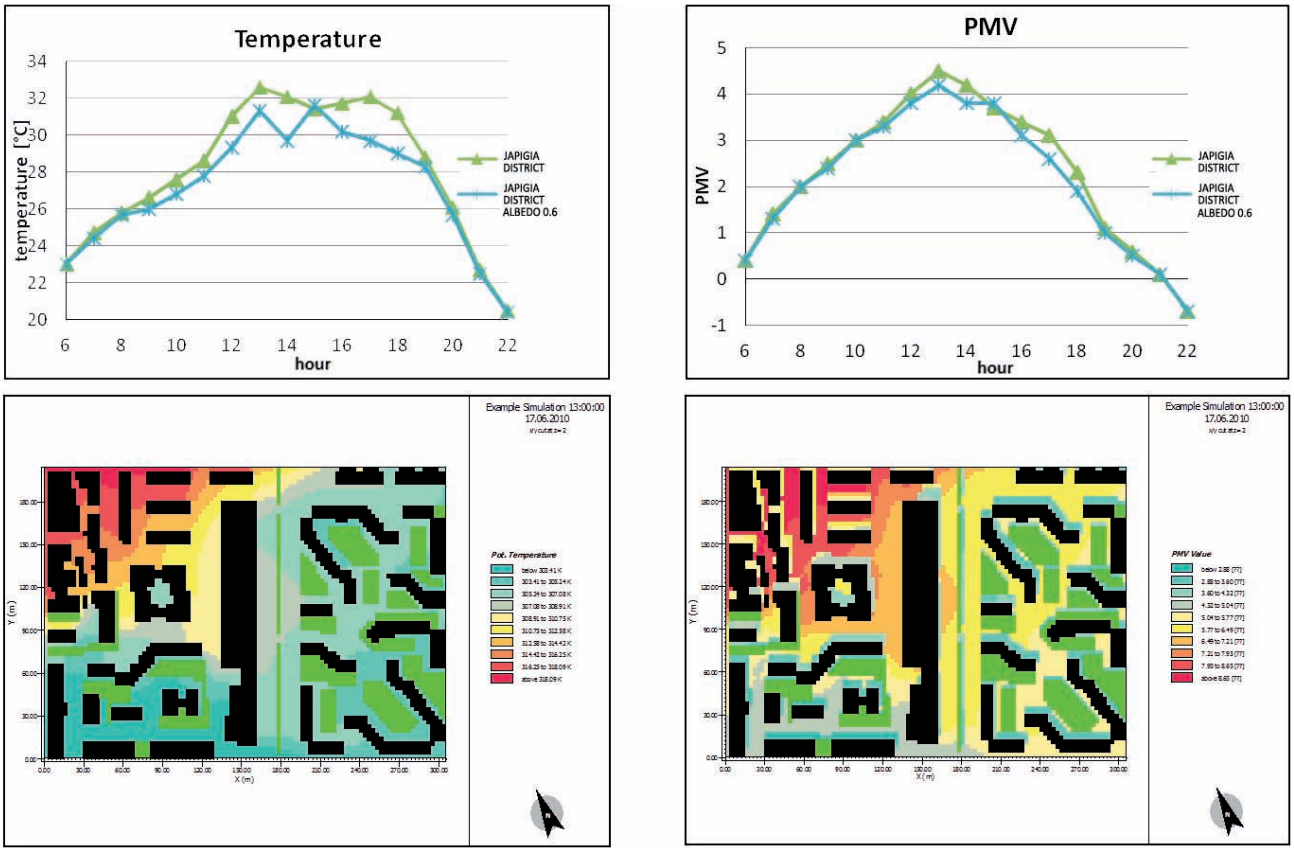


Figure 14 – Comparison of the temperatures and PMV values in current conditions (albedo: asphalt= 0,2 and pavements=0,4) and modified conditions (albedo: asphalt and pavements=0,6) for Japigia quarter.

Table 3 – Values of the temperatures and PMV in the three shape-fabric in current conditions.

	HISTORICAL CENTRE Built areas=74 % Green areas=0% Impermeable surfaces=26% Vertical ratio=3			MURATTIANO DISTRICT Built areas=62 % Green areas=0% Impermeable surfaces=38% Vertical ratio=1,5			JAPIGIA DISTRICT Built areas=34% Green areas=10% Impermeable surfaces=56% Vertical ratio=0,75		
Ora	T [°C]	Area sol. [%]	PMV	T [°C]	Area sol. [%]	PMV	T [°C]	Area sol.[%]	PMV
6	22.9	2	0.5	23.0	8	0.5	23.0	12	0.4
7	24.2	9	1.2	25.1	41	1.9	24.7	29	1.4
8	25.3	23	1.9	27.2	38	2.7	25.8	46	2.0
9	25.9	21	2.1	27.6	35	2.8	26.6	64	2.5
10	28.8	24	3.0	27.4	42	2.9	27.6	78	3.0
11	29.4	36	3.4	28.5	60	3.5	28.6	85	3.4
12	30.0	55	3.9	28.7	73	3.7	31.0	87	4.0
13	32.3	37	4.2	29.3	59	3.8	32.6	81	4.5
14	31.1	23	3.7	29.2	46	3.6	32.1	70	4.2
15	31.9	18	3.9	28.9	48	3.6	31.4	57	3.7
16	31.9	21	3.4	29.8	39	3.6	31.7	39	3.4
17	32.0	2	3.1	30.1	8	2.9	32.1	26	3.1
18	32.0	0	2.5	30.3	0	2.3	31.2	7	2.3
19	29.0	0	1.0	29.5	0	1.3	28.8	0	1.1
20	27.0	0	0.6	27.6	0	0.9	26.1	0	0.6
21	24.5	0	0.2	24.7	0	0.3	22.7	0	0.1
22	23.9	0	0.1	22.5	0	-0.2	20.5	0	-0.7

3. Prospects and conclusions

Thanks to the above experimentation it is possible to outline a guideline which considers the energy aspects and offers the ENVI-Met model as a tool to outline new different scenarios in the field of urban planning.

If it is true that the presence of comfortable open spaces plays a significant role in the urban planning, it is also true that the combined effects of sun radiation, temperature, humidity and wind contribute significantly to turn the urban space into a comfortable area. The climatic factors as well contribute to define how the urban space can be used (walking, standing, sitting, walking slowly, walking faster, or physical activities).

For the above reasons it is necessary to recognize the importance of the characteristics of the micro climates in an open urban space and their implications in terms of comfort for the inhabitants. For the urban spaces already built-up and arranged it is possible to study their current environmental characteristics, and maybe to draw up a mitigation plan or some improvements, in order to choose the most comfortable areas in which arrange the activities for the inhabitants.

The outcomes of the study are utilizable both in the central phase of the elaboration of the project, in order to integrate corrective and improving measures by means of an increase and a better arrangement of the green areas, an adequate choice of the materials, and in the final phase, as a tool to test the efficiency of the project.

The most significant parameters are: the choice of the materials; the sky view factor SVF; the orientation of streets and buildings; the height and distance ratio among the buildings; the study of the shadows and the sun axonometry; the collocation of the vegetation.

The use of appropriate materials, the so called "cold" materials, can optimize the conditions of thermal comfort during the summer. The high albedo of these materials reduces the heat storage caused by the direct sun radiation and the infrared radiation released by the surrounding urban area and by a high emissivity factor, both for the shortwave and long wave radiations. Moreover these materials warm up scarcely and release rapidly the energy absorbed. Their employ in the urban planning contributes to cool down the surface temperatures which affect the thermal exchange with the air.

The Sky View Factor establishes the radiant heat exchange between the city and the sky. A decrease of the Sky View Factor, caused by high buildings and other obstructions, reduces the night radiative cooling, therefore it is a factor that must be controlled. A correct planning of the street sections contributes to reduce the so called "urban canyon" effect. It must be prevented that the sun radiation absorbed and then released by the pavements and building surfaces after the daily exposure, would be captured by other buildings, limiting the thermal exchange toward the sky during the hours of the night. It can be generally said that a low Sky View Factor has a negative influence on the heat island.

About the orientation of streets and buildings, it must be attempted an optimization of the sunny areas during the winter, and a reduction of the sunlight exposure during the summer periods. The arrangement of the buildings must considers the main summer wind flows, in order to adopt strategies of natural cooling. Actually the study of the direction and intensity of the winds, of the trails created by the volumes of the buildings and the obstacles, implies a better control of the internal and external micro climate.

The ratio between the height and the distance of the buildings depends on the sunlight, therefore on the climate. Generally, it is possible to say that there is an optimal condition when a curtain has a complete sunshine, free from the across buildings influence. However, the ratio between the height and the distance cannot be unique, it actually varies depending on the orientation and the volumes that the area can produce.

The creation of green areas in the urban space represents a fundamental factor, also in relation to the urban micro climate. Compared to the other "urban" elements, the green plays a significant role and it is quite distinctive since it is a living entity, therefore it involves all our senses. The urbanization alters the climate persistently, with considerable effects on the solar radiation, temperature, relative humidity, precipitation and wind. It becomes crucial to consider these factors in order to appropriately plant and arrange the vegetation of the city.

We have to move our focus on the environmental quality of the urban spaces, but to do so it is fundamental that the public authorities develop a cultural sensitivity toward this issue, in order to avoid project interventions which alter negatively the urban micro climate. The researches and the analysis, like those reported in the paper, help us to define standard criterions in order to achieve a better quality of the environment and the climate of the urban space in its entirety. Those criterions, which are part of the guidelines, can provide a valid support, even to the public authorities, for the promotion and implementation of strategies of planning and requalification of the urban open spaces.

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Recycled plastic aggregates in manufacturing of insulating mortars

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Abstract

In this paper artificial aggregates based on recycled plastic materials, mostly polyolefin and polyethylene terephthalate waste, were used as partial replacement of natural aggregates for manufacturing hydraulic mortars. In particular, different amounts (10 to 50% by weight) of siliceous sand were substituted by the same weight of the above plastic waste, to obtain six mortars with different composition. The influence of plastic addition on physical properties (density, porosity, water vapour permeability) was studied. Moreover the thermal conductivity of the obtained mortars were evaluated. Recycled plastic substitution enhances the open porosity with an increase in water vapour permeability. Nevertheless, the presence of plastic aggregate leads to a significant reduction in thermal conductivity, which improves the thermal insulation performances of the mortar. For this reason the addition of recycled plastic aggregate in the manufacturing of hydraulic mortars can be considered a way to reduce the growing environmental impact of polymers and, at the same time, it allows the development of increasingly eco-sustainable building materials.

1. Introduction

The energy performance of a building is becoming increasingly important, because of environmental restrictions and rising costs of fuel and energy. These issues have led to the development of appropriate solutions, creating a fast growing sector in modern construction. To obtain buildings with good thermal insulation performances, the use of new materials of suitable thermal insulation properties should be held into consideration. Recent studies have reported the promising use of polymers in manufacturing of concrete, as part of the binder or as aggregate substitute (Yazoghli Marzouk et al., 2007; Saikia and de Brito, 2012). Polypropylene (PP) (Mesbah and Buyle-Bodin, 2008), polyethylene (PE) (Zoorob and Suparma, 2000), polyethylene terephthalate (PET) (Frigione, 2010) and other materials (Sivakumar and Santhanam, 2007) are some of the polymers used in the building industry either in fiber or sand shape.

In particular, the large growth in the use of plastic materials has generated a growing interest worldwide in reusing the various types of recycled polymers (Ahmadinia et al., 2011). Many authors have already studied the suitability of plastic waste, such as PET (Frigione, 2010) and polystyrene (Eskander and Tawfik, 2011) in cement and/or concrete manufacturing. The use of this type of waste in the construction field may represent an effective solution both to the problem of reducing the environmental impact of plastics and to the development of an increasingly sustainable building industry.

It is well known that manufacturing and use of increased amounts of Portland cement is a source of environmental concern, due to exceeding CO_2 production and the related greenhouse effect. To overcome the above problems, a renewed interest in use of hydraulic lime for the preparation of repair mortars or plaster has been reported in recent years (Iucolano et al., 2013). Hydraulic lime is also attractive for its favorable thermohygrometric features (i.e., transpiration, dehumidifying ability and insulation), which assure appropriate microclimatic conditions. According to these considerations, a natural hydraulic lime mortar was developed, which was obtained by replacing part of the natural aggregates (silica sand) with a fine synthetic aggregate derived from reprocessing of thermoplastic resins coming from the recycling of packaging. The aim of this research is to optimize the plastic waste addition in terms of physical and thermal performance of the resulting mortars.

2. Experimental

2.1 Materials

The binder used to manufacture the mortars studied in this research is a natural hydraulic lime (supplied by MGN srl, Vicenza), which according to the European Standards (UNI EN 459-1, 2001; UNI EN 459-2, 2001), belongs to the class designated as “NHL 3,5”. This hydraulic lime, hereafter referred to as NHL, was previously characterized by chemical, X-ray and

thermal analyses (Iucolano *et al.*, 2013).
All the mortars were obtained using two typologies of aggregate:
• a siliceous fine aggregate (S), supplied by Gras Calce company (Trezzo sull'Adda, Milan, Italy);
• a plastic aggregate (P), obtained from industrial waste, produced by the Company Vedelago Recycling Centre Ltd (Treviso) through a process that provides a plasticization and densification by extrusion of the polymeric fraction of the waste (figure 1 (a-d)). In particular, the recycled plastic material, called R-POMIX "POLIMAR" is classified as secondary raw material and it is compliant with the UNI 10667-16. The technical requirements, given by the supplier, are reported in Table 1.
The plastic aggregate mainly consists of suitably selected polymers, polyolefins (mostly polyethylene and polypropylene) and polyethylene terephthalate, which are ground,

Figure 1 – Recycled plastic sand.

Table 1 – Technical requirement of the plastic waste*.

CHARACTERISTIC	REQUIREMENTS
Polyolefin content	≥ 85% dry weight
Content of	
Other plastic materials	≤ 15% dry weight
Cellulosic materials	≤ 5% dry weight
Metals (except Al)	≤ 1% dry weight
Al content	≤ 1% dry weight
Bulk Density	300 kg/m^3
Humidity	≤ 10% dry weight

**Data given by the supplier.*

cleaned and sent to an extruder. Inside the extruder at 200 °C the transformation of the polymeric mass, fused and dense, into a plastic cast are obtained. The polymeric mass is then cooled and reduced in sand with particles < 8 mm.

Particle size distribution of the two aggregates was obtained by mechanical sieving, according to European Standards (UNI EN 933-1, 2009).

In order to complete the characterization of the plastic and silica aggregates, a sieving method, according to UNI EN 933-1, 1999, were performed. Both aggregates are classified as fine aggregates, since the main sieve size results lower than 4 mm (UNI EN 13139, 2003). In particular the synthetic sand (Figure 2) has a grain size < 2 mm and more than 95% of the sample passes through 1.4 mm mesh. In addition the silica sand presents a grain size < 1 mm (more than 90% already passing through a 0.5 mm mesh).

using a Micromeritics instrument (Autopore III).

Water vapour permeability measurements were carried out according to the UNI EN 1015-19, 2008. In particular, a disc of each mortar (d =12.5 cm; h = 3cm) was sealed over a KNO_3 saturated solution in a closed container at 93% relative humidity at 20°C. The containers were then placed in a climatic chamber (MSL Humychamber, mod. EC-125) at 20±2 °C and 50±5%relative humidity.

The test allows to evaluate the amount of mass transfer due to the diffusion of water vapour resulting from a difference in water pressure on the two parallel surfaces of the specimen. Each assembly was weighed at fixed time until constant mass weight was attained constant weight attainment, then water vapour transmission rate was determined by the change in mass at the steady state of the system. The water vapour permeability (W_{vp}) is a material constant, which is a

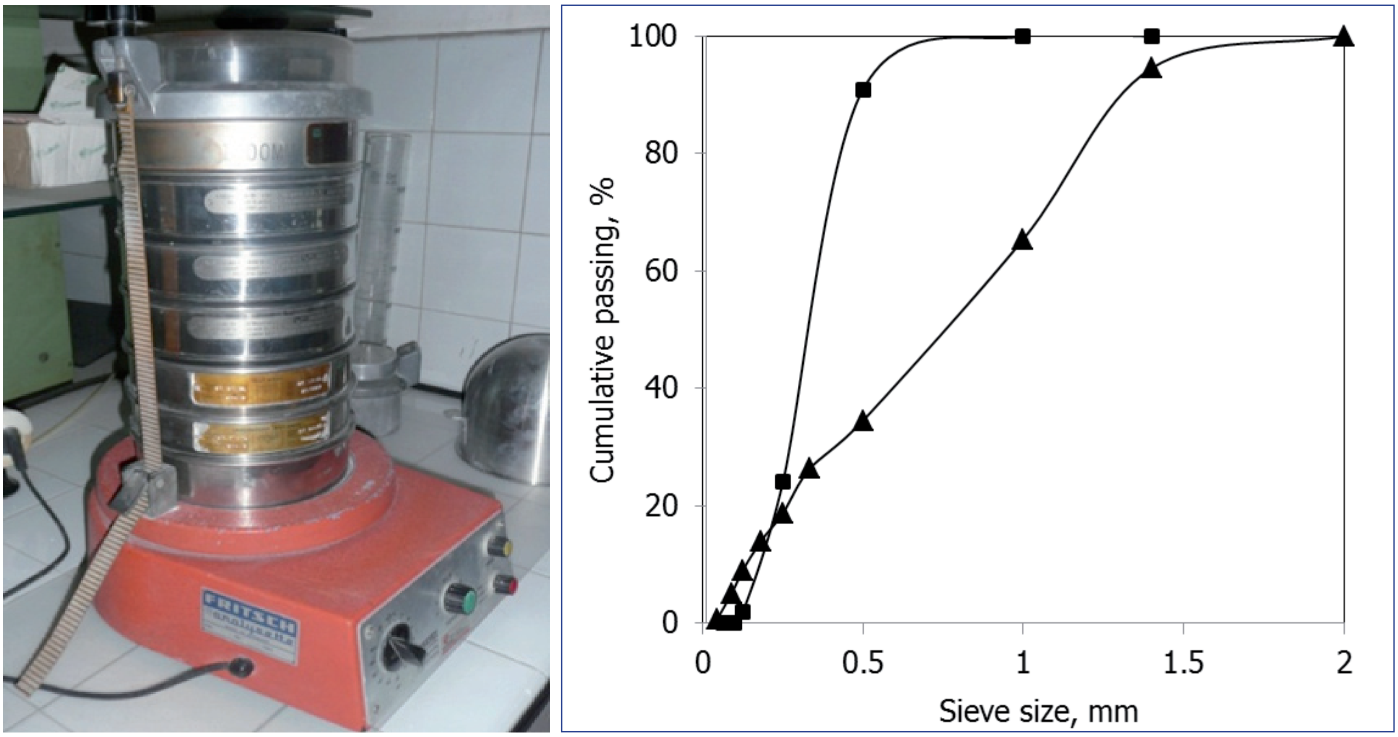


Figure 2 – Grain size distribution of plastic (▲) and siliceous (■) sand.

2.2 Methods

All the mortars were prepared as follow: the different components of the mortar were accurately weighed, mixed and dry-homogenized. Then, the appropriate amount of water was gradually added to this mixture. Therefore six mortars Mx were manufactured, where x (10, 15, 20, 25, 33 and 50%) corresponds to the weight amount of siliceous sand substituted by plastic sand. A reference mortar without the addition of synthetic aggregate (M_0) was also tested.

Real and apparent density, open porosity and pore size distribution were evaluated by mercury intrusion porosimetry,

function of density and porosity and it can be calculated using the following equation:

$$W_{VP} = \frac{t}{\frac{A\Delta P}{\Delta G/\Delta t} - R_A} \quad [kg \times m^{-1} \times s \times Pa]$$

where A is the cross-sectional area of the specimen perpendicular to flow (m²), ΔP is the difference in the water vapour partial pressure (Pa) between the dry side and the moist side of the specimen, ΔG/Δt is the water vapour flux (kg/s), t is the thickness of specimen (m) and R_A the resistance to water vapour diffusion of the air interspace between specimen and

saturated solution (0.048□109 Pa m^2 s/kg for a 10mm air interspace). Another important parameter is the water vapour resistance (μ), which measures the material's relative reluctance to let water vapour pass through, and is measured in comparison to the properties of air. The μ-value expresses the difficulty that water vapour molecules find in passing through a mortar, so the lower the coefficient, the higher the permeability is.
The thermal conductivity of the mortars was evaluated according to ASTM: C518-10 using a heat flow meter Netzsch HFM 436 (Lambda series). This apparatus is able to work at temperatures (T) between -20°C and 100°C and provides reliable results for materials with a thermal conductivity between 0.005 and 0.5 W/mK. The sample is placed between two plates, kept at different temperatures, on which two-heat flow transducers are connected (Figure 3).

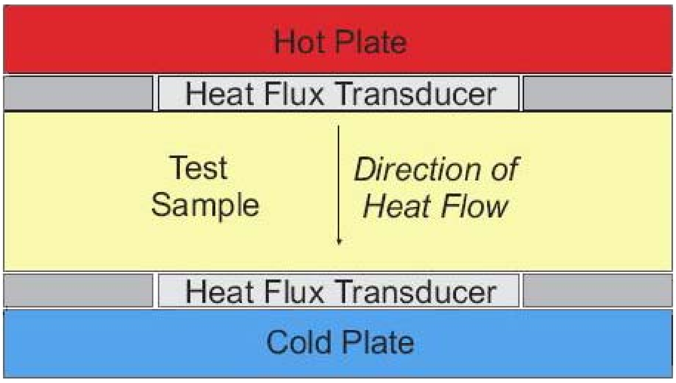


Figure 3 – Set up of the Netzsch HFM 436

The difference of temperature generates a heat flow from the hot to the cold plate (in accordance with the first principle of thermodynamics). When the thermal equilibrium is achieved, the instrument is able to determine the thermal conductivity (λ) of the sample. The experimental runs were carried out on specimens of size equal to 20x20x3 cm^3, manufactured in wooden moulds.
For each sample, the measurement of λ was performed in triplicate, with Tm varying between 10 and 40°C, keeping constant the value ΔT equal to 20°C.
Finally, microstructure of the fracture surfaces of the hardened compacts was investigated by means of scanning electron microscopy (SEM, Cambridge S440).

3. Results and discussion

3.1 Physical properties

Table 2 reports the main physical properties of the mortars studied in the present work.
The use of plastic waste as partial replacement of silica sand contributes to reduce the specific weight of the composite mortars. In fact compared to the reference mortar (M_0) the real density of plastic waste mixtures tends to decrease from 8% to 33%. Accordingly Saika et al. have reported that, regardless type and size, the use of plastic aggregate generally resulted in a decrease in dry density of the mortars. Such behaviour can be firstly explained taking into account that the sand of synthetic origin is lighter than a common river sand.
Inspecting Table 2 it is possible to observe a big difference in terms of open porosity between reference material (M_0) and all the mortars manufactured by substitution of synthetic sand. It should be noted that the M_{50} mortar proved not to be compact enough to be characterized by means of mercury intrusion. It appears evident that the addition of plastic aggregate led to lighter and more porous mortars compared to the reference. In particular, the open porosity changed from about 34% for the M_0 to 46% for the M_{33}.
Moreover inspecting SEM image of the plastic sand (Figure 4) particle size and morphology appears extremely heterogeneous.

Table 2 – Physical properties of manufactured mortars.

Mortar	Apparent density (kg/dm^3)	Real density (kg/dm^3)	Open porosity (%)
M_0	1.65	2.50	34.0
M_{10}	1.42	2.30	38.2
M_{15}	1.30	2.16	39.8
M_{20}	1.23	2.11	41.8
M_{25}	1.06	1.86	43.1
M_{33}	0.90	1.67	46.1

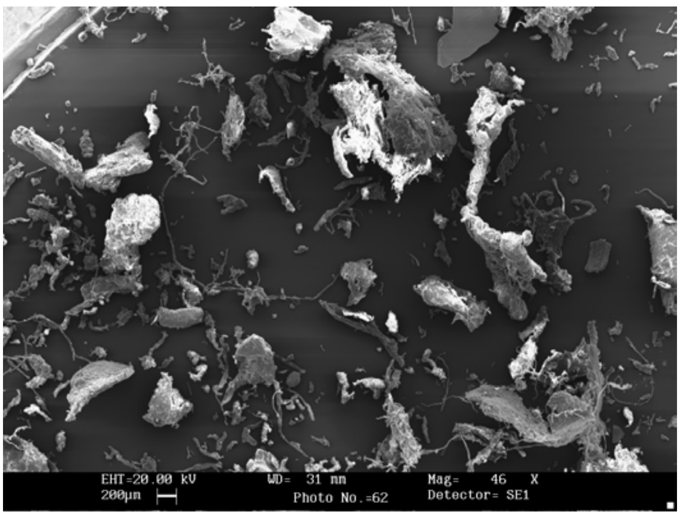


Figure 4 – SEM micrograph (46X) ofthe plastic waste sand.

In general, the interruption of the continuity of material microstructure, as a result of the inclusion of heterogeneities in a homogeneous body may cause an increase of the open porosity. Specifically, the morphology of the plastic sand, more similar to fibers than particles, is responsible of a worsening of the mortar workability. In fact Iucolano et al. have demonstrated that the addition of short fibers in hydraulic mortars can promote the formation of micro cavities in the interfacial transition zone between lime paste and fibers, hindering the hydration and/or carbonation of lime paste. Several authors (Frigione, 2010; Eskander and Tawfik, 2011; Siddique, 2008;Ismail and Al-Hashmi, 2008;Saikia and de Brito, 2012) reported that plastic aggregates exhibit a series of drawbacks, mainly due to their poor chemical compatibility with inorganic matrix, which could lead to the formation of micro cavities responsible for the increase of porosity. Furthermore the increase of porosity can be due to some surface hydrophobicity or excess of gas trapped in the blend (Corinaldesi, 2011).

Figure 5 shows the distribution of porosity as a function of the average pore diameter. By inspection of such a figure, the mortar M_0 has a narrow pore size distribution, which is evidence of the presence of a large number of pores with diameters of the same size. In particular, there are only two types of pores: a more numerous one, with pore size around 1 μm and another one, much less numerous, with pores of greater size (about 100 μm).

Instead, observing the curves related to mortars M_{10}, M_{20} and M_{33} (chosen as representatives of the explored compositional range) it appears that, in addition to the above discussed increase of total porosity, there is a dual effect associated with the use of the plastic aggregate. Firstly, there is an increase of macroporosity (pores with diameters of the order of 100 μm) to the detriment of microporosity (pores with diameters of the order of few microns) and then there is an extremely varied and fragmented size distribution, with the formation of new pores characterized by extremely different diameters.

The morphology of the manufactured mortars, investigated by scanning electron microscopy (SEM), confirmed that the presence of synthetic sand results in an increase of porosity. In fact, figure 6 shows that M_0 exhibits a much more compact and homogeneous texture, with pores clearly smaller than, for example, M_{33}.

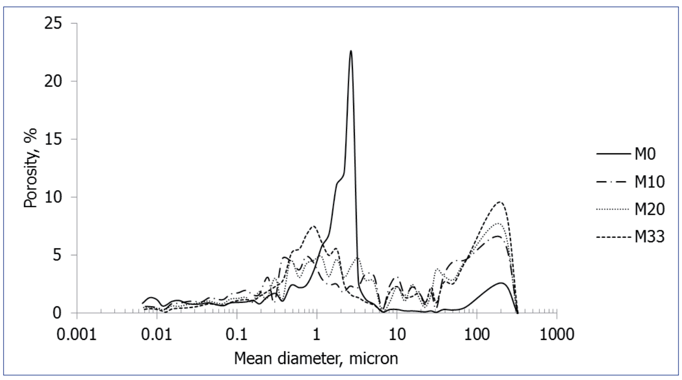
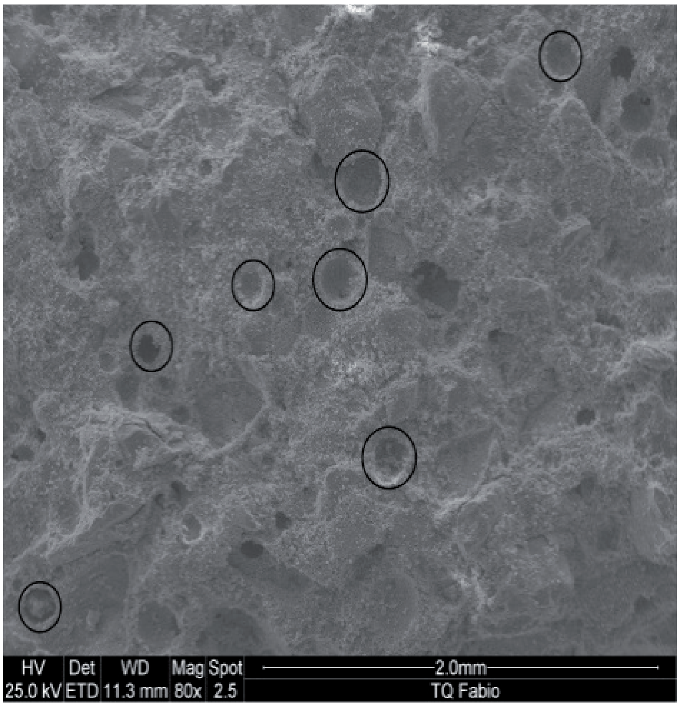
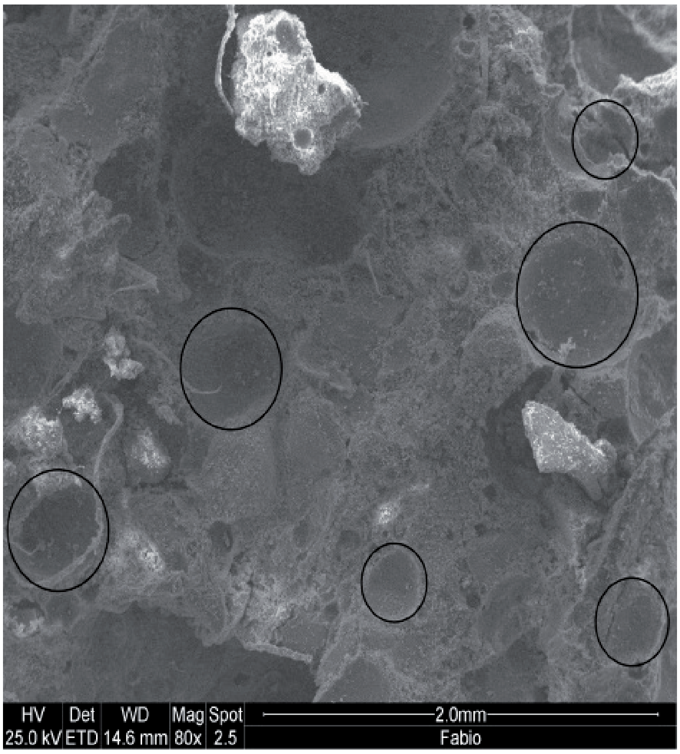


Figure 5 – Pore size distribution of M_0, M_{10}, M_{20} and M_{33}.



M_0



M_{33}

Figure 6 – SEM micrographs (80X) showing the different morphologies of M_0 and M_{33} mortars.

As far as the water vapour permeability is concerned, data reported in Table 3 show that the mortars manufactured with addition of synthetic sand are characterized, on the whole, by higher values of water vapour permeability ($2.8 \div 3.9 \times 10^{-11}$ kg/m•s•Pa) compared to the reference (8.58×10^{-12} kg/m•s•Pa).

Table 3 – Mean values of water vapour permeability (W_{VP})

and Water vapour resistance (μ).

	W_{vp}, (kg/m•s•Pa)	μ
M_0	8.58 ×10^{-12}	23
M_x[a]	(2.8 ÷ 3.9) ×10^{-11}	5 ÷ 7

[a] x ranging between 10% and 50%

In the second column of Table 3, water vapour resistance values (μ) of mortars with or without plastic aggregate are reported too, since this feature is frequently used to classify any material for building industry. In particular the water permeability features of the mortars manufactured with plastic aggregate were summarized in a single item M_x, since the variation of plastic percentage (from 10% to 50%) does not involve significant changes in terms of water vapour permeability and water vapour resistance. The water vapour resistance, μ, determines the material's reluctance to let water vapour pass through. High μ-value means high resistance to water vapour transmission.

This behaviour is closely related to the above discussed increase of porosity: a greater porosity enhances the vapour molecules capability to penetrate inside the mortar. Accordingly Saikia et al. reported that the increase in porosity, due to weak bonding between binder and plastic aggregate, is the cause of the higher permeability of mortar containing plastic waste.

Great attention is paid to this feature, because of the frequent problems with condensation and mold in the buildings. All the mortars manufactured with plastic sand, regardless of percentage, present μ-values at least one order of magnitude lower than a typical cement mortars (μ-value = 5-7 and 80-100, respectively).

3.2 Thermal conductivity

The mean values of the coefficients of thermal conductivity (λ) relative to the reference mortar M_0 and to the mortars prepared with synthetic sand were reported in Figure 7.

The results obtained showed, first of all, that the values of λ do not vary significantly within the range of temperature considered (10-40°C), so in Fig. 7 only the λ-values at T=20°C were reported. By inspection of this figure it appears that all the mortars prepared by addition of synthetic sand exhibit a thermal conductivity coefficient lower than the reference mortar. The thermal conductivity of materials depends upon many factors, including their structure, material mixture proportioning, type of aggregate inclusions, density, porosity, etc. (Corinaldesi et al.,2011;Yesilata, 2009).

Generally the plastic waste aggregates, for example PET (Yesilata, 2009) or rubber (Corinaldesi et al.,2011;Yesilata, 2009) have significantly lower conductivity than the natural aggregate typically used in mortar or concrete manufacture. In particular the recycled plastic aggregate were characterized by values of thermal conductivity five times lower than the silica sand (0.28-0.30 W/mK and 1.3-1.4 W/mK respectively).

Moreover the thermal insulating performance of the composite mortars containing plastic waste as aggregate is also strictly related to the porosity, which plays an important part in heat transfer.

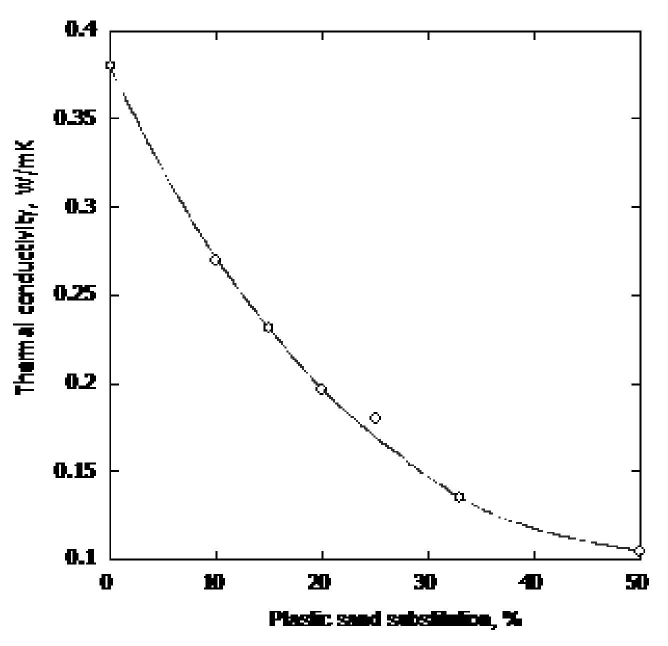


Figure 7 – Thermal conductivity (λ) measured at T_m=20°C and ΔT=20°C.

So the decreasing thermal conductivity came also from the increase in porosity induced by the synthetic sand. In fact the pores contain air which has a thermal conductivity (0.024 W/mK) much lower than all the other components of the mortar.

Finally, comparing the results with the literature (Corinaldesi et al.,2011), it appears particularly interesting that a replacement of only 20% of siliceous with synthetic sand is able to obtain a reduction of almost 50% of λ-value, passing from 0.38 W/mK of M_0 mortar to about 0.19 W/mK of M_{20}, with a marked gain in terms of thermal insulation. So the mortars containing plastic aggregates will have better thermal insulation properties than convectional mortars, which can be used to control heat loss from building during winter and heat gain during summer.

4. Conclusions

The experimental mortars have shown interesting potentiality as a base of green building materials, adding to the typical qualities of a natural hydraulic lime (widespread availability, low energy consumption during production, permeability, dehumidifying capacity) further features such as the low thermal conductivity. In fact, the prepared mortars have shown a value of thermal conductivity about 50% lower than a traditional mortar. This result is primarily due to lower thermal conductivity of the synthetic sand than silica, but also to the capacity of the aggregate plastic to facilitate the formation of micro voids. This improvement in porosity results in excellent thermal insulation performances. Another interesting feature of the studied mortars is the low water vapour resistance factor μ, 5-7 versus 80-100 for a cement mortar, which appears to be potentially useful for developing dehumidifying building materials, which can guarantee an adequate living comfort.

Finally one should consider that the use of secondary raw materials within the production phases of construction widens the virtuous cycle of disposal and reuse of waste for greater environmental protection and sustainable development.

Acknowledgment

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Pianificazione territoriale e difesa del suolo. Quarant'anni dopo la relazione "De Marchi"

Maurizio Tira and Michele Zazzi eds., Rome, Gangemi, 2010.

ISBN 978-88-492-2366-8

The book, published by the National Council of Engineers, the National Center for Urban Studies, "Gruppo 183" and the Italian Hydrotechnical Association, collects the experiences gained following the publication of the forward-looking *Inter-ministerial committee for the study of watercourse management and soil defence* led by Giulio De Marchi in 1970.
Starting from the results of the committee that inspired the National Law 183/89 (about Land defence and Basin Plans) and that are still relevant even after the entry into force of the recent European legislation (Directive 2000/60/EC concerning water policy and Directive 2007/60/EC concerning flood risks), an analysis of the Italian period 1970-2010 in relation to spatial planning applied to the Land defence is proposed.
The present difficult situation is characterised by an increasing disaffection towards spatial planning on the national scene, and at the same time with plenty of plnas often not commensurate with the actual needs of the population and careless to soil defence. The latter crushed between spatial planning and civil protection.
Despite major media events (including the flood in Florence in 1966 that led to the establishment of the "De Marchi" commission) are the reason that lights up the scientific debate regarding hydrogeological risk, the contributions inside the volume highlight mainly the importance and complexity of the management of the "water resources", connected to the "soil resources", governed by a number of different bodies.
After an assessment on the soil management in Italy in the past forty years (1970-2010), several Basin Authorities' representatives brief the path from the institution (1989) to the present day. The analysis dedicates a focus on regional planning in areas at landslide risk as well as other inherent aspects such as legal problems, related to administrative responsibilities between agencies and software for modelling and monitoring soil changes.
The book ends with a collection of presentations discussed at a round table during the national conference held in Rome on December 2^{nd} and 3^{rd}, 2010. They focus on the role of planning and of the engineers in the field of prevention of hazardous events. The debate shows a critical analysis about the role of institutions, the effects of policy decisions and investment priorities that the Government took in the last forty years.
The book as well as the conference, aim to refresh the very important experience of the "De Marchi" commission's report (a digital copy of the whole report has been prepared and is attached to the book), especially for young generations that hardly knew about that.
As the history is seldom "magistra vitae", most of the forecast of the powerful report have found an echo in the following administrations, at all levels, so leaving the Country in the same difficult situation as it used to be already forty years ago.

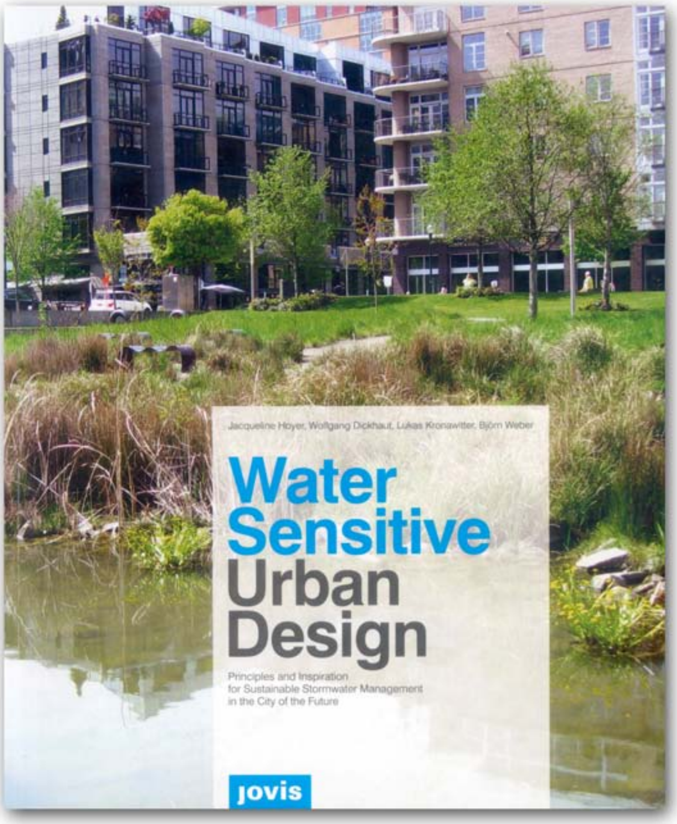
Anna Richiedei, Riccardo Bonotti

Water Sensitive Urban Design - WSUD

Principles and Inspiration for Sustainable Stormwater Management in the City of the Future

Jacqueline Hoyer, Wolfgang Dickhaut, Lukas Kronawitter, Björn Weber eds.,Berlin, Jovis, 2011

ISBN 978-3-86859-106-4



In recent years, considerable advances have been made in techniques and legislation for decentralized stormwater management worldwide. However, decentralized stormwater management systems are still underutilized and acceptance among citizens and professionals is still lacking. Indeed, decentralized stormwater management will be essential for the sustainable development of cities in the future. The main question that needs to be answered is: How can sustainable stormwater management be integrated with urban planning in order to create liveable, sustainable, and attractive cities? The approach of Water Sensitive Urban Design (WSUD) proposes a solution.

This manual, developed by the Hafen City University of Hamburg, in the ambit of the European research project SWITCH (Managing water for the city of the future, under the sixth research framework programme of the European Union). The book was published by Jovis Verlag GmbH in March 2011. It is organised into four chapters plus an introduction and the conclusions.

- *The first chapter* provides an overview of the WSUD approach, underlining the differences between conventional stormwater management in cities, the problems with conventional stormwater management and the variations in stormwater in different climate zones around the world.
- *The second chapter*, the ideas of WSUD and sustainable stormwater management, is organised in three parts: definitions, technical elements, solutions and drivers. The first defines the WSUD as an interdisciplinary cooperation of water management, urban design and landscape planning and clarifies that the primary objective is to combine the demands of sustainable stormwater management with the demands of urban planning. The second lists the technical elements and solutions grouped according to their primary function: water use, treatment, detention and infiltration, conveyance and evapotranspiration. The third gives an overview of international and national regulations, engineering standards and guidelines primarily focused on Europe, Australia and USA.
- *The third chapter* identifies principles for a successful WSUD, focusing on six issues: water sensitivity, aesthetics, functionality, usability, public perception and acceptance, as well as integrative planning.
- *The fourth chapter* presents an international selection of case studies ranging from small scale (site level) up to large scale (city level), demonstrating WSUD principles in the context of temperate climates. All the projects come complete with a fact sheet, several images and construction details, and were assessed against the following principles of WSUD: water sensitivity, aesthetic benefit, integration in the surrounding area, appropriate design, appropriate maintenance, adaptability, appropriate usability, public involvement, acceptable costs, integration of demand, interdisciplinary planning, impact on public perception.

WSUD strives to harmonise the urban built environment and the urban water cycle, combining the functionality of water management with principles of urban design and planning. The approach embraces interdisciplinary cooperation of water management, urban design, architecture and landscape planning in order to achieve WSUD goals as well

as integrating water management concerns into overall concepts and development plans.
The application perspectives of the WSUD method, supported by the implementation of new quantitative techniques, pave the way for interesting types of interventions in the urban environment that could be included in the implementation tools of the plans and could turn policies in the Environmental Strategic Assessment of plans and the Environmental Impact Assessment of designs into technical choices.

Salvatore Losco

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