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Supporting sustainable urban planning process based on scenarios development

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Abstract. The transition towards sustainable cities requires extensive improvement of environmental and energy consumption performances. However, the design of alternative sustainable scenarios is a complex issue which involves a large number of indicators and multiple stakeholders. In this regard, the use of appropriate assessment tools and decision-making models for addressing this issue are needed. This study aims at presenting research activities with a specific focus on the definition of policies and decision-making models to guide future transformations in the city, developing a "sustainable path". The result is a new multi-criteria indicators-based system for supporting decision making at the city level. This includes the organization of a workshop in order to select the relevant indicators and to assign the stakeholders' preferences using a multi-criteria method . This approach is used in order to investigate the stakeholders' perspectives on the impact of each indicator on the different future sustainable scenarios. Eight indicators have been selected, and accordingly, assessed through the collection of data for the "baseline" scenario. Next step will involve the definition of different forward-looking sustainable scenarios and the assessment of their impacts through the selected indicators. Finally, all the scenarios will be verified through a second interactive workshop as part of the sustainable urban planning process to choose the best scenario.

1. Introduction

Cities play a central role in facing big challenges of our time, like the one related to climate change and global warming. Urban contexts can be considered one of the main responsible for the effects of climate change. In fact, they occupy less than 10% of the Earth surface and are responsible for more than 70% of energy-related GHG emissions [1,2]. In 2015, the UN adopted the Agenda 2030 [3] which reflects the integrated nature of current challenges by identifying 17 goals Sustainable Development Goals (SDGs) articulated in 169 targets to be reached by 2030. Among the SDGs, Goal 11 is completely dedicated to cities and human settlements in general, with the aim of making them inclusive, safe, resilient, and sustainable.

Cities are also possible places for the development of concrete and rapid solutions for more sustainable development. Therefore, we can say that city-scale is the privileged scale for action, where innovation and technological advancement happens. Furthermore, cities have the collective power to scale up solutions [4] and directly tackle global challenges. In this process, local governments have the

deal of connecting local needs of the urban population with global trends [5]. For this reason, different cities around the world began to develop new sustainable strategies and actions plan integrating different disciplines that are often treated separately in city governance. Some challenges are still recognizable in the process of transition toward reaching the SDG11 and its evaluation including: (i) localization can be a problem in terms of compromises between global dimension of goals and specific features local contexts [5,6]; (ii) data collection is still a challenge, in fact, even if data revolution and smart cities offer the potential to produce a big amount of data, in some cases technology is not implemented and moreover, there is the need of enhancing citizens engagement in these aspects [6]; and (iii) indicator selection process should be able to reflect urban complexity, for this purpose, it is necessary to adopt a holistic approach and consider scientific and political role of selected criteria [6–8].

MOLOC (Morphologies low carbon) is a co-financed project from the Interreg Europe Programme 2014-2020[1], which aims at developing a new city-building approach with the specific attention on quality of life and energy efficiency. Six EU partners are involved in the project for designing and testing innovative ways of achieving low-carbon cities. The City of Turin is one of the partners of MOLOC and is developing its low-carbon strategies through the activities of the new City Masterplan.

This study provides in-depth analysis in order to systemize the information and define urban strategies toward energy transition and resilience. In particular, the present study illustrates a part of project activity results with the aim of identifying and assessing the most relevant indicators to revise the new City Masterplan. Into this, a spatial georeferenced database and other information sources of urban context related to energy transition and climate change adaptation and mitigation process have been created.

The rest of the paper is structured as follow: Section 2 illustrates the methodologies adopted for the selection of the indicator and the ones used for their evaluation. Section 3 analyses the results in terms of selected indicators and the successive creation of the baseline scenario of the City of Turin. Finally, conclusive remarks are discussed in Section 4 and future developments are identified.

2. Methodology

The selection of the indicators to be used for the evaluation of the sustainability performance level of the City of Turin in relation to the re-writing of the General Masterplan was developed in four different operational steps using different qualitative and quantitative methodologies (Table 1).

Table 1: Operational steps used for indicators selection

Phase	Methodology
1. Exploratory phase	Focus groups and Interview
2. Preparatory phase	Online questionnaire
3. Workshop	SRF
4. Validation phase	Focus group

In the first phase, exploratory phase, 25 indicators were selected from the 178 indicators of the CesbaMed project[2] through several focus groups within the project team and other external experts, and a semi-structured interview with the urban planning office of the City of Turin for the correct inclusion of the new General Masterplan principles. Successively, in the second phase (preparatory), an online questionnaire was distributed among public administrative stakeholders in order to rank the 25 indicators selected in previews step.In the workshop phase (3), different stakeholders (i.e., public administration, private companies, researchers, and citizens) were involved to select and rank a final set of 10 indicators. The etherogeneity of the group allows the inclusion of different backgrounds, points of view and priorities. The 30 participants were divided into two mixed groups to discuss more easily about the selection of proper indicators. During the final plenary phase results of each group were presented,

[1] https://www.interregeurope.eu/moloc/
[2] https://cesba-med.interreg-med.eu/

discussed, and finally aggregated. The workshop was conducted using the SRF multicriteria methodology [9,10]. The methodology, introduced by Simons in 1990 [11], allows the inclusion of qualitative and quantitative criteria and define a priority rank among different point of view of the involved stakeholders. SRF methodology is based on the use of a deck of card composed by: Coloured cards named "criteria cards" on which criteria are expressed and White cards. During the workshop participants are asked to rank the "criteria cards" from the less important to the more important (if two cards have the same importance are posed at the same level). In a second phase white cards are inserted between the others to represent importance distance between criteria (e.g., no cards represent a light difference, one card a small difference, two card a big difference and so on).

In conclusion, the validation phase (4) was carried out thourgh a focus group with local administration in order to confirm the qualitative rank resulting from the workshop, verify methodologies for the evaluation of indicators and the availability of data.

After the fina selection of KPIs, their impact assessment was performed. Consequently, the baseline scenario is determined taking into account all eight KPIs. Data used for the evaluation process were collected from several sources and entities: public dataset, private dataset, and previous research projects. Due to the heterogeneity of unit of measurement related to indicators, different methodologies were used to collect information and evaluate the KPIs.

Furthermore, in the evaluation process some common principles were defined in advance:

- Indicators should be homogeneously measurable in the entire municipal area;
- Only quantitative data are considered;
- Data are elaborated and represented with the software ArcGIS, as they are important territorial attributes and their interpretation is strictly connected to the spatial variable.

3. Results and Discussion

This section shows the results of the selected indicators and their measurement that will be used to evaluate the sustainability performance of the City of Turin in the context of the design of the new General Masterplan of the city. The set of indicator resulting from the process explained in Table 1 is the first outcome of the project discussed in section 3.1. . Furthermore, the definition of a baseline scenario of the City of Turin is the main outcome here reported in section 3.2. .

3.1. Selected indicators

Eight indicators were selected through the process described in section 2. All the indicators are based on the CesbaMed framework. Some indicators were used in the same way by adopting the same evaluation method, while others were modified in order to better fit the city-scale of analysis and the purpose of the project. Table 2 presents the final list of selected indicators and their description.

Table 2: Selected indicators for the evaluation of the new General Masterplan of Turin

Issue	Indicator	Description	Unit of Measurement
A. Built Urban System	A1. Quality of land	The average value of the vegetation quality ratios of all the Municipality of Turin's permeable areas	nr
	A2. Intermodality facilities	Modes of transport proximity to the main car parks, railway and underground stations	nr
C. Energy	C1. Total average annual thermal energy consumption for residential building operations	The average value of annual thermal energy consumption for residential buildings operations	kWh/m^2/year
	C2. Total average annual electrical energy consumption for residential building operations	The average value of annual electrical energy consumption for residential buildings operations	kWh/m^2/year

D. Atmospheric Emission	D1. GHG emission from energy used for all-purpose in residential buildings	GHG Emission due to primary energy used for residential buildings operations	kg CO_2 eq./m^2/year
F. Environment	F1. Ambient air quality with respect to particulates <10 mu (PM10)	Atmospheric PM10 concentration detected by control units	µg/m³
	F2. Albedo	The albedo of external surfaces of the Municipality of Turin	%
G. Social Aspects	G. Availability and proximity of key public human services to residential buildings	Percentage of residential buildings located within a buffer of 800m, 500m, 300m, starting from the key municipal services (health and educational facilities, public green)	%

It is possible to notice how the indicators reflect different aspects of sustainability issues at the city level. In fact, they can be aggregated in five different categories: urban system, energy, atmospheric emissions, environment, social aspects. For the urban system, two indicators were selected: "quality of land" and "intermodality facilities": the first one was recognized as a priority in the whole process of selection because it does not only refer to the conservation of permeable soil but also considers the level of vegetation quality of green surfaces thanks to the Normalized Difference Vegetation Index (NDVI)[3]. Even mobility aspects were considered important by the participants to the workshop even for its consequences on other categories (e.g, atmospheric emissions) and "inter-modality facilities" was chosen to measure it for coherence with the scale of analysis and the possibility of considering the connection with surrounding territories. Furthermore, this is a way to expand and coherently analyse the concept of sustainable mobility, by going beyond the individual cycle and pedestrian mobility. For the "energy" category two indicator were selected. Both are related to both thermal and electricity energy consumption. In fact, in the online questionnaire, all the participant stress more importance to consumption despite the share of renewable energy production. For the "atmospheric emissions" the indicator "GHG emissions from energy used for building operations" was selected as the most significant indicator, expressed in tCO_2eq. "albedo" and "air quality" was selected for the "environment" category. Air quality is one of the most crucial issue perceived challenges in the Turin area: traffic, industries, and a disadvantaged geographical position make Turin as one of the most polluted European cities, and all the involved stakeholders agreed in the selection of this indicator. Albedo was chosen as one of the aspects to be considered to mitigate the heat island effect present in urban areas. Although it is not the only element influencing this phenomenon, it offers an overall picture of the phenomenon in the municipality. During the workshop phase, "availability and proximity of key public human services" was re-introduced in the "social aspect" category. The indicator was chosen to evaluate social impacts of the new General Masterplan instead of "involvement of the population in the urban planning process" which was selected in the preliminary phase and preparatory phase. However, during the workshop, it was considered as pre-determined indicators that will follow the entire process without the need of been monitored.

3.2. Baseline scenario

Successively the phase dedicated to the selection of indicators, they were quantified in order to create a common baseline for the City of Turin. Mean values of every criterion successively will be used to evaluate the sustainability performance level according to the CesbaMed procedure by the adoption of the SNTool. For the majority of indicators, geo-referenced data were collected and the evaluation of

[3] Data source: Arpa (2019): http://webgis.arpa.piemonte.it/geoportalserver_arpa/catalog/search/resource/details.page?uuid=ARLPA_TO:SENTINEL2_NDVI_2016-01-18-10:00

indicators was done throughout the ArcGis software. This procedure has been applied for the following indicators: Quality of land, Intermodality facilities, albedo and availability and proximity of key public human services. This type of analysis has allowed having a very precise overall picture of the urban context. Thanks to this approach it was possible to observe, not only numerically but also geographically, where the most problematic areas are, where services and main resources are concentrated, and where potentially strategic areas of intervention for the City are located.
However, this depth analysis isn't taken into consideration by SNTool, which uses only the final indicator's value. Calculations and maps obtained with ArcGIS software will be used for the SWOT analysis and in the construction of a future scenario for guide and assess the process toward a more sustainable city. They will allow selecting the interventions, concentrating capitals and optimizing efforts in areas where intervention is needed or protecting areas where it is necessary to maintain the current state.
In this section, the assessment of some of the most important and significative indicators is reported and will compose a complete image of the city of Turin both in terms of strengths and weakness.

3.2.1. Quality of land

Starting from the indicator "conservation of land" which considered the percentage of non-occupied land with ecological value, the indicator aims at evaluating the quality of outdoor spaces and not only its extension in relation to building rate. For doing so, the conservation indicator was cross with the (NDVI) which describes the vigour level of vegetation in a normalized way. NDVI values for vegetation can range from 0 to 1. For the Turin case-study, 5 categories were used to arrange the NDVI values.

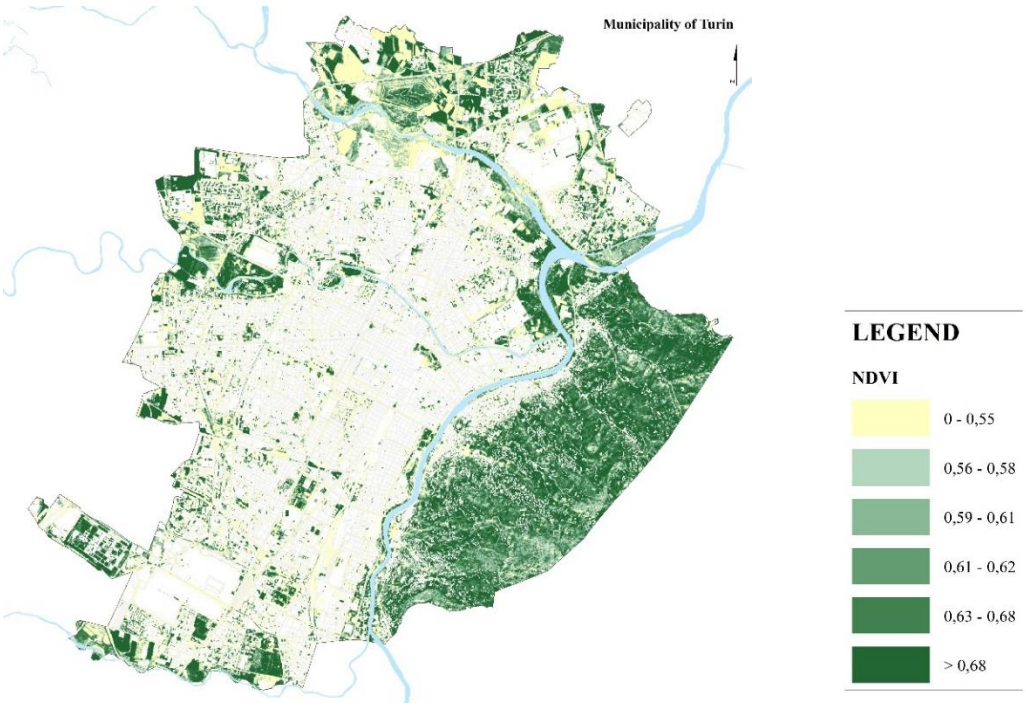

Figure 1: Quality of land. Map of the vegetation quality of permeable areas

There is a large extension of high-quality green areas, in particular in the east hill part of the city. Moreover, the green infrastructure appears fragmented and in the urbanized areas green spaces have very low quality. A mean value is calculated for permeable areas, the result is 0,59, corresponding to the second class, under the threshold of acceptance of 0.69.

3.2.2. Intermodality of facilities

The indicator measures proximity of different means of transport to principal railway stations, subway stations and park&ride parking. A high level of intermodality is made by the possibility of choice between different means of transport and represent a fundamental aspect for a sustainable transition of an urban context, offering alternatives to the use of private cars. The intermodal hub was analysed considering the access to the city: park&ride parking for car access, railway station and subway station as the arrival point for commuters. Starting from every hub a walking distance of seven minutes was considered and mobility services in the area were counted.

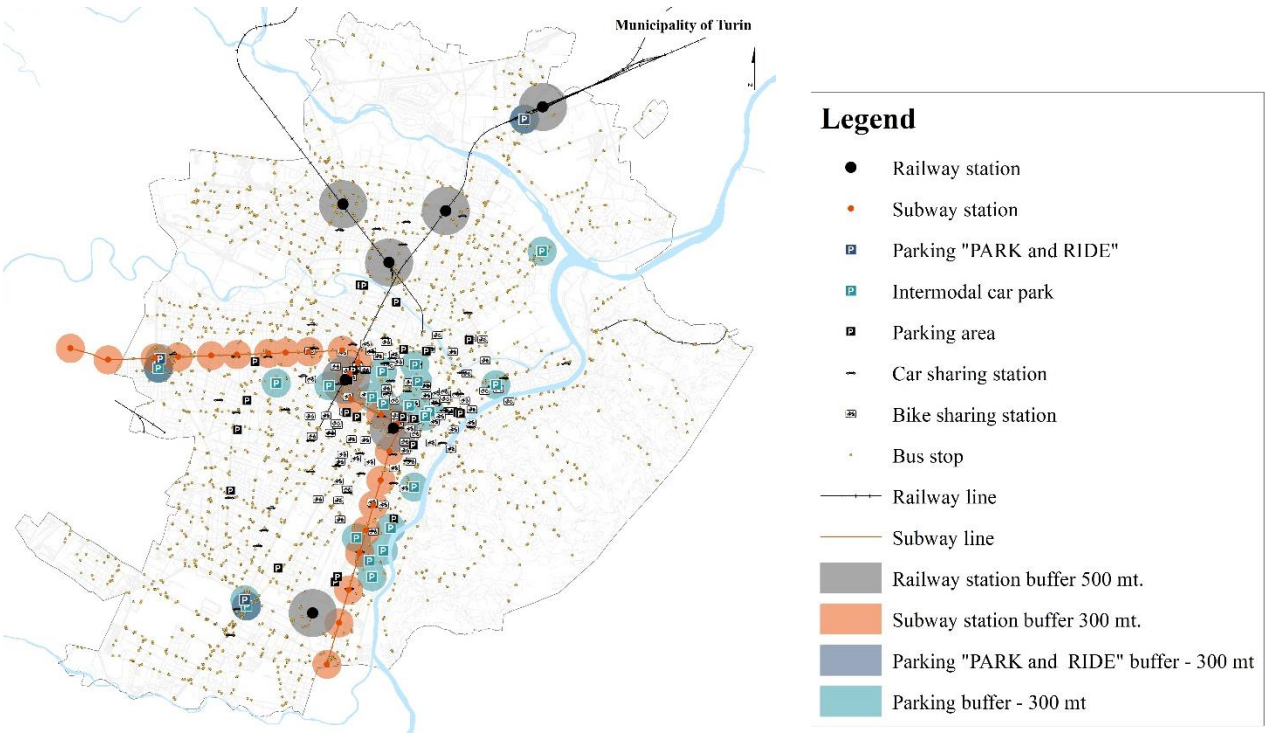

Figure 2: Intermodality of facilities. Map of mobility services and accessibility buffers

Central railway stations have a high level of intermodality and the bus network is equally distributed in the municipal area. Moreover, the north part of the city has a low level of intermodality, with a total absence of some services (subway, car-sharing, bike-sharing, parking).

3.2.3. Total final thermal and electrical energy consumption for building operations

Those two indicators evaluate the consumption of thermal energy and electrical energy in order to identify hotspots of high or low consumption, analyse possible variables related, and suggest specific strategies for different areas. For thermal energy, both district heating (DH) and heating systems were considered. The proposed assessment method is mainly based on existing census data and real measured heating energy consumption data (i.e., both thermal and electrical). Moreover, GIS was used to identify the geometrical characteristics, data and information of the building stock. For the energy system, important correlation can be done with the construction date of the residential buildings. In fact, more than 90% of residential buildings were built before 1980.

From the analysis, the average annual thermal energy consumption is 89 kWh/m^2/year and the electrical one is 31 kWh/m^2/year.

3.2.4. Availability and proximity of key human services

This indicator aims at evaluating in a quantitative manner how key human services are accessible from residential buildings within a 10 minutes walking distance. Three different mian type of services were considered: (i) green areas, (ii) educational facilities of different school levels, (iii) sanitary system categorized into hospitals, pharmacies, and other medical stations.
Since the different types of services were considered, buffers were defined based on the catchment area of each service as listed in Table 3. The percentage of residential buildings inside the buffer area is then calculated.

Table 3: Used buffers for the measure of accessibility and proximity of key human services

Service	Buffer
Kindergarten	300m
Primary/Secondary school	500m
Highschool	800m
Hospital	800m
Medical station	800m
Pharmacy	300m
Neighbourhood green spaces (<500 m2)	300m
District green spaces (>500 m2 and <10.000 m2)	500m
Extensive urban parks (>10.000 m2)	800m

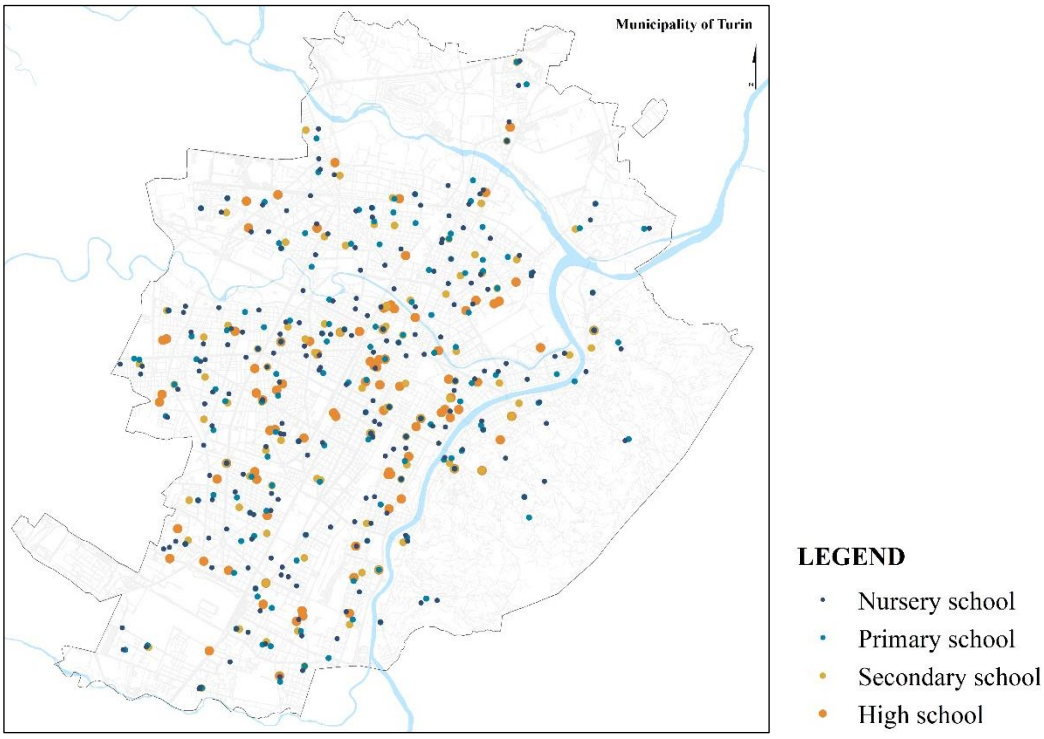

Figure 3: Educational facilities in the Turin Municipal Area

Green spaces have high accessibility and more than 90% of citizens have access to urban parks. Furthermore, it is possible to notice a good distribution of services in the entire municipal area. Moreover, health services are accessible by foot only from 50% of the population, with wide areas hight-populated not served.

4. Conclusions

The paper reports part of the MOLOC project done in collaboration with the City of Turin. The work phase aimed at selecting a proper set of indicators for evaluating the current Sustainability status of the City of Turin and define a common baseline scenario. The selection of indicators was conducted through several phases that involved both administrative and private stakeholders. The final list is based on CesbaMed indicators, adapted to the city-scale of analysis and the specific local context. The resulting indicator provides also an integrated picture of sustainability issues including indicators for all dimensions of sustainability. In the second phase, the baseline scenario was built by using data from a different dataset. In this sense, the baseline scenario will be read as an integrated picture with high-quality geo-referenced data allowing the recognition of specific potentiality and weakness of the area.

As a result, worst performances emerged in the energy and social aspects. An old building stock and geographic position of the city reinforce the bad performance in the energy sector, while a fragmented localization of public services and scarcity in high-populated areas lead to low accessibility to some categories of human services. Forward steps are related to the implementation of the SNTool of CesbaMed project in this city-level project. At the same time starting from results of this phase and the implementation of SNTool some future scenario will be developed in order to include sustainability principles in the new General Masterplan of the City of Turin. These findings contribute in several ways to understand sustainability performance at the city-scale level by the selection of proper indicators through a participative process. Moreover, findings will be also the basis for further analysis of the area and for the definition of future-scenario for envisioning possible spatial transformation toward the achieving of global goals of sustainable development.

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