

Innovative DSS for intelligent monitoring and urban square design approaches: A case of study

Alessandro Massaro, Giuseppe Birardi, Fabio Manca, Claudia Marin, Vitangelo Birardi^a, Daniele Giannone, Angelo Maurizio Galiano

Keywords:

DSS
Multiple correspondence analysis (MCA)
Urban square design
Data processing

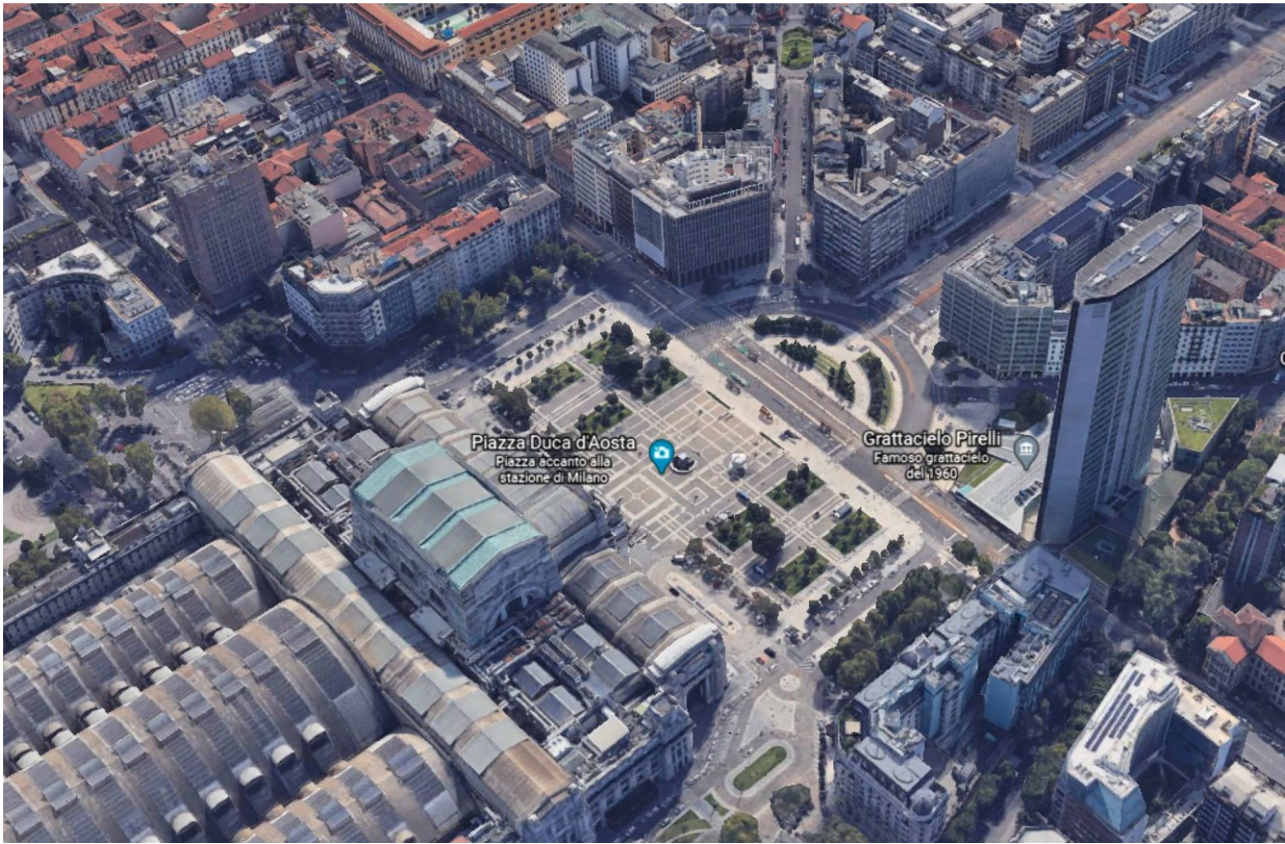
A B S T R A C T

In this paper we proposed a new platform based on data processing suitable for urban square design optimization. The re-design of square in cities is important to make the urban squares livable especially for cities with high population density. Innovative solutions about green space design, computer vision and environmental sensing have been implemented, observing experimentally the influence of the public space on people's behaviour. Furthermore, the platform processes data about weather condition, objects detected by image processing algorithms, environmental pollution and occupancy patterns to perform correlation analysis. A Convolutional Neural Network (CNN) has been used to predict people occupancy over time, basing on a weather dataset. The platform implements a Decision Support System (DSS) aimed to read the data, and provide guidelines for urban square design optimization. The DSS is constructed by data modeling, data mining and multiple correspondence analysis (MCA) tools tailored on the specific case of study. Experimental observations provide insights for a self-adaptive urban square design. Multiple correspondence analysis best fits qualitative and quantitative data obtained from sensors, and highlights people's behaviour in the urban square in correlation with different variables. After a complete overview of factors which can influence the livability of a square and economical/social models are presented different results about citizen behaviour interpretation in function of weather data and attitudes. The proposed framework can be potentially applied for a generic urban square.

1. Introduction

The public space such as the square is a place dedicated to the citizen community. Urban green spaces bring socio-economic, educational, health and environmental benefits for the whole community (Vargas-Herna'ndez, Pallagst, & Hammer, 2018). They also contribute to the conservation of rainwater, the seizure of pollutants, and provide spaces for social events, relaxation and refreshment for visitors. Some environmental and ecological benefits of urban green areas are the maintenance of biodiversity in urban environments (Cilliers et al., 2017; Goddard, Dougill, & Benton, 2010; Savard, Clergeau, & Mennechez, 2000), CO₂ reduction (Jo, 2002; Marchi, Niccolucci, Pulselli, & Marchettini, 2017; Strohbach, Arnold, & Haase, 2012), O₂ contributions (Kuttler & Strassburger, 1999), landscape conservation, and in general the improvement of the urban climate (Hamada & Ohta, 2010; Honjo & Takakura, 1990; Morakinyo, Lau, Ren, & Ng, 2018; Shashua-Bar & Hoffman, 2000; Yu, Guo, Zeng, Koga, & Vejre, 2018).

Urban green acts as a sustainable drainage system, helps to prevent and control erosion due to surface water (Vargas-Herna'ndez, Pallagst, & Zdunek-Wielgołaska, 2018; Zhang, Xie, Zhang, & Zhang, 2012). Other environmental benefits are the reduction of pollution, the purification of water and air (De Ridder et al., 2004; Wolch, Byrne, & Newell, 2014), and the decrease in noise levels (Koprowska, Łaszkiewicz, Kronenberg, & Marcin'czak, 2018). Urban green spaces provide also physical and psychological wellbeing for the citizen community. Green areas are frequented both for activities like running or walking, and also for alleviating stress problems. Contact with nature bring also health benefits (Carrus et al., 2015; Hartig, 2008; Maas, Verheij, Groenewegen, De Vries, & Spreeuwenberg, 2006; Roe & Aspinall, 2011; Vujcic, Tomicevic-Dubljevic, Zivojinovic, & Toskovic, 2019; Ward Thompson et al., 2012) thus reducing health care costs. Evidence of social benefits provided by plants and flowers in office and urban environments has been reported in (Brown, Schebella, & Weber, 2014; Cook, Hall, & Larson, 2012; Dennis et al., 2018; HUSTI, CONT, IU, RADU, NEACS, U, &



/fig. 1. Site of the case of study: Milan, Italy, Duca d' Aosta square.

CANTOR, 2015; Kamioka et al., 2014; Mattson, 2010). In this direction ISPRA (Higher Institute for Environmental Protection and Research) has prepared a significant report that provides useful information about the socio-cultural services of green areas (ISPRA, 2010). Other factors correlated to the urban green space are: natural and built elements, total area of the green area, distance from the city center, duration and frequency of visits, activities performed, relaxation perceived, well-being perceived, emotions (Dentamaro, Laforteza, Colangelo, Carrus, & Sanesi, 2011). Concerning emotions, environmental psychology studies on exposure to natural scenarios have been studied in (Beil & Hanes, 2013; Ulrich et al., 1991), besides, other researchers have examined the reduction of perceived noise determined by the psychological effect of the sight of plants (Yang, Bao, & Zhu, 2011).

Focusing on the link between plant and emotions, some studies have analyzed the effects of foliage views on human attitudes (Adachi, Rohde, & Kendle, 2000), the correlation between foliage color and emotions (Kaufman & Lohr, 2004), and the correlation between flowers and emotions (Barnard, 2004). The same choice of plants can also be oriented towards ecological aspects such as the reduction of pollution (Crane & Stevens, 2006), allowing the formulation of bioindicators of weather forecasts (Chinlamianga, 2011). Moreover, since perfumes and essences have an effect on the human psyche (Sowndhararajan & Kim, 2016), one could choose particularly fragrant plants to implement an innovative "therapeutic path" for the citizen. The design criteria for therapeutic gardens oriented towards "environmental psychology" have been studied in (Ivarsson & Grahn, 2010). However, in 2013 Memluk (2013) discussed the following general specifications validating the main goal of the proposed research based on urban square livability:

- o Create identity, sense of place and contribute to the overall image of the city;
- o Promoting public participation;

- o Encourage social activities, communication and social integration;
- o Improve the characterization of the environment (for example by inserting alternative energy technologies);
- o Create a public square serviceable for long periods;
- o Create social environments and meeting situations;
- o Achieve environmental sustainability and low-cost maintenance through environmentally design strategies;
- o Promoting art, cultural activities and entertainment.

With regard to the "support" technology of the marketing activities that could potentially be carried out, the image processing could provide an automatic evaluation of the squares crowding (Roqueiro & Petrushin, 2007), and by face recognition (Ernst, Ruf, & Kueblbeck, 2009; Galiano et al., 2016; Massaro, Barbuzzi, Galiano, Vitti, & Pellicani, 2017) other information of the citizen such as the identity, the age, the sex and the emotions. Concerning Decision Support Systems (DSS) it can be adopted for the monitoring of the plants and soil (Riezzo et al., 2013; Todorovic et al., 2013), while for the control of the acoustic pollution and the air can be actuated by Internet of Things -IoT- technologies suitable for smart cities (Talari et al., 2017). The DSS can be implemented and improved by data mining, artificial intelligence algorithms, which can be (Kotu & Deshpande, 2014):

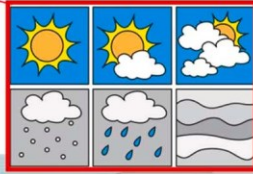
- Classification algorithms;
- Regression algorithms;
- Anomaly Detection Algorithms;
- Time series algorithms;
- Clustering algorithms;
- Association Analysis algorithms;
- Correlation Matrix algorithms.

It is observed that the classification and clustering algorithms are

Square IMUE Architecture

(1) Weather:

- citizen flux analysis in different weather conditions
- citizen seasonal flux analysis

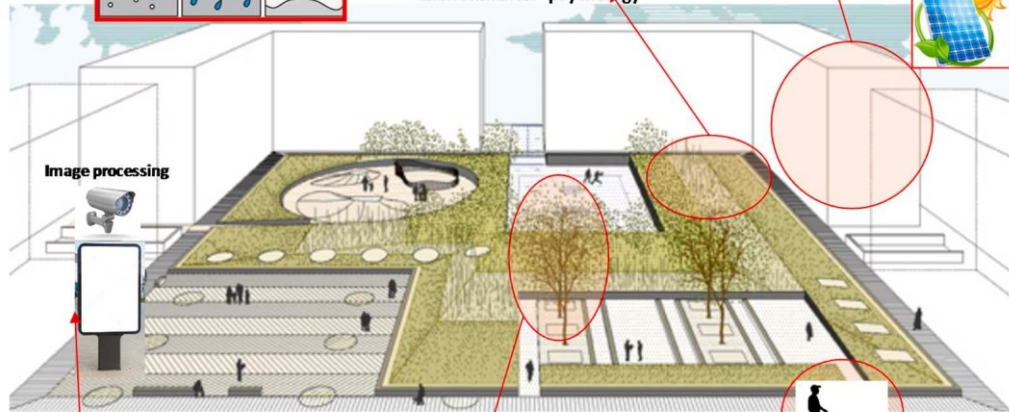


(2) «Automated Architect»:

- Socio-cultural history of the city district where is placed the square
- Analysis of the surrounding environment (proximity to commercial activities, historical / modern scenario)
- Colors, perfumes, lights
- Alternative energy, acoustic analysis
- Design and architecture of the place
- Geolocated data and web social

(3) Green Area:

- Project data
- «Environmental» psychology



(4) Plants:

- Monitoring with sensors of the health status of plants
- Effects on citizens (positioning of plants)
- Colors, perfumes, lights (effect on citizens)

(6) Advertising signs:

- Strategic marketing

(5) Citizen:

- Face recognition (automatic reading of sentiment, sex, age)
- activities and pattern analysis in crowded areas (image processing)

Fig. 2. Square IMUE architecture. The architecture is composed by six modules important for the square design conditioning people behaviour: (1) weather conditions, (2) square design aspects including socio-cultural aspects and energy efficiency, (3) green area design, (4) plants locations and plants care, (5) citizen recognition and behaviour tracing, (6) signs for the strategic marketing. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

able to define the association rules between the different data processing variables, and to “segment” the citizen based on the socio-psychoeconomic-cultural context. Correlation algorithms can instead provide important information about the correlation of different attributes (correlation between lights and odors, or between green technologies and frequency of access to the square, etc.). Finally, predictive algorithms (regression algorithms, time series forecasting, neural networks, etc.) can provide important indications about the future state of a square, or of marketing and/or business intelligence perspectives. Furthermore, multiple correspondence analysis (MCA) can be adopted to appreciate independently e simultaneously the effects of all the qualitative and quantitative variables, purifying them from mutual interference (Massari, Massari, Manca, & Girone, 2016). Some studies are focused on the sustainable cities and society concerning the topics of urban vegetation planning and pollution monitoring (Han, Tan, Zhou, Li, & Qian, 2020), the increase of green infrastructures, and at the same time, the reduce of environmental noise (Renterghem, Dekoninck, & Botteldooren, 2020). Urban vegetation and the environment impact are therefore import elements for urban square design. The introduction of Industry of Things (IoT) sensors allows to support environment monitoring by improving decision making (Ahad, Paiva, Tripathi, & Feroz, 2020), thus suggesting to add sensor in the experimental urban square to improve data processing. Other important aspects to analyze for the public livability are the impact of microclimate on social behaviour in

dense urban cities (Fahed, Kinab, Ginestet, & Adolphe, 2020), environmental compensation about the social-ecological quality (Voghera & Giudice, 2020), the effect of trees on urban quality (Riondato, Pilla, Basu, & Basu, 2020), and the viability of public spaces (Foshag et al., 2020). All these elements are important to define the whole application scenario.

The analyzed state of the art is followed for the definition of the main specifications of an industry research project oriented on the urban square livability and social approaches about urban elements of Milan. The chosen city of the case if study is significant for its high density population. Specifically, the experimentation has been performed in the urban square in front of the railway station (see “piazza Duca d’Aosta” indicated in Fig. 1).

2. Preliminary project specifications

In this section are reported the main goals of the “SQUARE IMUE” (Square Intelligent Marketing for Urban Ecosystem) project, following the principles found in the state of the art. The main attributes involved for the urban square design are illustrated in the scheme of Fig. 2. Below are listed the main specifications of the project summarized in Fig. 3:

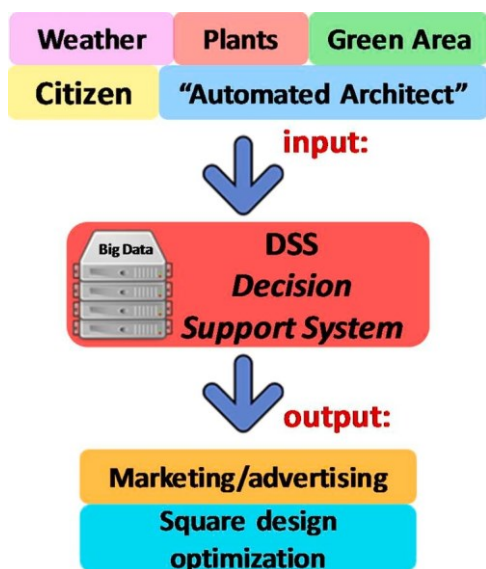


Fig. 3. Main specifications of the project “Square IMUE”: the DSS input are the variables related to the points (1),(2),(3),(4),(5) of Fig. 2, and the DSS output concern the specifications to optimize square design and the strategies able to bring people closer to the advertising signs.

2.1. Care, planning and remodeling of urban spaces through green areas

This includes the planning of the allocation of plants and greenery to guarantee new public spaces in urban areas, and a new way of experiencing the city involving the society in squares with green areas. This “concept” leads companies to co-design the urban ecosystem by bringing them closer to an interaction with the citizen.

2.2. Reception and integration of “vulnerable” citizens

The planning of the square will give an opportunity to “vulnerable” citizens (handicapped people, elderly people with critical issues, blind person, etc.) to grow and live with their problems by going to urban squares, meeting new people, and participating in collective activities. These motivations therefore initiate a progressive treatment path, supporting social integration and educating the citizen to respect the green by socializing with “fragile” citizens. The fragile category can be stimulated to attend the public urban spaces thus improving their health psychological status.

2.3. Interaction and communication with companies for the activation of marketing strategies with a return on the public good (care of the square)

The companies, through the DSS interfaced with a Big Data system, will activate targeted marketing and advertising strategies: through the application of artificial intelligence algorithms it will be possible to predict the commercial trends of citizens and will they will intelligently design advertising spaces. The statistical approach involved the analysis of multiple multivariate analysis techniques, such as factorial analysis, cluster analysis, principal component analysis, multidimensional scaling, canonic correlation, discriminant analysis, etc. Among all, the model that responded to the demands of this specific study was the model of multiple correspondences analysis, that was supportive to analyze the behaviour of the visitors of the square, based on the climate, the brightness, time slots and days of high frequency. The strategic marketing approaches will be oriented on the spatial allocation of the advertising signs (places of major occupancy) and on the efficacy evaluation of the related contents in terms of citizen observation time.

2.4. Technological innovation of the squares through the introduction of smart cities technologies

Through specific weather stations and sensors that transmit weather data and terrain conditions in the cloud, can be monitored in real time the health status of the plants, providing also information about weather risks predicted by DSS. The analysis of wind, rainfall, soil moisture, atmospheric humidity, presence of CO₂, and direct solar radiation will be used for the planning of the care of plants and greenery, and for the allocation of new plants that will best adapt to the environmental conditions of the square “ecosystem”. Face recognition extracting information such as sex, age, humor, and activities can be an interesting tool for analyzing the impact of the citizen with the square. Image processing will also be used to analyze the spaces of the most frequented square, the daily / seasonal overcrowding, and to ensure greater security. Moreover, the design includes technologies of alternative energy sources (photovoltaic, mini-wind) making the square of the “green” type. Finally, the acoustic sensors will instead give indications about the impact of the citizen on squares by analyzing a different dB level of acoustic noise.

The DSS represents the core of the proposed platform indicating, by graphical dashboards, the social urban square indicators based on experimental observations, providing at the same time a tool for architects to re-design the spaces. The term “Automated Architect” of Fig. 2 encloses this concept and means that the DSS output can automatize the urban square optimization, by providing to architects new elements for the re-design such as: architectural aspects, socio-economic environment, sensorial elements (plants, perfumes, lights), technologies with low environment impact (acoustic absorbance panels, alternative energy technologies) etc.

The strategy is to formulate a DSS able to integrate statistical approaches, economic indicators and technologies able to provide dashboards oriented on urban square sustainability evaluation. In particular in the prototype platform multiple correspondence analysis MCA is able to process image vision and sensor outputs. MCA combines more variables such as weather data, citizens occupancy, and people flux thus providing a framework of the social impact of the urban square. All data and processed data are collected into a graphical dashboard showing also different indicators matching with the preliminary main specification of the project.

3. Platform design and framework

3.1. Platform design

The dataflow of the platform design is summarized in Fig. 2 where the DSS processes input data for the evaluation of square features and marketing strategies (output of the system). The input data are classified in the following classes:

(1) Weather data: weather data provide information about the number of citizens in the square in function of different weather conditions, about the choice of plants (design of green areas based on seasonal plants or flowers), and about marketing activities to be carried out using advertising signs; an image processing tool provides the condition of “crowding” for certain hours of the day characterized by particular weather conditions; the weather data are stored into a Big Data system so that the DSS can make predictions of turnout of squares with a low rate of calculation error, using historical inflow data correlated with weather data.

(2) “Automated Architect” data: these data include all the solutions of the urban square design (green spaces and types, alternative energy technologies, visual impacts, etc.) useful to reformulate spaces observing citizens behaviour and to re-design new square layouts integrated into urban ecosystems; historical and socio-cultural information of the neighborhood in which the square is located (or where will be built) support the choice of the new solutions to make the square more livable and frequented according also to the surrounding environment

(modern or historical scenarios, presence of commercial structures or other attractions such as cinemas, theaters, etc.); in addition data of scientific studies about the effects of lights and perfumes of plants are useful in order to establish the plant optimal spaces based on the square layout; other data such as exposure to sunlight, and exposure to wind are indicative for the planning of possible technological solutions as mini wind turbines and photovoltaics; the proposed platform is adopted to collect citizen feedbacks about the "impact" of the square to be process to identify positive and negative adopted solutions; furthermore the acoustic and CO₂ pollution sensors also provide important information about the impact of noise and air on the citizen who frequents the square and consecutively about the square "livability".

(3) Green area data: the data of the green area mainly concern the

project data (extension, allocation, orientation, etc.), and information pertaining to the psychological effects of the green area and of plants and flowers on citizens and on fragile people (the effects will be analyzed with the aim of evaluating the therapeutic effect in an "environmental" psychology perspective).

(4) Citizen Data: citizen's interest and emotions in observing advertisements represent an important specification; a camera traces the citizen patterns within the square, counting the number of people at different time points (assessment of crowding), and evaluating the citizen segmentation (classification for sex, age, etc.).

All the mentioned data will be stored into the Big Data system.

The DSS outputs will mainly consist of correlations between attributes, predictive calculation of the impact of a square and of marketing and business intelligence strategies, analysis of correlations between endogenous and exogenous attributes and variables for determining factors of greater influence for the design of a square, multivariate analysis and, in particular, multiple correspondence analysis. The experimentations are performed in the urban square of "Piazza Duca D' Osta" in Milan.

3.2. Platform framework and analytical models

Basing on SROI framework (Kehl, Then, Krlev, & Mildenberger, 2018; Purwohedhi & Gurd, 2019; Sukthomya & Laosiritaworn, 2018; White, 2018) a novel methodology — namely "Strategic Return on Investment" StROI — was developed by the research team to measure quantitatively whole system impact generated by CCI in the experimental set. In particular the aim has been to measure the strategic value generated for every stakeholder involved in the project, given the upfront economic and social value invested.

The process has been articulated in 5 steps:

- 1 Identification of expected results of each stakeholder
- 2 Quantitative analysis of inputs and outputs by domain.
- 3 Impact definition and value estimation through proxies development.
- 4 Impact calculation and normalization.
- 5 Cost/benefit analysis

Impact value estimation can involve the qualitative and quantitative investigation of different domains, and therefore must be backed to a large extent by reliable data and specific literature. As a reference, tree planting provides various ecosystem services to urban species, and impact value estimation in urban environment has been defined in a number of ways (Go'mez-Baggethun et al., 2013; Gratani, Varone, & Bonito, 2016; MacFaden, O'Neil-Dunne, Royar, Lu, & Rundle, 2012; Millward & Sabir, 2011; Peper et al., 2007). In New York City municipal forest resource analysis (Peper et al., 2007) total value of annual benefits (B) for each park and street tree (j) in each management area (i) benefits has been calculated as:

$$B = \sum_i \left[\sum_j i(e_{ij} + a_{ij} + h_{ij} + p_{ij}) \right] \quad (1)$$

e = price of net annual energy savings = annual natural gas savings + annual electricity savings;

a = price of annual net air quality improvement = PM10 interception + NO₂ and O₃ absorption + avoided power plant emissions – BVOC emissions;

c = price of annual CO₂ reductions = CO₂ sequestered – releases + CO₂ avoided from reduced energy use;

h = price of annual stormwater runoff reductions = effective rainfall interception;

p = price of aesthetics = annual increase in property value.

Even if total output values can be calculated by functions as the one herein described, the strategic value of each output/impact can be different for each stakeholder (and so his interest in Corporate Community Involvement (CCI)). Input, output and impact traceability has been supported by assigning a "stakeholder class" for every value estimation (the value generated by newly planted trees could be different for each stakeholder and for different reasons), so that analysis can be grouped by stakeholder or domain (environment, sociality, corporate reputation, finance etc.). As a result the research problem has been framed by a function where Strategic Return on Investment (StROI) for each stakeholder (SH) was calculated as:

$$StROI = \sum_{k \in \{SH_1, SH_2\}} \frac{\sum_{i=1}^{MS} \sum_{j=1}^{dim(x_j)} S_j(x_{ji})}{I_i} \quad (2)$$

where x_j is the vector which identifies k class impacts associated with output j , with components (x_{j1}, x_{j2}, \dots) and dimensions $dim(x_j)$. Main stakeholders are identified with k class (SH₁, SH₂). I_i is a measure of the investment, where MS is the total number of investments of each stakeholder SH.

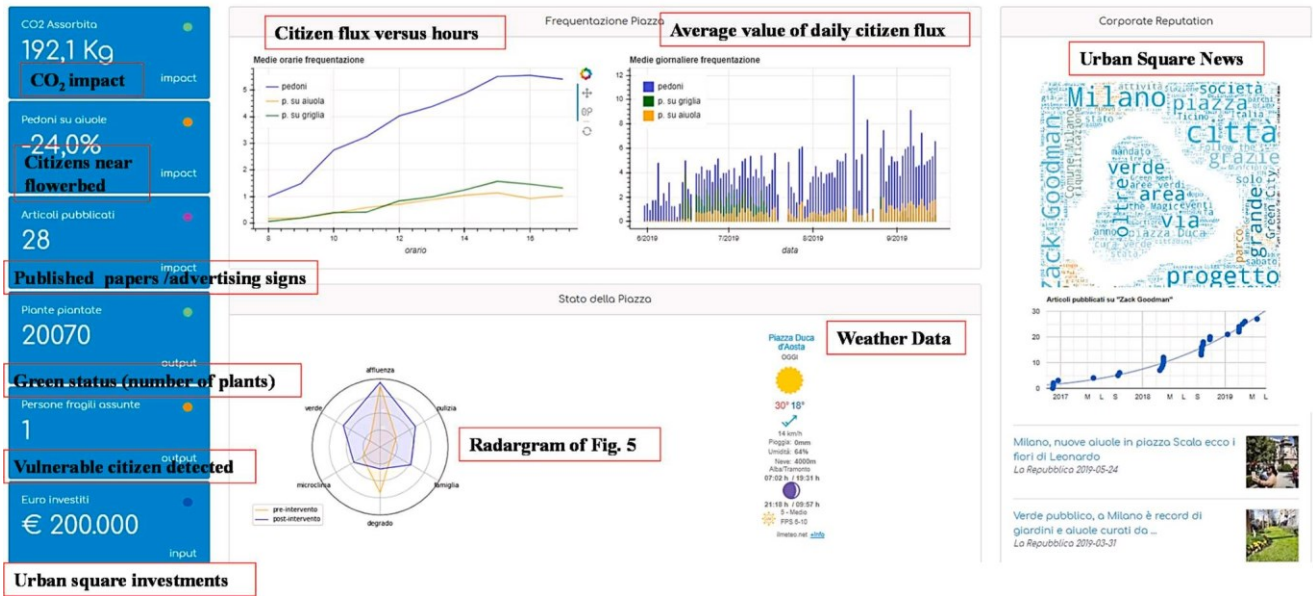
With more detail, every redevelopment project results in $n(k)$ outputs, where for each output (x_j) a number $dim(x_j)$ of impacts is measured with the function S_j .

In the experimental set, 40 trees, 30 summer flowering shrubs and 20,000 herbaceous plants were planted in a 2600 m² public area in front of Milan Central Railway Station.

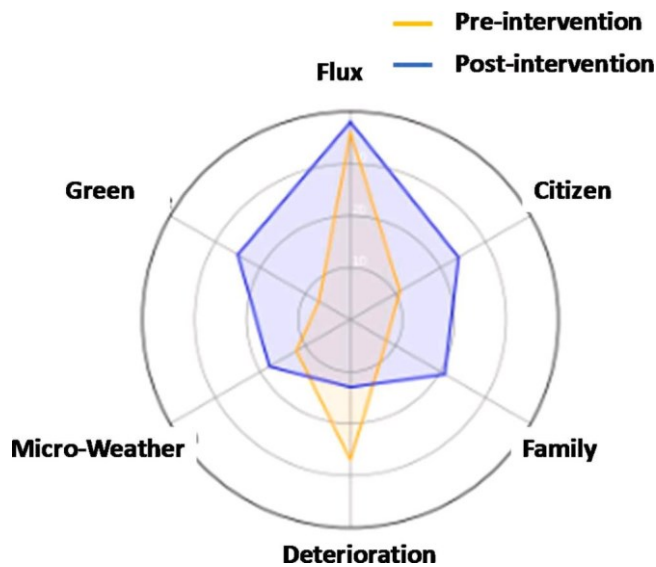
Sensing devices were carefully designed to be used in urban environment and to be 100 % solar powered. After various site inspections and with the agreement of every stakeholder, 2 video stations with auxiliary IR timelapse function and 1 weather station with a custom set of sensors (air temperature, air moisture, noise pollution level, soil moisture, precipitation, air pollution) were designed, prototyped, tested and installed in the area.

DSS software application has been developed in Python using different libraries. Web scraping for Corporate Reputation scoring has been developed using Beautiful Soup on articles ranked in google news and selected by keywords, with a reputation scoring based on Loughran and McDonald lexicon (University of Notre Dame, 2016). Front-end graphics are based on Bokeh. Exploratory data analysis has been performed using pandas, numPy and Altair. Human detection has been performed using RetinaNet model. Age estimation on face detection has been performed with a Histogram of Oriented Gradients (HOG) feature descriptor, Sentiment and gender estimation are based on a Haar Cascade classifier. A Convolutional Neural Network (CNN) was used to identify garbage laying on pedestrian path and to predict people occupancy over time, basing on a set of weather data (temperature, humidity, pressure).

Calculations on tree planting benefit was performed with i-Tree. i-Tree is a suite of urban forestry software tools designed to help communities of all size strengthen their urban forest management and



/fig. 4. Data control panel of the implemented platform. The graphical dashboards indicate: economical aspects related the square investments, the plants and green status condition, the weather data, the Kiviat radar diagram summarizing attributes before and post design intervention, statistical data and news. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).



/fig. 5. Kiviat radar diagram with a pre and post intervention estimation: the indicated variables are the weather conditions detected in the experimental square (micro-weather), the deterioration degree indicator of the square, the detection of families, the detection of single or groups of citizens, the green status indicator, and the people flux quantified during the day. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

advocacy efforts by quantifying the structure of community trees and the value of ecosystem services that trees provide, based on peer-reviewed USDA Forest Service Research (<https://www.itreetools.org/>. Accessed: 02-Jan-2020.). Within *Learn about i-Tree (2020)*, street tree populations are assessed using Streets. i-Tree Streets uses tree inventory data to quantify structure, function and value of annual benefits. Descriptions of the numerical models used to calculate effects of trees on energy use, carbon storage, air pollutant uptake, rainfall interception and residential property values are found in (Maco & McPherson, 2003).

Additional information on the assumptions and calculations used in i-Tree Streets to compute structure, function and value can be found in six Tree Guidelines documents, one for each climate zone.

4. Platform dashboard

4.1. Platform dashboard

The main dashboard of the “SQUARE IMUE” platform is illustrated in Fig. 4. It is structured in four main blocks:

1 (left):

- measured CO₂;
- persons on flower beds;
- published articles;
- planted plants;
- fragile people (senior citizens, children, etc.) recognized by image processing;
- investments;

2 (top middle):

- graph about average hourly measured people flux;
- graph about average daily measured people flux;

3 (top bottom):

- radargram about comparison between attributes before and post intervention (see Fig.5);
- real time weather data;

4 (right):

- statistic about published papers;
- news.

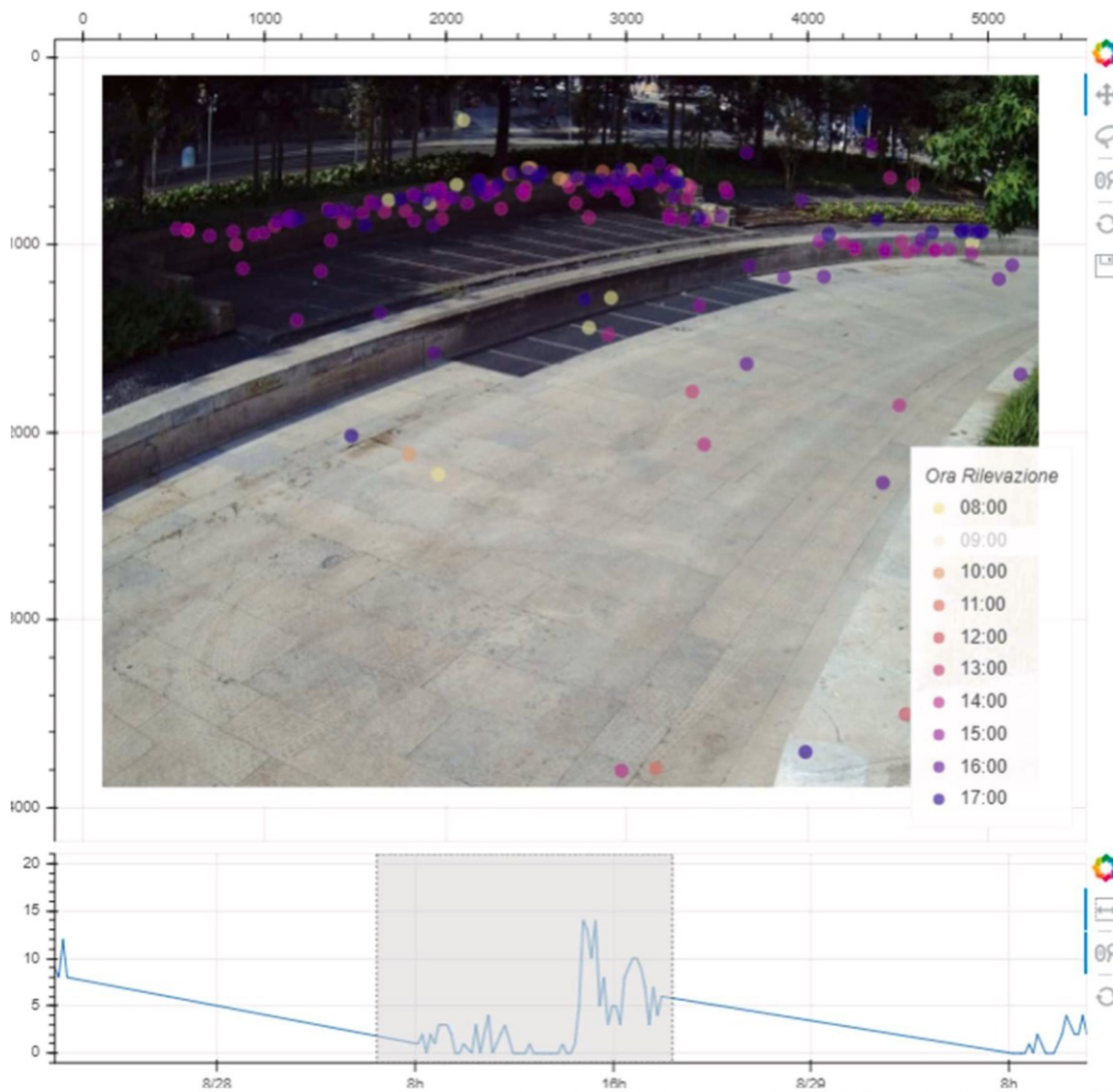


Fig. 6. Detected people location (above) and occupancy (below) over time. The plot indicates how the people flux is distributed in a specific monitored region of the square. The information associated to the hour is used to understand people behaviour during the whole daily time.

4.2. Image processing results

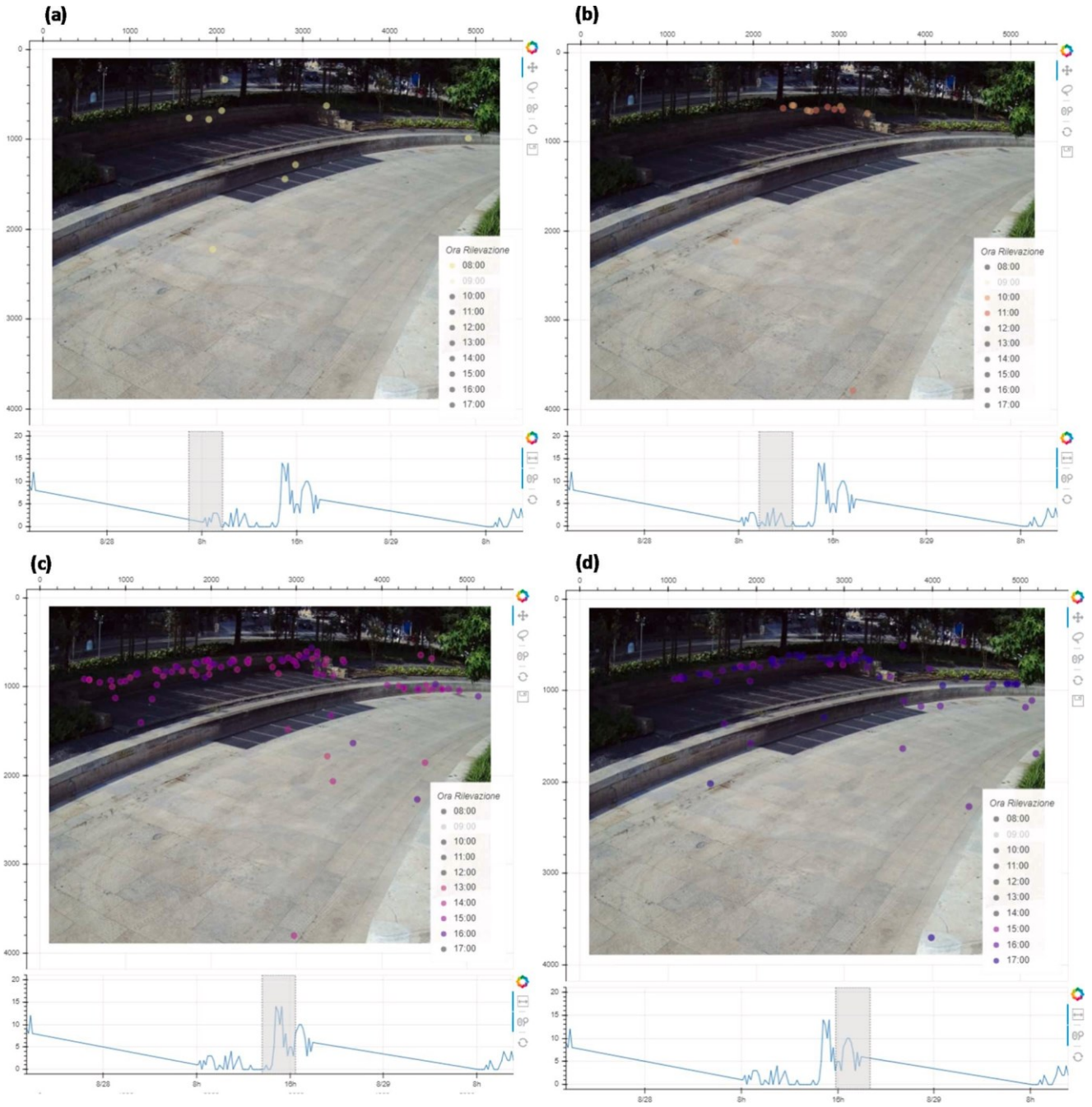
In this section are illustrated the image processing results. Fig. 6 and Fig. 7 show different samples of the interface used to study people's location and occupancy over day time. In the image above, dots represent people detections. A different color is assigned on hourly basis in order to highlight with overlay meaningful changes connected to daily routine. The line graph underneath reports detection number variations over time. Such interfaces have been used extensively to classify patterns in people's behaviour, and eventually to detect a improper use of the public space due to sub-optimal design of the square. Fig. 7 shows detection variation during one day. During the afternoon, the public space has revealed to be overcrowded in a defined area with a low wall not intended for use as park bench by initial design. The area was partially hidden and shaded by vegetation, eventually promoting crime activities. The analysis suggested the intervention of interdicting the access to the area with a barrier, which resulted in turn in a 95 % decrease of people detection on other green areas not intended for people use.

Fig. 7 illustrates the temporal dynamics of the people flux and occupancy: at 8 a.m. are checked few citizens in the monitored area (Fig. 7 (a)); between 10 a.m. and 11 a.m. are observed few citizens only in a

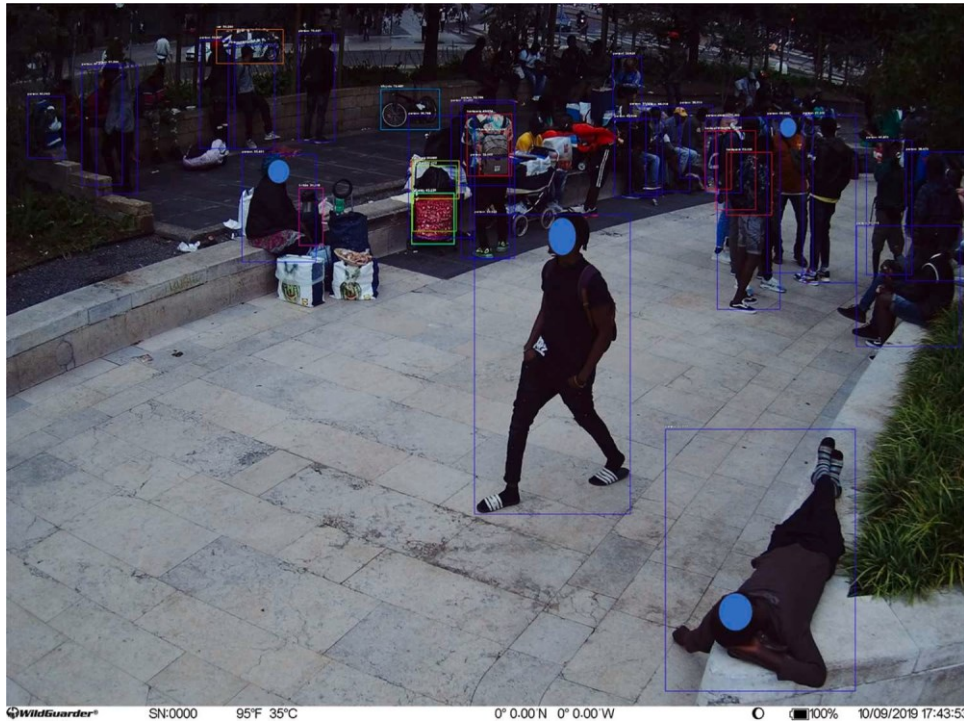
specific location (Fig. 7 (b)), between 13 a.m. and 4 p.m. more citizens occupy the monitored area in different zones (high occupancy proved by Fig. 7 (c)); between 4 p.m. and 5 p.m. is observed a slow occupancy decrease of the occupancy (Fig. 7 (d)).

The platform is able also to detect objects: in Fig. 8 are illustrated the windows areas recognizing objects. The object recognition is performed by a CNN network (Resnet 50 model) able to classify the image detected by the installed camera by recognizing different objects (bicycles, bags, scooters, etc.) and animals (dogs, cats, etc.). In the Box plot of Fig. 9 is illustrated a statistic of persons and objects detected by the CNN algorithm: the analyses of the used objects, of the people locations, and of traced patterns support to understand how the urban square is lived.

The same statistical approach is reported in Fig. 10 (a) and Fig. 10 (b), indicating people number over time on a test day, where the blue line represents the actual values (ground truth) and the other lines are the output of the image processing algorithm. A critical aspect of the CNN image processing algorithm is the detection of people during overcrowding, leading to high bias in the image processing results (see Fig. 10 (a)). In order to minimize the processing error, algorithm parameters (learning rate, minimum percentage probability of detection, epochs number) have been tuned, obtaining convergent results (see Fig. 10 (b)).



/fig. 7. (a),(b),(c),(d) Differences in people occupancy patterns during daily time. The people behaviour is also function of the occupancy patterns distributed during the daily time. The proposed analysis is also usable to understand the people's habits.



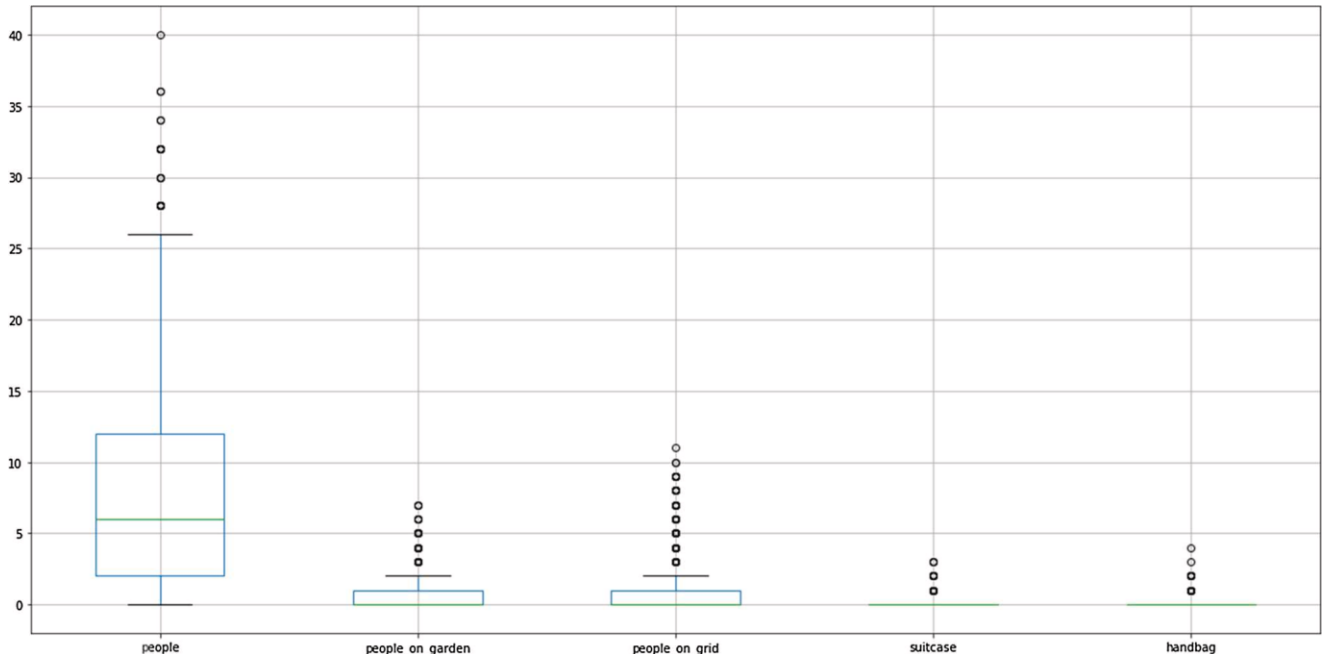
/fig. 8. People and object detection through image vision algorithms: object recognition is adopted to understand how the urban square is lived, by defining a generic people behaviour. Image vision CNN algorithms are adopted also to recognize fragile person and families.

5. Multiple correspondence analysis (MCA)

Bivariate data analysis has been led using the chi squared test that allowed to analyze the correlation between the time slots and the days of the week. Furthermore, the same model was used to analyze the relationship between the following two variables: persons identified on the flowerbeds and detected persons. Both tests show a high correlation between the variables with a p-value below 0.000 (P value <0.000) (Table 1).

It has been used multiple correspondence of different variables to study the structure of relationships existing in a set of categorical variables and to interpret the relations among the categories of those variables by means of their projection in a space with a reduced number of dimensions (Table 2).

Multiple correspondence analysis (MCA), that is an extension of correspondence analysis to more than two variables, leads to the determination of several latent variables, orthogonal to each other with denominated dimensions in a number equal to the rank of the data



/fig. 9. Box plot for descriptive statistic of people and objects detected by computer vision algorithms. The box plot indicates the distribution of the recognized objects and persons supporting the analysis of the square livability and the people behaviour by analyzing the used objects.



Fig. 10. (a): Ground truth (blue line) and people detected by the CNN algorithm with and without image postprocessing (orange and red lines). (b): Ground truth (blue line) and people detected by the CNN algorithm without image post-processing after hyperparameters tuning (orange line). The second plot indicates the convergence between actual and processed results thus proving the correct choice of the CNN parameters (learning rate, epochs number, etc.) for object and people detection. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Table 1
Contingency table between time slots and days of the week.

Days	Time slots			Total		
	8—10	10—12	12—14	14—16	16—18	
Monday	24	24	21	24	21	114
Tuesday	22	24	24	21	24	115
Wednesday	22	24	24	22	21	113
Thursday	24	22	24	25	21	116
Friday	24	24	22	24	20	114
Saturday	34	36	35	38	23	166
Sunday	35	36	32	36	36	175
Total	185	190	182	190	166	913

Chi squared test, P-Value < 0,000.

matrix employed. The total variability is named as total variance or total inertia and it is equal to the sum of variances or inertias of the dimensions. It is possible to obtain a lower number of orthogonal variables through the passage from the categories of the original variables to the dimensions. The following dimensions show decreasing quotas of the total inertia, so that only a few are necessary, in almost all cases 2 or 3, to concisely and effectively represent the most significant quota of the relationships among the categories of observed variables. Projecting the categories on the axes of the dimensions produces simple representations, facilitating interpretation, and more specifically, by limiting attention to two dimensions, facilitating the interpretation of the proximity or distance between the different categories of the diverse variables as association or disassociation (Manca, 2004).

Multiple correspondence analysis, that has been carried out using the SPSS (*Statistical Package for Social Sciences*) Categories module, has been applied to the following 6 variables: brightness sensor, humidity,

Table 2

Contingency table between persons identified on flowerbeds and detected persons.

Detected persons	Persons identified on flowerbeds					Total
	1	2	3	4	5	
1	9	0	0	0	0	9
2	25	2	0	0	0	27
3	25	9	0	0	0	34
4	35	16	2	0	0	53
5	45	24	5	0	0	74
6	34	21	9	0	0	64
7	23	22	3	3	1	52
8	16	13	7	1	0	37
9	14	12	5	2	0	33
10	7	7	4	1	0	19
11	2	6	1	0	0	9
12	0	1	1	0	0	2
13	1	1	0	1	0	3
14	0	0	1	0	0	1
16	0	1	0	0	0	1
17	1	0	0	0	0	1
Total	237	135	38	8	1	419

Chi squared test, P-Value <0,000.

temperature, people passing by, people on flowerbeds, people in the middle of flowerbeds, corresponding to a total of 38 categories.

The analysis has been led considering the eigenvalues higher than their average, calculating the corrected inertias of the relative dimensions by utilizing the Benzecri criteria, where the variance quota of axis l is:

$$\zeta_l = \frac{G\lambda_l}{K - G}$$

and the average of eigenvalues is: $\bar{\lambda} = \bar{\epsilon}$

The percentages of variance of the first axes are generally modest, because of the elevated dimensionality of the point clusters. In order to leverage on the importance of the first axes, Benzecri (1979) proposed the use of modified quotas of variance.

For: $l = 1, 2, \dots, l_{max}$ so that: $\lambda_l > \bar{\lambda}$,

$$1) \text{ The pseudoeigenvalues: } \lambda'_l = \frac{G}{G-1} (\lambda_l - \bar{\lambda})^2;$$

$$2) \text{ The sum: } S = \sum_{l=1}^{l_{max}} \lambda'_l;$$

have been calculated.

Therefore: $l < l_{max}$ the modified quotas are: $\zeta'_l = \frac{\lambda'_l}{S}$ (Brigitte Le Roux - Henry Rouanet, 2010).

The model of multiple correspondence analysis has been firstly applied on the variables "people on the flowerbeds" and "brightness sensor". The values of the Cronbach indexes are high in all the cases illustrated in appendix A and highlight the complete validity of the dimensions considered. The results of MCA analysis discussed in the Appendix show for the specific case of study that:

- there is no presence of people on the flowerbeds with low brightness values;
- there is no presence of people on the flowerbeds with high humidity rate;
- there is no presence of people on the flowerbeds with high temperatures;
- people do not spend time in the middle of flowerbeds in conditions with low brightness;
- people go in the middle of the flowerbeds only if the humidity level is not so high;

- high temperatures avoid people to spend time in the middle of the flowerbeds;
- with high humidity level, people do not pass by the square;
- people do not pass in condition with low brightness values;
- people pass only in conditions of low temperatures.

The choice of multiple correspondence model among all the multivariate statistical models available is suitable for the specific case of study because it allows the simultaneous analysis of a set of variables by reducing them to a smaller number of dimensions (called factors) that express combinations of the same variables. The model elaborates a particular multiple contingency table using the chi-square distance and analyses the relationship between rows and columns separately, but also jointly. For each variable, a set of new variables is defined, a square matrix is produced, that can be considered as a multiple distribution of frequencies and the dispersion of each variable with respect to the respective marginal totals is analyzed. These operations are carried out using the chi-square metric which measures the distance between two profiles (the distribution of people present in the square by days of the week and time slots, distribution of people present on the flower beds and low humidity level, distribution of the number of people and high humidity, distribution of people on the flower beds and high temperatures, etc.) by weighting each element by the inverse of its importance on the total frequencies. As a result of the weightings made, the contribution of the low frequency variables is re-evaluated and the contribution given by the high frequency variables is reduced. The goal is to build a few dimensions capable of reproducing most of the inertia present between the variables analyzed in a small number of factors that express combinations of the original variables. For the graphical representation of a greater number of variables, the multiple correspondence model has been used because it represents a robust model and this is evidenced by the Cronbach test which highlights values that measure the goodness of fit of the model to the collected data.

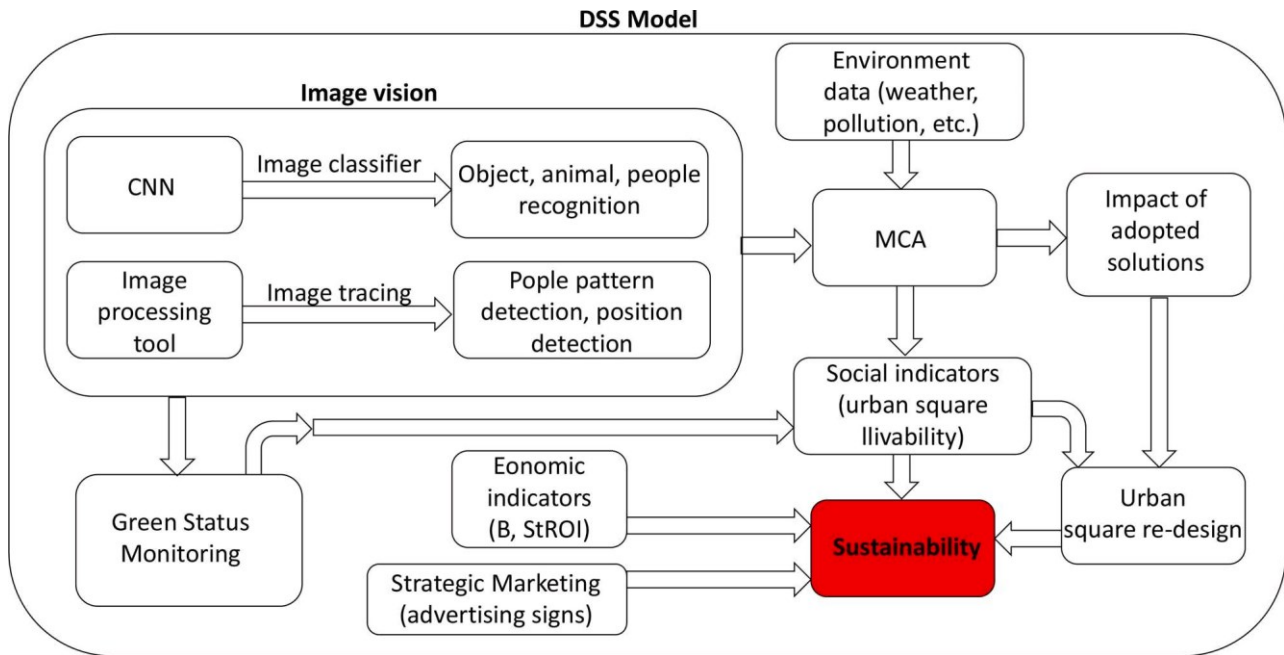
6. Conclusion

The proposed work describes different methodologies for the urban square monitoring to design and to re-design the spaces improving citizens livability. The paper introduces an innovative model of a DSS oriented on social and economic sustainability involving different technologies, economic indicators and MCA approach. All the facilities of the proposed DSS model and discussed in the paper are linked as illustrated in Fig. 11. The matching between parameters denoting the social impact of the urban square solutions, the citizen behaviour, the urban square status monitoring and economic aspects are able to provide graphical dashboards supporting sustainability evaluation.

The experimentation has been performed in Italy, in Duca d' Aosta square of Milan. The indicator modeling, the image processing and the multivariate analysis have been adopted for the square design optimization. In particular convolutional neural networks provided people tracking time monitoring and object recognition, besides the statistical approach has been applied for the correlation analysis between people behaviour and weather sensors data. The image processing highlighted the people attitude to stop in precision locations in particular time windows, and represents a powerful tool to identify specific citizens including fragile persons and families living the square.

A particular attention has been addressed to the analysis of occupancy patterns of people flux during daily time, to people detection, and object recognition thus supporting a statical analysis oriented on the definition of square livability parameters and on the citizen behaviour in squares. In this direction, the MCA is a useful tool to support people behaviour analysis by processing simultaneously other different variables potentially influencing the people behaviour such as meteorological variables, brightness conditions, pollution, and specific locations of the experimental urban square.

All the proposed approaches can be adopted for the monitoring of



/fig. 11. DSS model.

other urban squares as pilot methodologies to take into account for social analyses. The people behaviour analysis can be important also for strategic marketing by adding advertising board in in places preferred by citizens. The marketing output of the project is also to define preferred square locations to install advertising signs. This strategic marketing analysis is important because private investors could finance the square re-design and renovation according the estimated indicators. All the indicators are summarized into a graphical dashboard facilitating the control and the square adjustments in order to increase locally the social welfare. The proposed study is very important for all sites having high density of population and also for city parts characterized by a social degrade. The adopted technologies can be applied also for public uses including infrastructure monitoring and environment noise and pollution: other technologies such as infrared thermography, gas sensor, and acoustic analysers should be implemented in order to observe citizen behaviour and urban square microclimate, and to control subterranean waters, gas pollution, and acoustic noise.

Declaration of Competing Interest

The authors report no declarations of interest.

Acknowledgments

The work has been developed in the frameworks of the Italian projects: "Sistema di supporto alle decisioni orientato alle attivita` di marketing correlati alla progettazione intelligente e innovativa delle piazze 'SQUARE IMUE'" ['Decision support system oriented to marketing activities related to intelligent and innovative planning of squares']. Author gratefully thanks for their contribution the researchers B. Boussahel, D. Convertini, L. D'Alessandro, E. D. Fonte, V. Maritati, A. Palmisani, and M. Vincenti. Authors also gratefully thanks R. Belli and G. Tirri of Zack Goodman S.r.l (Italy).

Appendix A. MCA results

The first two dimensions explain the 82.7 % and the 82.1 % of the total corrected inertia. The following Fig.12 shows that there is no presence of people on the flowerbeds with low brightness values.

The contribution to overall inertia for the humidity variable is considerable on both dimension: 90.1 and 89.3 % respectively. Fig. 13 illustrates that there is no presence of people on the flowerbeds with high humidity rate.

For the temperature variable, the contribution to overall inertia is 81.4 and 81.1 % respectively. There is no presence of people on the flowerbeds with high temperatures, as shown in Fig. 14.

The model of multiple correspondence analysis applied on the variables "people in the middle of flowerbeds" and "brightness sensor" confirms, with a total inertia of 76.8 and 72.3, that with low brightness values, people do not spend time in the middle of flowerbeds (see Fig. 15).

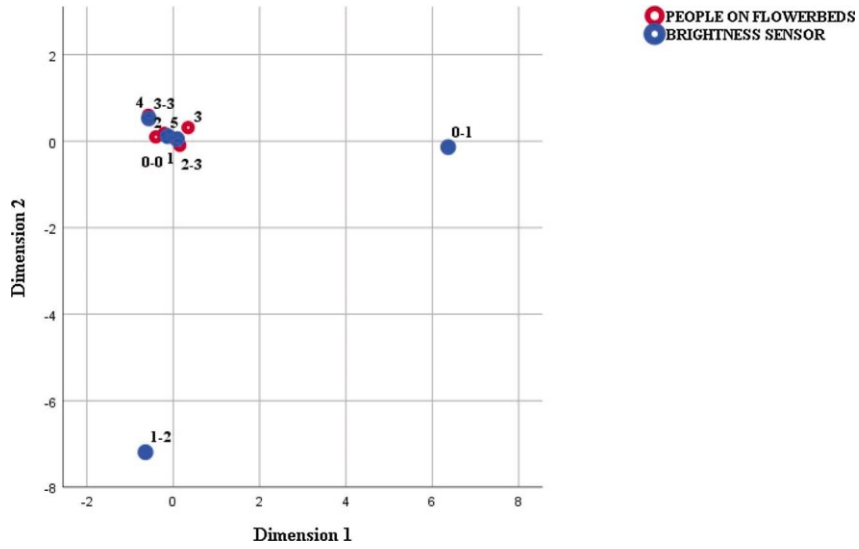
The association of the variables "people in the middle of flowerbeds" and "humidity" shows a total inertia of 77.4 % in the first dimension and of 72.7 % in the second dimension. As illustrated in Fig. 16, people go in the middle of the flowerbeds only if the humidity level is not so high.

High temperatures avoid people to spend time in the middle of the flowerbeds. The overall inertia in this case is 76.1 % for the first dimension and 72.5 % in the second one (see Fig. 17).

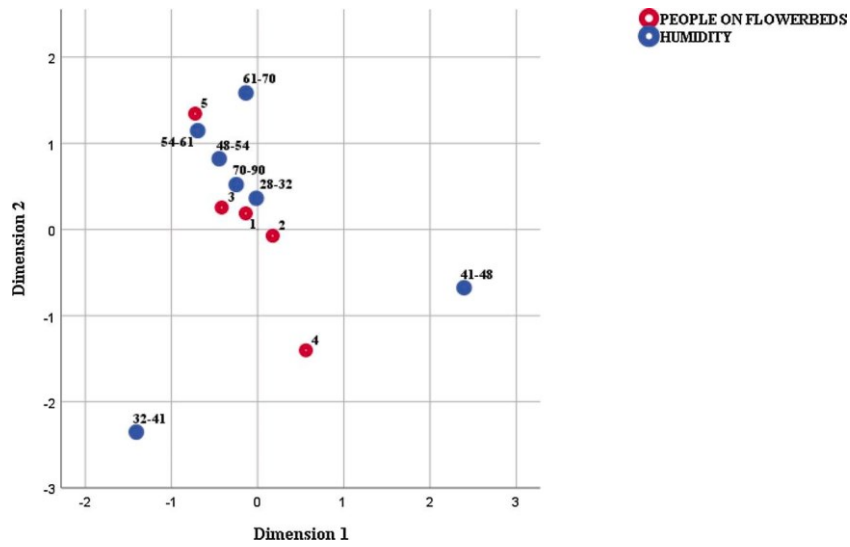
The following Fig. 18 illustrates that with high humidity level, such as 54–61 and 61–70, people do not pass by the square. For these two variables, the first dimension presents an overall inertia of 90.1 % and the second dimension an overall inertia of 89.3 %.

Regarding the association between "people passing by" and "brightness sensor", with a total inertia respectively of 92.1 % and 91.8 % in the two dimensions, it has been confirmed that people do not pass by the square with low brightness values (see Fig. 19).

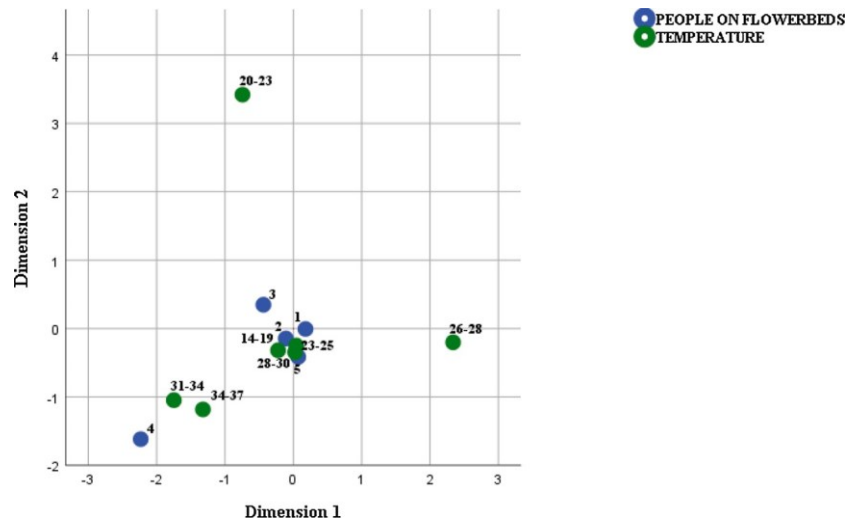
In the last Fig. 20 it has been shown that people pass by the square only with low temperatures and the association is confirmed by the high level of the overall inertia of the two dimensions, 87.4 % and 86.9 %.



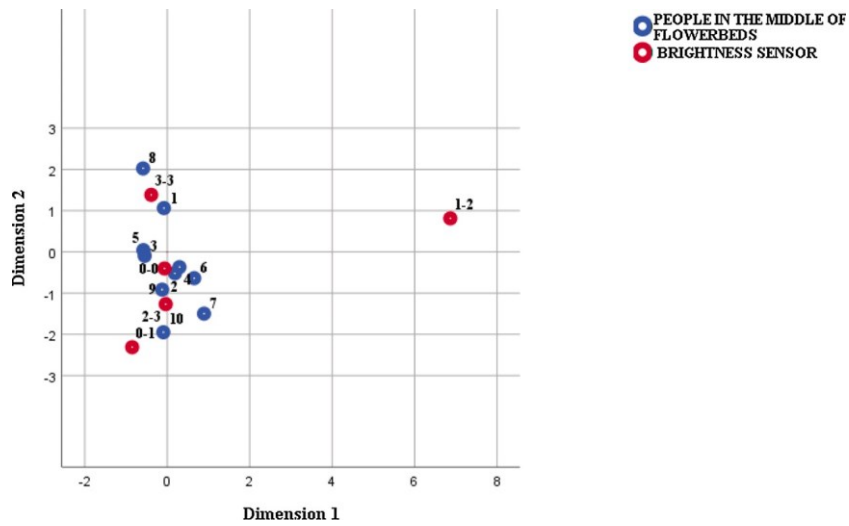
/fig. 12. Coordinates of "people on flowerbeds" and "brightness sensor" on the plane of the two dimensions.



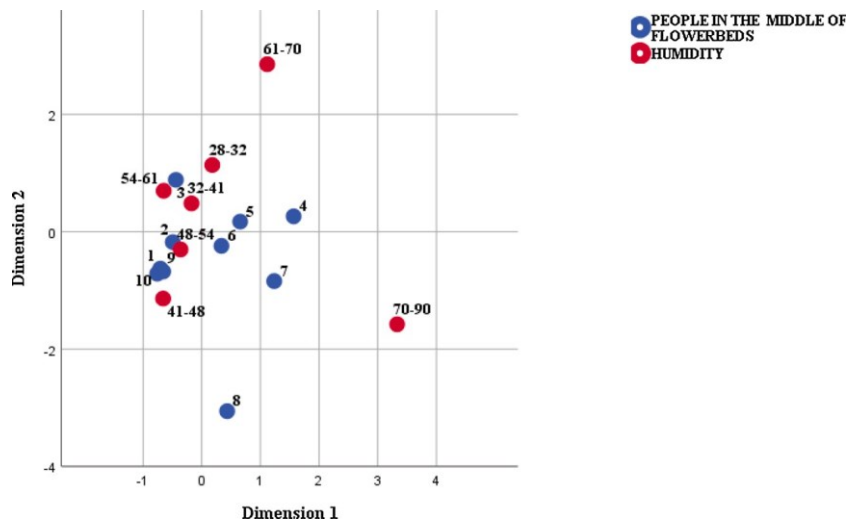
/fig. 13. Coordinates of "people on flowerbeds" and "humidity" on the plane of the two dimensions.



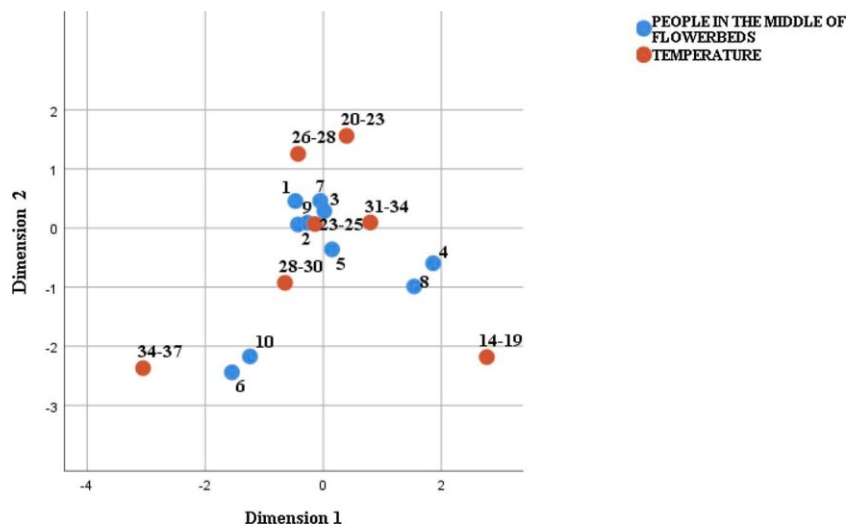
/fig. 14. Coordinates of "people on flowerbeds" and "temperature" on the plane of the two dimensions.



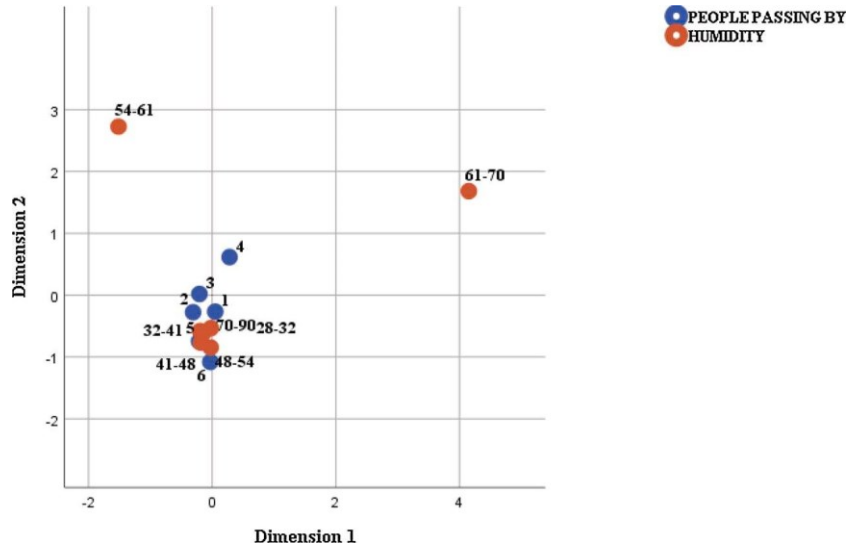
/fig. 15. Coordinates of “people in the middle of flowerbeds” and “brightness sensor” on the plane of the two dimensions.



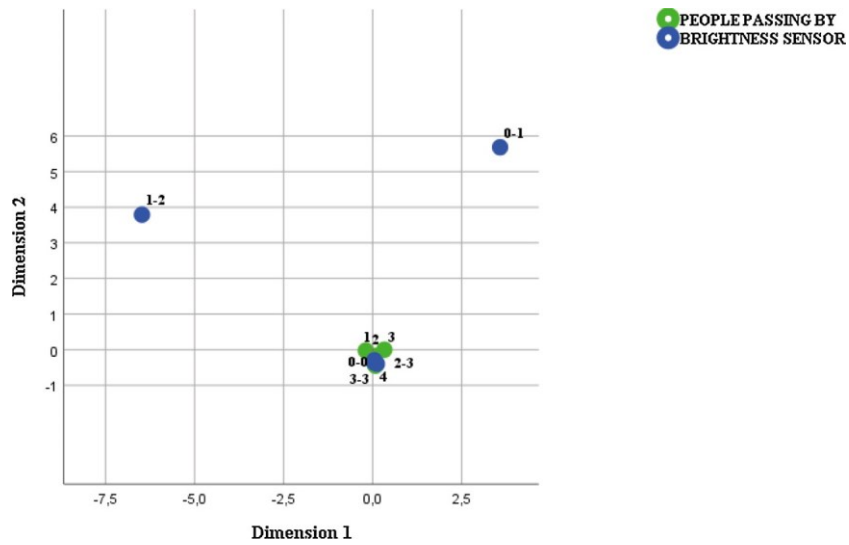
/fig. 16. Coordinates of “people in the middle of flowerbeds” and “humidity” on the plane of the two dimensions.



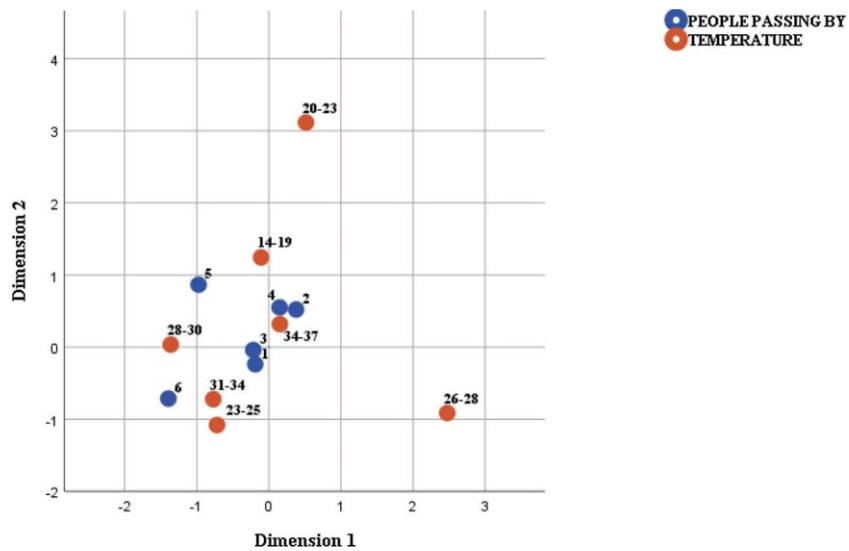
/fig. 17. Coordinates of “people in the middle of flowerbeds” and “temperature” on the plane of the two dimensions.



/fig. 18. Coordinates of “people passing by” and “humidity” on the plane of the two dimensions.



/fig. 19. Coordinates of “people passing by” and “brightness sensor” on the plane of the two dimensions.



/fig. 20. Coordinates of “people passing by” and “temperature” on the plane of the two dimensions.

References

- Adachi, M., Rohde, C. L. E., & Kendle, A. D. (2000). Effects of floral and foliage displays on human emotions. *Horttechnology*, 10, 59–63. <https://doi.org/10.21273/HORTTECH.10.1.59>
- Ahad, M. A., Paiva, S., Tripathi, G., & Feroz, N. (2020). *Enabling technologies and sustainable smart cities*, 61, Article 102301. <https://doi.org/10.1016/j.scs.2020.102301>
- Barnard, J. (2004). *Bach flower remedies: Form & function*. *Lindisfarne books*.
- Beil, K., & Hanes, D. (2013). The influence of urban natural and built environments on physiological and psychological measures of stress- A pilot study. *International Journal of Environmental Research and Public Health*, 10, 1250–1267. <https://doi.org/10.3390/ijerph10041250>
- Brown, G., Schebella, M. F., & Weber, D. (2014). Using participatory GIS to measure physical activity and urban park benefits. *Landscape and Urban Planning*, 121, 34–44. <https://doi.org/10.1016/j.landurbplan.2013.09.006>
- Carrus, G., Scopelliti, M., Laforzezza, R., Colangelo, G., Ferrini, F., Salbitano, F., et al. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. *Landscape and Urban Planning*, 134, 221–228.
- Chinlampaing, M. (2011). *Traditional knowledge, weather prediction and bioindicators: A case study in Mizoram, Northeastern India*.
- Cilliers, S. S., Siebert, S. J., Du, T. M. J., Siebert, S. J., Du, T. M. J., et al. (2017). *Managing urban green spaces for biodiversity conservation: An African perspective* (pp. 167–185). <https://doi.org/10.4324/9781315402581-11>
- Cook, E. M., Hall, S. J., & Larson, K. L. (2012). Residential landscapes as social-ecological systems: A synthesis of multi-scalar interactions between people and their home environment. *Urban Ecosystems*, 15, 19–52. <https://doi.org/10.1007/s11252-011-0197-0>
- Crane, D. E., & Stevens, J. C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban For Urban Green*, 4, 5–123. <https://doi.org/10.1016/j.ufug.2006.01.007>
- De Ridder, K., Adamec, V., Ban ˘uelos, A., Bruse, M., B ˘urger, M., Damsgaard, O., et al. (2004). An integrated methodology to assess the benefits of urban green space. *The Science of the Total Environment*, 334–335, 489–497. <https://doi.org/10.1016/j.scitotenv.2004.04.054>
- Dennis, M., Barlow, D., Cavan, G., Cook, P., Gilchrist, A., Handley, J., et al. (2018). Mapping urban green infrastructure: A novel landscape-based approach to incorporating land use and land cover in the mapping of human-dominated systems. *Land*, 7, 17. <https://doi.org/10.3390/land7010017>
- Dentamaro, I., Laforzezza, R., Colangelo, G., Carrus, G., & Sanesi, G. (2011). Assessing the restorative potential of different types of urban and periurban green spaces. *For-Riv di Selvic ed Ecol For*, 8, 162–178. <https://doi.org/10.3832/efor0673-008>
- Ernst, A., Ruf, T., & Kueblbeck, C. (2009). A modular framework to detect and analyze faces for audience measurement systems. *INFORMATIK 2009 - Im Focus Das Leben, Beitrage der 39* (pp. 3941–3953). Jahrestagung der Gesellschaft fur Informatik e.V. (GI).
- Fahed, J., Kinab, E., Ginestet, S., & Adolphe, L. (2020). *Impact of urban heat island mitigation measures on microclimate and pedestrian comfort in a dense urban district of Lebanon* 61. <https://doi.org/10.1016/j.scs.2020.102375>, 102375.
- Foshag, K., Aeschbachag, N., Ho ˘fle, B., Winkler, R., Siegmund, A., & Werner, A. (2020). *I Viability of public spaces in cities under increasing heat: A transdisciplinary approach* 59. <https://doi.org/10.1016/j.scs.2020.102215>, 102215.
- Galiano, A., Massaro, A., Barbuzz, D., Legrottaglie, M., Vitti, V., Pellicani, L., et al. (2016). Face recognition system on mobile device based on web service approach. *International Journal of Computer Science and Information Technologies*, 2130–2135.
- Goddard, M. A., Dougill, A. J., & Benton, T. G. (2010). Scaling up from gardens: Biodiversity conservation in urban environments. *Trends in Ecology & Evolution*, 25, 90–98.
- Go ˘mez-Baggethun, E., Gren, ˆA., Barton, D. N., Langemeyer, J., McPhearson, T., O ˘farrell, P., et al. (2013). Urban ecosystem services. *Urbanization, biodiversity and ecosystem services: Challenges and opportunities: A global assessment* (pp. 175–251). Netherlands: Springer.
- Gratani, L., Varone, L., & Bonito, A. (2016). Carbon sequestration of four urban parks in Rome. *Urban For Urban Green*, 19, 184–193. <https://doi.org/10.1016/j.ufug.2016.07.007>
- Hamada, S., & Ohta, T. (2010). Seasonal variations in the cooling effect of urban green areas on surrounding urban areas. *Urban For Urban Green*, 9, 15–24. <https://doi.org/10.1016/j.ufug.2009.10.002>
- Han, L., Tan, X., Zhou, W., Li, W., & Qian, Y. (2020). Better urban vegetation planning for maximum utility in air pollutant reduction: A theoretical perspective and preliminary analysis in Chinese cities. *Sustainable Cities and Society*, 62, Article 102377. <https://doi.org/10.1016/j.scs.2020.102377>
- Hartig, T. (2008). Green space, psychological restoration, and health inequality. *Lancet*, 372, 1614–1615.
- Honjo, T., & Takakura, T. (1990). Simulation of thermal effects of urban green areas on their surrounding areas. *Energy and Buildings*, 15, 443–446. [https://doi.org/10.1016/0378-7788\(90\)90019-F](https://doi.org/10.1016/0378-7788(90)90019-F)
- HUSTI, A. M., CONT, IU, I., RADU, M., NEACS, U. I., & CANTOR, M. (2015). Psychological benefits of ornamental plants used in office environments. *Bull Univ Agric Sci Vet Med Cluj-Napoca Hortic*, 72. <https://doi.org/10.15835/buasvmcn-hort:10625>
- ISPPA. (2010). *Gestione Ecosistemica Delle Aree verdi urbane*. Analisi E Proposte.
- Ivarsson, C. T., & Grahn, P. (2010). Patients' experiences and use of a therapeutic garden: From a designer's perspective | Patients' experiences and use of a therapeutic garden: From a designer's perspective. *Schweizerische Zeitschrift fur Forstwes*, 161, 104–113. <https://doi.org/10.3188/szf.2010.0104>
- Jo, H. K. (2002). Impacts of urban greenspace on offsetting carbon emissions for middle Korea. *Journal of Environmental Management*, 64, 115–126. <https://doi.org/10.1006/jema.2001.0491>
- Kamioka, H., Tsutani, K., Yamada, M., Park, H., Okuizumi, H., Honda, T., et al. (2014). Effectiveness of horticultural therapy: A systematic review of randomized controlled trials. *Complementary Therapies in Medicine*, 22, 930–943. <https://doi.org/10.1016/j.ctim.2014.08.009>
- Kaufman, A. J., & Lohr, V. I. (2004). Does plant color affect emotional and physiological responses to landscapes? *Acta Horticulturae*, 229–233. <https://doi.org/10.17660/ActaHortic.2004.639.29>
- Kehl, K., Then, V., Krlev, G., & Mildenerberger, G. (2018). Adapting the measuring rod for social returns in advanced welfare states: A critique of SROI. *Meas control sustain spanning theory pract*.
- Koprowska, K., Laszkiewicz, E., Kronenberg, J., & Marcin ˘czak, S. (2018). Subjective perception of noise exposure in relation to urban green space availability. *Urban For Urban Green*, 31, 93–102. <https://doi.org/10.1016/j.ufug.2018.01.018>
- Kotu, V., & Deshpande, B. (2014). *Predictive analytics and data mining: Concepts and practice with RapidMiner*. Elsevier Inc.
- Kuttler, W., & Strassburger, A. (1999). Air quality measurements in urban green areas - A case study. *Atmospheric environment* (pp. 4101–4108). Elsevier Science Ltd.
- Learn about i-Tree. (2020). *i-Tree*. <https://www.itreetools.org/>. Accessed 2 Jan.
- Maas, J., Verheij, R. A., Groenewegen, P. P., De Vries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: How strong is the relation? *Journal of Epidemiology and Community Health*, 60, 587–592. <https://doi.org/10.1136/jech.2005.043125>
- MacFaden, S. W., O ˘Neil-Dunne, J. P. M., Royar, A. R., Lu, J. W. T., & Rundle, A. G. (2012). High-resolution tree canopy mapping for New York City using LIDAR and object-based image analysis. *Journal of Applied Remote Sensing*, 6. <https://doi.org/10.1117/1.jrs.6.063567>, 063567–1.
- Maco, S. E., & McPherson, E. G. (2003). A practical approach to assessing structure, function, and value of street tree populations in small communities. *J Arboric*, 29, 84–97.
- Manca, F. (2004). *Statistica multivariata applicata alle ricerche di marketing*. Cacucci.
- Marchi, M., Niccolucci, V., Pulselli, R. M., & Marchettini, N. (2017). Urban sustainability: CO₂ uptake by green areas in the historic centre of siena. *Int J Des Nat Ecodynamics*, 12, 407–417. <https://doi.org/10.2495/DNE-V12-N4-407-417>
- Massari, B., Massari, A., Manca, F., & Gironi, F. (2016). Multiple correspondence analysis for customer segmentation in large retail groups. *Electron J Appl Stat Anal EJASA, Electron J App Stat Anal Electron J Appl Stat Anal*, 09, 637–654. <https://doi.org/10.1285/i20705948v9n4p637>
- Massaro, A., Barbuzz, D., Galiano, A., Vitti, V., & Pellicani, L. (2017). Simplified & efficient face recognition system on real image set & synthesised data. *International Journal of Biometrics*, 9, 143–162. <https://doi.org/10.1504/IJBM.2017.085678>
- Mattson, R. H. (2010). Biofeedback evidence of social and psychological health benefits provided by plants and flowers in urban environments. *Acta horticulturae* (pp. 751–757). International Society for Horticultural Science.
- Memluk, M. Z. (2013). *Designing urban squares. in: Advances in landscape architecture*. InTech.
- Millward, A. A., & Sabir, S. (2011). Benefits of a forested urban park: What is the value of Allan Gardens to the city of Toronto, Canada? *Landscape and Urban Planning*, 100, 177–188. <https://doi.org/10.1016/j.landurbplan.2010.11.013>
- Morakinyo, T. E., Lau, K. K. L., Ren, C., & Ng, E. (2018). Performance of Hong Kong's common trees species for outdoor temperature regulation, thermal comfort and energy saving. *Building and Environment*, 137, 157–170. <https://doi.org/10.1016/j.buildenv.2018.04.012>
- Peper, P. J., McPherson, E. G., Simpson, J. R., Gardner, S. L., Vargas, K. E., & Xiao, Q. (2007). *New York City, new york municipal forest resource analysis*.
- Purwohedi, U., & Gurd, B. (2019). Using Social Return on Investment (SROI) to measure project impact in local government. *Public Money Manag*, 39, 56–63. <https://doi.org/10.1080/09540962.2019.1537706>
- Renterghem, T. V., Dekoninck, L., & Boddeldoreen, D. (2020). Multi-stage sound planning methodology for urban redevelopment. *Sustainable Cities and Society*, 62, Article 102362. <https://doi.org/10.1016/j.scs.2020.102362>
- Riezzo, E. E., Zippitelli, M., Donato, I., Todorovic, M., Cantore, V., & Buono, V. (2013). *Hydro-Tech-an integrated decision support system for sustainable irrigation management (II): Software and hardware architecture* (pp. 443–451).
- Riondato, E., Pilla, F., Basu, A. S., & Basu, B. (2020). *Investigating the effect of trees on urban quality in Dublin by combining air monitoring with i-Tree Eco model* 61. <https://doi.org/10.1016/j.scs.2020.102356>, 102356.
- Roe, J., & Aspinall, P. (2011). The restorative benefits of walking in urban and rural settings in adults with good and poor mental health. *Heal Place*, 17, 103–113. <https://doi.org/10.1016/j.healthplace.2010.09.003>
- Roqueiro, D., & Petrushin, V. A. (2007). Counting people using video cameras. *Int J Parallel, Emergent Distrib Syst*, 22, 193–209. <https://doi.org/10.1080/17445760601139096>
- Savard, J. P. L., Clergeau, P., & Mennechez, G. (2000). Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning*, 48, 131–142. [https://doi.org/10.1016/S0169-2046\(00\)00037-2](https://doi.org/10.1016/S0169-2046(00)00037-2)
- Shashua-Bar, L., & Hoffman, M. E. (2000). Vegetation as a climatic component in the design of an urban street. An empirical model for predicting the cooling effect of urban green areas with trees. *Energy and Buildings*, 31, 221–235. [https://doi.org/10.1016/S0378-7788\(99\)00018-3](https://doi.org/10.1016/S0378-7788(99)00018-3)
- Sowndhararajan, K., & Kim, S. (2016). Influence of fragrances on human psychophysiological activity: With special reference to human electroencephalographic response. *Scientia Pharmaceutica*, 84, 724–751.

Strohbach, M. W., Arnold, E., & Haase, D. (2012). The carbon footprint of urban green space-A life cycle approach. *Landscape and Urban Planning*, 104, 220–229. <https://doi.org/10.1016/j.landurbplan.2011.10.013>

Sukthomya, D., & Laosiritaworn, W. (2018). Modeling of the relationship between corporate social responsibility and stock price with artificial neural network. In *2018 7th International Conference on Industrial Technology and Management* (pp. 213–217).

Talari, S., Shafie-khah, M., Siano, P., Loia, V., Tommasetti, A., & Catalano, J. (2017). A review of smart cities based on the internet of things concept. *Energies*, 10, 421. <https://doi.org/10.3390/en10040421>

Todorovic, M., Cantore, V., Riezzo, E. E., Zippitelli, M., Gagliano, A., & Buono, V. (2013). *Hydro-tech: An integrated decision support system for sustainable irrigation management (I): Main algorithms and field testing* (pp. 410–417).

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, 11, 201–230. [https://doi.org/10.1016/S0272-4944\(05\)80184-7](https://doi.org/10.1016/S0272-4944(05)80184-7)

University of Notre Dame. (2016). *Textual analysis repository for accounting and finance*. <https://sraf.nd.edu/textual-analysis/resources/>.

Vargas-Hernandez, J. G., Pallagst, K., & Hammer, P. (2018). Strategic management innovation of Urban Green spaces for sustainable Community development. *Handbook of engaged sustain* (pp. 917–944).

Vargas-Hernandez, J. G., Pallagst, K., & Zdunek-Wielgołaska, J. (2018). Urban green spaces as a component of an ecosystem. *Handbook of engaged sustainability* (pp. 885–916). Springer International Publishing.

Voghera, A., & Giudice, B. (2020). Defining a social-ecological performance to prioritize compensatory actions for environmental regeneration. *The experimentation of the environmental compensation plan*, 61, Article 102357. <https://doi.org/10.1016/j.scs.2020.102357>

Vujcic, M., Tomicevic-Dubljevic, J., Zivojinovic, I., & Toskovic, O. (2019). Connection between urban green areas and visitors' physical and mental well-being. *Urban For Urban Green*, 40, 299–307. <https://doi.org/10.1016/j.ufug.2018.01.028>

Ward Thompson, C., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape and Urban Planning*, 105, 221–229. <https://doi.org/10.1016/j.landurbplan.2011.12.015>

White, L. (2018). A Cook's tour: Towards a framework for measuring the social impact of social purpose organisations. *European Journal of Operational Research*, 268, 784–797. <https://doi.org/10.1016/j.ejor.2017.06.015>

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities “just green enough.” *Landscape and Urban Planning*, 125, 234–244. <https://doi.org/10.1016/j.landurbplan.2014.01.017>

Yang, F., Bao, Z. Y., & Zhu, Z. J. (2011). An assessment of psychological noise reduction by landscape plants. *International Journal of Environmental Research and Public Health*, 8, 1032–1048. <https://doi.org/10.3390/ijerph8041032>

Yu, Z., Guo, X., Zeng, Y., Koga, M., & Vejre, H. (2018). Variations in land surface temperature and cooling efficiency of green space in rapid urbanization: The case of Fuzhou city. *China. Urban For Urban Green*, 29, 113–121. <https://doi.org/10.1016/j.ufug.2017.11.008>

Zhang, B., Xie, G., Zhang, C., & Zhang, J. (2012). The economic benefits of rainwater-runoff reduction by urban green spaces: A case study in Beijing, China. *Journal of Environmental Management*, 100, 65–71. <https://doi.org/10.1016/j.jenvman.2012.01.015>



Giuseppe Birardi. Giuseppe Birardi works as researcher at Dyrecta Lab Srl - research institute accredited by the Italian Ministry of University and Scientific Research. He has over 7 years of experience in the R&D industry encompassing a wide variety of roles and responsibilities in both large and start-up companies. His current research interests include deep learning, natural language processing, agroecology, permaculture.



Fabio Manca, PhD, is a researcher of Statistics (SECS/S-01) at the Department of Education, Psychology, Communication of the University of Bari Aldo Moro since December 2002. Member of the teaching staff for the PhD program in “Population, family and territory”. Ordinary member of the Italian Statistical Society (SIS). Author of numerous national and international publications in statistics. Member of the scientific technical council of the interuniversity center CIRPAS (Ricerca, Popolazione, Ambiente e Salute).



Claudia Marin, PhD, is a researcher of Statistics (SECS/S-01) at the Department of Education, Psychology, Communication of the University of Bari Aldo Moro since July 2006. Ordinary member of the Italian Statistical Society (SIS). Author of numerous national and international publications in statistics. Member of interuniversity center CIRPAS (Ricerca, Popolazione, Ambiente e Salute) and of the interdepartmental center CIPSAIMEGA (Psicologia Applicata per gli interventi in Ambito Medico, Economico, Giuridico e Ambientale).



Vitangelo Birardi. Vitangelo Birardi is an entrepreneur with 20 years of work and research experience in the field of financial accounting and information technologies. He received M.S. degree in Economics from University of Bari Aldo Moro, Italy in 2001. He is CFO at Dyrecta Lab Srl - research institute accredited by the Italian Ministry of University and Scientific Research.



Daniele Giannone. Daniele Giannone works as researcher and developer at Dyrecta Lab Srl - research institute accredited by the Italian Ministry of University and Scientific Research. He received B.S. degree in Informatics and Software Production Technologies from University of Bari Aldo Moro, Italy in 2017. His current research interests include artificial neural networks, image processing, big data.



Alessandro Massaro. Professor Alessandro Massaro (ING/INF/01, FIS/01, FIS/03) carried out scientific research at the Polytechnic University of Marche, at CNR, and at Italian Institute of Technology (IIT) as Team Leader by activating laboratories for nanocomposite sensors for industrial robotics. He is in MIUR register as scientific expert in competitive Industrial Research and social development, and he is currently head of the Research and Development section and scientific director of MIUR Research Institute Dyrecta Lab Srl. Member of the International Scientific Committee of Measurers IMEKO and IEEE Senior member, recently received an award from the National Council of Engineers as Best Engineer of Italy 2018 (Top Young Engineer 2018).



Angelo Maurizio Galiano. Angelo Maurizio Galiano is CEO at Dyrecta Lab Srl - research institute accredited by the Italian Ministry of University and Scientific Research. He has more than 20 years of experience in the field of Information Technologies. He received M.S. degree in Education Science in 2009. His current research interests include neural networks, smart health, predictive analytics.

DSAN mod. B

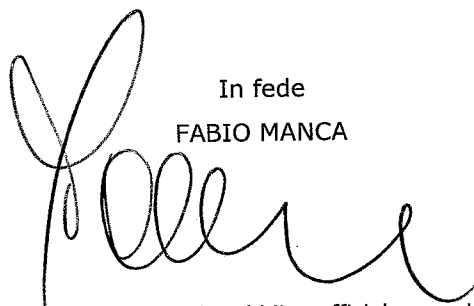
DICHIARAZIONE SOSTITUTIVA DI CERTIFICAZIONE
(art. 46 DPR 28/12/2000 n. 445)

Il Sottoscritto FABIO MANCA nato a COPERTINO _ (LE) il 31 MARZO 1966 residente a BARI (BA) in via GUGLIELMO OBERDAN n. 10 C.F. MNCFBA66C31C978P , consapevole delle responsabilità penali previste per le ipotesi di falsità in atti e dichiarazioni mendaci così come stabilito negli artt. 75 e 76 del DPR 28/12/2000 n. 445

DICHIARA

Che la pubblicazione dal titolo **INNOVATIVE DSS FOR INTELLIGENT MONITORING AND URBAN SQUARE DESIGN APPROACHES: A CASE OF STUDY** è frutto del lavoro congiunto degli autori. Tuttavia la stesura dei paragrafi 3.1 e 5 è da attribuire a Fabio Manca, la stesura del paragrafo 3.2 è da attribuire a Claudia Marin, il paragrafo 1 è da attribuire ad Alessandro Massaro, i paragrafi 2.1 e 2.2 sono da attribuire a Giuseppe Birardi e Vitangelo Birardi, il paragrafo 4.1 è da attribuire a Angelo Maurizio Galiano ed il paragrafo 4.2 è da attribuire a Daniele Giannone.

In fede
FABIO MANCA



NB: la presente dichiarazione non necessita dell'autenticazione della firma da parte di pubblico ufficiale e sostituisce a tutti gli effetti le normali certificazioni richieste o destinate ad una pubblica amministrazione nonché ai gestori di servizi pubblici e ai privati che vi consentono. L'Amministrazione si riserva di effettuare controlli a campione, sulla veridicità delle dichiarazioni (art. 71, comma 1, DPR 445/2000). In caso di dichiarazione falsa il cittadino sarà denunciato all'autorità giudiziaria.