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Strategies and measures for sustainable urban transport systems

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Abstract

Increasing sustainability of urban transport systems is a crucial objective of all strategic plans both at national and European level. Different strategies and measures can be adopted to improve the efficiency of transport systems, according to a large set of factors that can affect the results of the implemented actions. A comprehensive study has been carried out in order to define a methodology able to define effective and efficient strategies and measures, allowing to increase the sustainability level of different kinds of cities, from small-medium sized to large metropolitan areas. The methodology has been tested on a group of 50 Italian cities, whose characteristics have been analysed through an initial set of more than 200 indicators. Three main groups of indicators have been taken into account: *State indicators*, *Sustainability indicators*, *Policy indicators*. The main aim has been to identify existing relationships between Sustainability and Policy indicators for cities showing commonalities in terms of State indicators. A correlation analysis allowed to identify 53 relevant indicators from the initial set of 200, while a cluster analysis, based on a hierarchical model, allowed to group the cities into five different groups, according to their population size and density. Correlations between relevant indicators have also been analysed within each group, while linear regression models have allowed to describe some functional relations between Policy and Sustainability indicators. A benchmarking exercise has allowed to identify strategies and measures adopted by the best performers within each group, hence defining possible paths to a better sustainability level for the remaining cities. Finally, recommendations for a correct urban mobility planning procedures have been produced.

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1. Introduction

Cities represent the heart of life and the driving force of the economy. The great majority of European citizens live in urban areas, which generate approximately the 85% of the Gross Domestic Product of the European Union. The population growth has hit the peripheries, the urban area, and rural territories within large urban sprawls. Consequently, mobility has considerably grown, as the use of private vehicles, due to the lack of coherent and systematic policies of service supply and demand. The consequences are: congestion lasting longer and longer and over greater distances; air pollution with local and global effects; serious traffic accidents; low accessibility to public transport with worsening of social exclusion. A sustainable urban mobility system, allowing citizens and goods to move freely and safely with respect of the environment, is crucial for our quality of life and the health of the economy. However, many factors make difficult the improvement of the level of sustainability of urban transport: economic factors, social acceptability factors, political acceptability factors, and technical planning capacity. Focusing on this last factor, the definition of the most effective mobility management policies depends on two main critical aspects: the difficulty in selecting the most suitable policies in the urban context and the difficulty in characterizing such urban context by way of appropriate indicators. The second aspect is prior to the first. The acquaintance with mobility in urban context requires a thorough monitoring in order to define the structural characteristics of the city, the level of sustainability reached and the ongoing mobility management policies. Through appropriate indicators, the monitoring process, repeated in time, allows, moreover, the definition of trends and the comparison of current situation with that of other cities (benchmarking). Indicators collection and analysis are affected by several critical factors: are data available? Are they accessible? Are they comparable with those of other situations, and what is their quality? What is their cost?

A limited number of international studies aimed to define the structure of these types of indicators. Newman and Kenworthy (1989) and Kenworthy and Laube (1999) identified and gathered a wide collection of indicators for a group of large cities from different continents, mainly by analysing the relationship between transport and land-use factors as well as the use of automobiles. In UITP (2005), the focus was aimed to 50 large cities, primarily European, by analysing the relationship between indicators of land-use, public transport, private transport, infrastructure and transportation system performances. In the IRTAD Annual Report (IRTAD, 2011) attention was paid to road safetyand the focus was on countries rather than cities. An effort to define a well-structured methodology of monitoring sustainability indicators, with recommendations on the orders of priority, can be found in TRB (2008), but some issues (not covered in literature) are unsolved in the application to medium-sized cities. Many research projects have been dealing with the development of sustainable policies for urban transport. The programs CIVITAS (2012) and LUTR (2012) carried out research based on the evaluation of sustainable mobility policies in many European cities. Some international databases (Konsult, 2012, Victoria, 2012), containing different types of political methodologies for improving sustainability of urban transport, related expected results, capacity and critical factors, have been created.

The main critical issue, beyond the practical difficulty of implementing the most effective policies, is the selection of the most effective and efficient set of policies for each urban transport system. The object of this study, and, therefore, the whole process of analysis, is to define a methodology that allows the evaluation of performance in cities of different sizes and to identify for each city the most appropriate set of policies, defining a path to improve sustainability. The methodology developed has been applied to a sample of 50 of Italy's largest cities. The study was conducted in the field of the General Mobility Plan of the Ministry of Infrastructure and Transport of Italy. The study is composed by the following interacting steps:

- definition of indicators,
- clustering of cities in homogenous groups,
- analysis of functional relationships among indicators,
- identification of the most effective policies, through a benchmarking analysis.

The following paragraphs shows the methodological aspects that summarize each of these steps. The complete results of the applications are available from the authors.

2. Indicators

Since the objective of the study was to improve the sustainability level of cities through policies, representative indicators of structural characteristics (*State Indicators*) were used to gather cities with similar features, to allow better a comparison between them, and to identify more clearly the transferability of policies and measures selected. S*ustainability Indicators* were used to assess the current conditions of each city, trying to find out the relationship between them and implemented policies (*Policy Indicators*), in order to identify good practices in terms of successful policies within each group and paths to sustainability. From a set of 200 indicators, a subset has been obtained through a correlation analysis, therefore the sample test could be more manageable. Data concerning Italian cities were obtained from National Statistic Institute (ISTAT), Automobile Club Italy (ACI), the National Account for Transport and Infrastructure, the Census Bureau, Training and Research Transport Institute (ISFORT), Legambiente, Italian Environment Protection and Technical Services Agency (APAT), and Euromobility database, along with data obtained through survey conducted by research Centre for Transport and Logisitics (CTL) of "Sapienza" University of Rome during years from 2001 to 2010. A starting analysis allowed to remove data relating to the same indicator (provided by different sources), or expressed with different measurement units. Therefore, a total of 186 indicators have gained, and gathered in 13 classes: each of them was further collected by typology depending on sustainability level, adopted policies, and territorial features:

- *State Indicators*: Territorial variables, Vehicle fleet, Urban mobility, and Commuters mobility.
- *Sustainability Indicators*: Road accidents, Air pollution, Public Transport (PT) demand, Modal share of Urban mobility.
- *Policy Indicators*: PT supply, Private transport supply, Management measures, Road space allocation, Regulatory measures.

A correlation analysis was applied in order to reduce the number of indicators, through a sort of skimming of redundancy in the equivalent class, or those shortly related with *Sustainability Indicators*. The correlation analysis was achieved on data from a sampling of 50 Italian cities, allowing to evidence the main correlations (Bravais--Pearson correlation coefficient R>|0.75|)between indicators in the same class and among those and *Sustainability Indicators*. Thus, 53 indicators were obtained (see Table 1): 17 State Indicators, 13 Sustainability Indicators and 23 Policy Indicators. Further, a Factor Analysis and a conventional Correlation Analysis were conducted, both without significant results.

Table 1. State, Sustainability, and Policy Indicators.

	Name (unit of measure)	Description
State indicators		
Territorial variables	Population (N° inhab.)	Number of inhabitants
	Area (km^2)	Extension of urban area
	Density (N°inhab./km^2)	Population density
	Residential Area Density (N°inhab./km^2)	Population density of residential area
Vehicle fleet	Euro 3-4 Vehicles (% N° euro 3-4 veh./N°veh.)	% of euro 3-4 vehicles
	GPL and Methane Vehicles (% N° GPL&Methane veh./N°veh.)	% of GPL and Methane vehicles
	Motorization Rate (N° cars/N°inhab.*1000)	Number of cars per 1000 inhabitants
	PTW(Powered Two Wheelers) Rate ((N° PTW/N°inhab.)*1000)	Number of PTW per 1000 inhabitants
	Freight vehicles Density (N° freight veh./$km^{2)}$	Number of freight vehicles per km^2
Urban mobility	Urban trips (% N° urban trips/N°inhab.)	% of commuters in urban area
Commuter mobility (extra-urban trips)	Attraction share of PT (% N° PT extra urban trips/N° extra urban trips)	% of attracted commuters using PT
	Attraction share of private car (% N° car extra urban trips/N° extra urban trips)	% of attracted commuters using private car
	Attraction share of PTW (% N° PTW extra urban trips/N° extra urban trips)	% of attracted commuters using PTW
	Attraction share of bicycle (% N° bicycle extra urban trips/N° extra urban trips)	% of attracted commuters using bicycle
	Attraction share of pedestrian (% N° pedestrian extra urban trips/N° extra urban trips)	% of attracted commuters by walk
	Attraction share of other modes (% N° other extra urban trips/N° extra urban trips)	% of attracted commuters using other modes
	Total attraction share (% N° extra urban trips/inhab.)	% of attracted commuters

Sustainability indicators		
Accidents	Accidents rate ((N° accidents/N° inhab.) *1000)	Number of accidents per 1000 inhabitants
Pollution	Average PM10 (µg/mc)	Average emissions of particles of dm <10µm
	Average NO_2 (µg/mc)	Average emissions of nitrogen oxides
	Days with highest level of PM10 (N° days)	Days of exceeded limits of PM10 in at least one control unit
	Number of hours with highest level of NO_2 (N° hours)	Hours of exceeded limits of nitrogen oxides
	Number of hours with highest level of O_3 (N° hours)	Hours of exceeded limits of ozone
Public transport demand	PT demand (N° users-year/N° inhab.)	Number of PT users in one year per capita
Urban mobility (modal split)	Share of PT (% N° PT urban trips/N° urban trips)	% of employed using PT
	Share of private car (% N° car urban trips/N° urban trips)	% of employed using private car
	Share of PTW (% N° PTW urban trips/N° urban trips)	% of employed using PTW
	Share of bicycle (% N° bicycle urban trips/N° urban trips)	% of employed using bicycle
	Share of pedestrian (% N° pedestrian urban trips/N° urban trips)	% of employed by walk
	Share of other modes (% N° other urban trips/N° urban trips)	% of employed using other modes
Policy indicators		
Public transport availability	PT Service supply (Veh-km-year/N° inahab.)	Vehicles-km produced by public transport per N° inabitants
	PT Route network ((km/N°inhab.)*1000)	Kms of route network per 1000 inhabitants
	PT Reserved lane percentage (% km reserved lanes/km route network)	% of reserved lanes on route network
	PT Service frequency (Veh.-km/km route network)	Vehicles-km produced by public transport per route network
	PT network density (km/kmq)	Kms of route network per city area
Private transport supply	Road network length ((km/N°inhab.)*1000)	Kms of urban roads per 1000 inhabitants
	Pay on-street parking slots ((N°slots/N°cars)*1000)	Pay on-street parking slots per 1000 cars
	P&R slots ((N°slots/N°cars)*1000)	P&R slots per 1000 cars
	Pay parking slots in ZTL ((N°slots/N°inhab.)*1000)	Pay parking slots in restricted zones per 1000 inhabitants
	Pay parking slots in city center ((N°slots/N° inhab.)*1000)	Pay parking slots in city center per 1000 inhabitants
	Pay parking slots in other urban areas ((N°slots/N° inhab.)*1000)	Pay parking slots in other urban areas per 1000 inhabitants
	Regulated on-street parking slots ((N°slots/N° inhab.)*1000)	Regulated on-street parking slots per 1000 inhabitants
	Cost of on-street pay parking – 1st hour (€)	Cost of on-street pay parking for the 1st hour
	Cost of pay P&R– 1st hour (€)	Cost of pay P&R for the 1st hour
Management measures	Car free day (0/1)	
	Ecological Sunday (0/1)	
	Traffic restriction (0/1)	
Road space re-allocation	ZTL ((ZTL kmq/kmq)*100)	Restricted zones area compared to total urban area
	Pedestrian areas ((mq/N°inhab.)*100)	Pedestrian areas compared to total urban area
	Bike lane length ((bike lanes km/kmq)*100)	Bike lane length compared to total urban area
Regulatory measures	Urban Transport Plan adoption (0/1)	
	Urban Mobility Plan adoption (0/1)	
	Mobility Manager (0/1)	

3. City clustering

Characteristics of an urban transportation system are particular depending on the city features. The factors that can influence a transportation system are several: size, urban density, orography, climate, historical origins, income, culture, etc. The awareness of these factors is very important, both to understand the reason for certain predictions of an urban transportation system and to measure the transferability of *best practices* from one city to another. This leads to the question: *what will make an intervention that was successful in one city successful into another?* The answer isn't easy. Several methods have been proposed in literature, but no one has been able to elaborate consistent quantitative relationships that could give a rationally answer. In this way, the methodology suggested has to be necessarily founded on logical and quality considerations. Therefore, to simplify both the comparison between cities transportation system and transferability prediction of policies adopted, it needs to evaluate cities cluster with similar features (for example: large cities and small/medium size cities). A *cluster analysis* was conducted with the objective of grouping cities by similar characteristics and based on numerosity. Two cluster analysis techniques have been applied (hierarchical models and k-means algorithm), taking into account different combinations of State Indicators. Both methods attempt to determine homogeneous groups, minimizing the variability within clusters. The main difference between the two methods is that in the hierarchical model, the number of clusters is not fixed, because it proceeds with attempt from the beginning of aggregation trials; on the other hand, the k-means algorithm method requires a fixed number of the cluster achieved. The application of both methods pointed out that the hierarchical model is the best in terms of cluster homogeneity. Several clustering tests were carried out regarding State Indicators, both singularly and in groups of two or three. Finally, the hierarchical clusterization was performed on two indicators "Population [N°. inhab.]" and "Population Density [N° inhab./Km²]". The tree analysis produced several aggregation levels (dendrograms), obtained by the cluster hierarchical analysis. Moreover, it showed the best clustering in terms of numerosity and homogeneity of the same groups, was that leading to 5 clusters. The fifth cluster was reserved only to the city of Rome (see Table 2).

Table 2. Results from the clusterization method.

I° cluster		II° cluster	III° cluster	IV° cluster	V° cluster
Ancona	Piacenza	Aosta	Bari	Milano	Roma
Campobasso	Potenza	Bolzano	Bergamo	Napoli	
Catanzaro	Ravenna	Cagliari	Bologna	Torino	
Ferrara	Reggio Calabria	Catania	Brescia		
Foggia	Reggio Emilia	Livorno	Firenze		
Forlì	Rimini	Messina	Genova		
L'Aquila	Sassari	Prato	Monza		
Latina	Siracusa	Verona	Padova		
Modena	Taranto	Vicenza	Palermo		
Novara	Terni		Pescara		
Parma	Trento		Salerno		
Perugia	Venezia		Trieste		

On the other hand, unsatisfying outcome resulted from the use of the K-means method. Adopting the same number of clusters (5), and using State Indicators for the aggregation, 42 cities were included in only one cluster compared to the five available (Fig. 1). The city of Rome, which was in a separately cluster, was added to the IV° cluster. The *first cluster* was made up of cities on average about 130,000 inhabitants and 600 pop/Km², therefore, small cities with low population density. In the *second cluster*, the average population increases to 170,000 inhabitants, but the main difference from the first one is in population density: an average of 1600 pop/Km²; therefore, these are small cities with high population density. The *third cluster* is made up of medium-sized cities, with a population about 290,000, on average about 3,000 pop/Km² of density. The *fourth cluster* consists of the three biggest cities: Milan, Turin, and Naples, characterized by on average about one million inhabitants and high density (7,400 pop/Km²), although Rome, included in the fifth cluster, has less area density (around 2,000 pop/Km²), but more than twice population of the fourth cluster's cities.

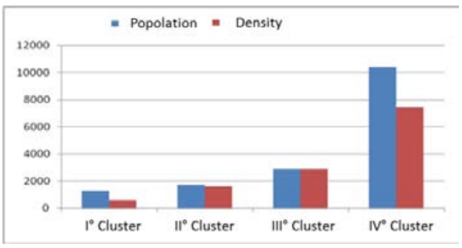


Fig. 1. Population and Population density.

Comparing some of the Sustainability and State Indicators of all five clusters, we can observe that from the I° to the IV˚-V˚ cluster:

- "Accident rate" increases;
- "Average NO_2" and "Average PM10" increase and "Days with highest level of PM10" increase (Fig. 2);

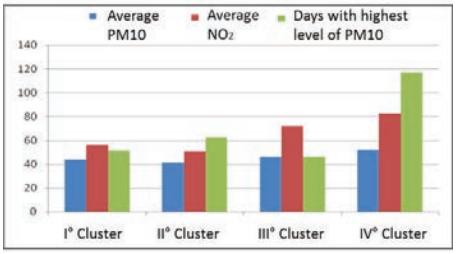


Fig. 2. Pollution.

- "PT demand", "Share of PT" and "Attraction share of PT" increase (Fig. 3).
- "PT network density" decreases, "PT Service supply" and "PT Reserved lanes percentage" increase (Fig.3);

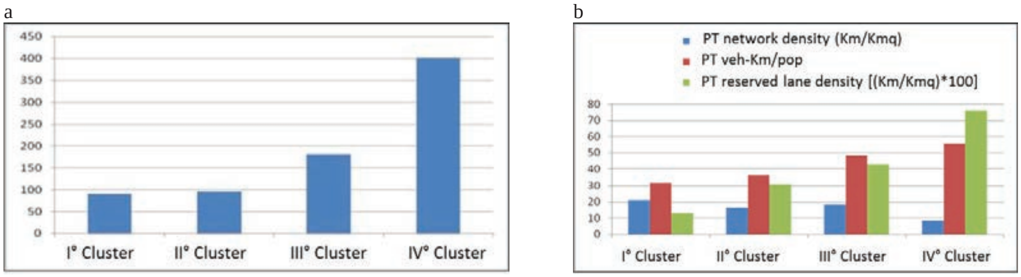


Fig. 3. (a) PT demand; (b) PT network density ,Service supply and Reserved lanes percentage.

- "P&R slots" decreases; "Regulated on-street parking slots" is constant and "Pay on-street parking slots" increase (Fig.4);

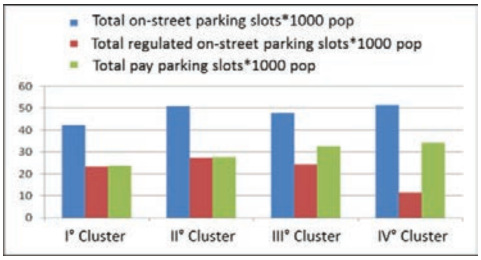


Fig. 4. Parking availability.

- "Share of private car" and Attraction share of private car" decrease;
- "Total attraction share" increases;
- "ZTL" and "Bike lane length" increase, while "Pedestrian areas" is quite stable.

4. Relationships between indicators

Statistical analyses, either on the entire sample of cities or within clusters, have been conducted. The aim was to identify the functional relations among different types of indicators, in order to select the most effective policies.

4.1. Analysis of correlations within the whole sample

Significant results (R ⩾ 0.6) emerged from the Correlation of the 53 variables performed on the whole sample of cities, are reported below. The results obtained confirmed that the environmental sustainability (pollution level) tends to increase in cities having an higher public transport demand both in terms of annual consumption and urban modal share. Thus, since the pollution level is strictly correlated to the "PT demand [N° users-year./N° inhab]", it has been decided to adopt the latter as a replaced indicator of sustainability. Especially for the environmental sustainability, results show a correlation with the following policy indicators:

- "PT Service frequency [Veh.-km/km route network]" (correlation coefficient equal to 0.70),
- "On-street parking slots" and "P&R slots [(N° slots/N°inhab.)*1000]" (correlation coefficient equal to 0.60),
- "Pedestrian areas " [(m²/100 pop)]" (correlation coefficient equal to 0.74),
- "Cost of pay P&R" (correlation coefficient equal to 0.64).

With a lower correlation coefficient (0.57), the "PT demand", in terms of modal share, is positively correlated to "PT reserved lane density." In addition, the "Bike lane length [bike lanes km/kmq)*100]" is correlated to "Share of bicycle" (correlation coefficient equal to 0.60), indicating that a policy increasing the availability of cycling infrastructure leads to an increase in the use of bike. Otherwise, concerning the "Accidents rate", a significant correlation did not emerge. This result may depend both on the lack of reliable accident data and the complexity of the phenomenon, which is influenced from several factors related to the local characteristics of infrastructure and, therefore, unlikely relatable with statistical analyses aggregated to other transport variables. Other interesting results emerging from this analysis concern, for instance, the correlation between "Motorization rate" and the modal share. As can be deduced, the positive correlation between the "Motorization rate" and the "Share of private car" is strong, as well as, consequently, the correlation between "Motorization rate" and the "Share of public transport" is negative. The correlation between "PTW rate" and the related share (correlation coefficient equal to 0.84) is even more stronger.

4.2. Analysis of correlations in a single cluster

A correlation analysis on 53variables for the first three clusters has been conducted, seeking a relationship between policy and sustainability variables. Significant correlations, those with correlation coefficients ≥ |0.7|, are reported below. The results obtained from the correlation analysis of *I˚ cluster* showed that pollution and "Accident rate" do not have significant correlations. The "PT demand [N° users-year/N°inhab.]" is directly correlated with "PT Service supply. [vehicle-Km-year/N°inhab.]" (correlation coefficient equal to 0.70). In addition, an increase of the "Bike lane length" means an increase of bicycle and motorcycle mobility and a reduction of private car transport.

The results of the analysis of *II° cluster* showed several correlations; however, some of those are not reliable due either to the lack of data or to outliers. Relevant correlations showed that: increasing "P&R slots", "PT demand" grows; an increase in the "Cost of on-street pay parking" means a reduction of the "Accident rate," a reduction of the "Share of private car" and an increase of the "Share of bicycle"; an increase in the "PT Service supply" means a reduction either of the "Share of PTW" or the "PTW rate."; a decrease of the number of "Pay parking slots in city center" leads to reduction of the "Attraction share of private car," as well as an increase of the "Attraction share of PT."; the reason may be due to the fact that increasing pay parking, which are affected to a greater turnover compared to free parking, the likelihood of finding parking increases; thereby, an increase in private car mobility occur; moreover, pay parking leads people to use public transport during the peak hours and private transport during off-peak hours; in the first case, the demand of transport is composed by systematic trips characterized by a long period of stay at destinations that, therefore, should bear high parking costs; whereas in the second case, the non--systematic demand, having a briefer stay at destinations, can support the cost; finally, an increase of "Bike lane length" means an increase of bike mobility. Also in *III° cluster*, some links between variables are unreliable, either for the lack of data or for outliers. In summary: an increase of PT availability, whether in terms of “PT Service supply” or of “PT Service frequency,” implies an increase of the related demand of transport; an increase of the “Bike lane length” brings an increase of the “Share of bicycle”; an increase of the “Attraction share of PTW” and an increase of the “Pedestrian areas” causes an increase of the “Accident rate”. This relation could be due to the fact that both “Attraction share of PTW” and “Pedestrian areas” are likely to increase the level of accident exposure.

Based on the analysis of results, for each cluster, overall assumptions about variables of sustainability have been made:

- Correlations and regressions carried out on indicators concerning pollution level gave the most contradictory results.
- The “Accident Rate” in *I° cluster* does not provide significant information; in the other clusters, it grows with private transport demand (II° – cars, III° – PTW), and in the III° cluster with pedestrian mode.
- The “PT demand,” in terms of modal share of urban and commuters mobility, increasing with “PT Service supply” and “PT Service frequency,” is a reliable sustainability variable for the following benchmark analyses.

4.3. Regression analysis in individual clusters

From the correlation analysis carried out on clusters, some correlations between policy and sustainability indicators have been identified; among those the modal share, the PT demand and the accident rate are included. The graphic representation of variable’s variation compared to another one (scattergram) brings to an immediate detection of possible outliers in some cities. By calculating the linear regression equation and the related R^2 coefficient on such data, it allows to assess the results coming from the previous correlation analysis in a critical manner. The results obtained from this regression analysis confirm those of the correlation analysis, except for some relationships among indicators less significant due to the inconsistency of sample or to the presence of outliers. As an example, the results obtained from the *III° cluster* are reported in Fig. 5, that shows the relationship between the “PT demand” and, respectively, the “PT Service supply” and the “PT Service frequency”. Fig. 6 shows the relation between the “Accident rate” and the Attraction share of PTW”.

a b

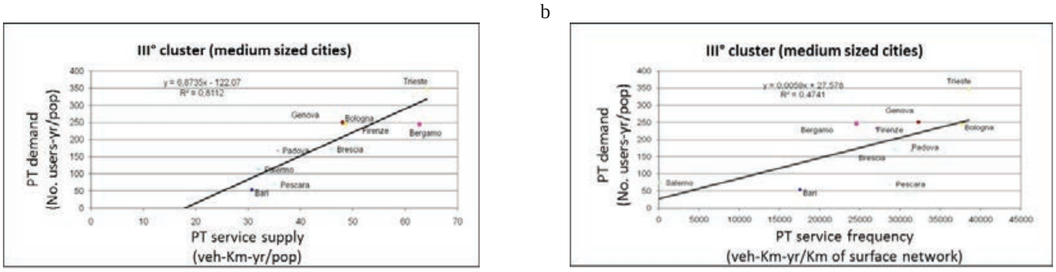


Fig. 5. (a) Service supply – PT demand; (b) PT Service frequency – PT demand.

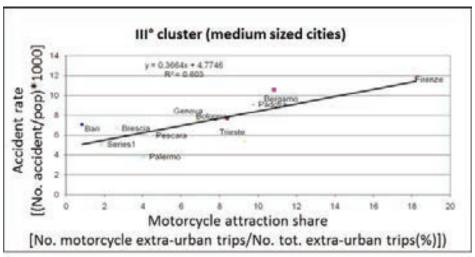


Fig. 6. Attraction share of PTW – Accident rate.

5. Benchmarking analysis

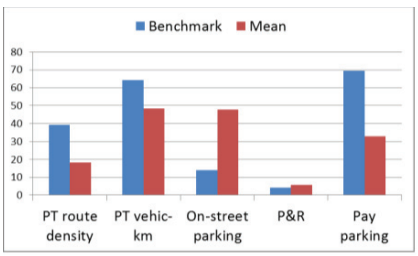
Clusters benchmarking was carried out using public transport indicators. Cities, within each group, were organized in an index, calculated as the ratio between the value of variable for each city and the maximum value of that variable in the cluster. Identifying the “best performers” of each cluster, a comparison has been made between policies adopted by these ones and those adopted on average in the cluster. By this way, “best policies” were identified, that, for cities belonging to the same cluster, could be a sort of reference for the other cities. As an example, we propose the results of the *III° cluster* analysis. As reported in Table 3, Trieste, Genoa and Bologna are the best in terms of public transport, whereas the lowest values were recorded for Pescara and Bari.

Table 3. Classification of the III° cluster in function of Public transport demand.

III cluster- medium-sized cities	Public transport demand
Trieste	1.00
Genoa	0.72
Bologna	0.72
Bergamo	0.71
Firenze	0.67
Monza	0.52
Brescia	0.50
Padova	0.48
Palermo	0.33
Salerno	0.21
Pescara	0.20
Bari	0.16

In the following figures, we report a comparison between the average values of clusters and the values of the benchmark cities (Fig. 7). Considering trends of benchmark cities, we can see that: Trieste shows low “PT network density” (-16%) and high “PT Service supply” (+32%), low availability of “Regulated on-street parking slots” (-71%) and “P&R slots” (-25%), low “ZTL” (-88%); Genoa has an high “PT network density”(+114%), important “PT reserved lane percentage” (+153%), low availability of “Regulated on-street parking slots” (-67%) and “P&R slots” (-61%); Bologna presents low “PT network density” (-37%), elevated “PT reserved lane percentage” (+126%), “Regulated on-street parking slots” (+84%), “ZTL” (+72%). From the pooled-data analysis it is apparent that: Trieste and Bologna PT service favors the service supply with a production (vehicles-Km) always greater than the average value, despite of route density, always less than the average value; reserved lane percentage of Genoa and Bologna is always much greater than the average value; P&R slots is less than the average value. Trieste and Genoa availability of parking is less than the average value, but it is balanced out with an increase of pay parking cost, also smaller than the average value. Bologna has an elevated availability of parking with a greater increase of pay parking cost.

a



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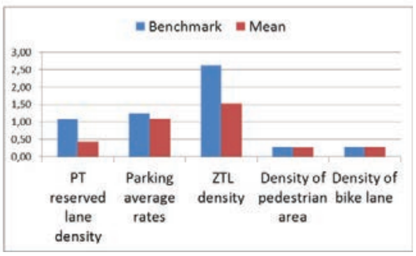

Fig. 7. (a) Comparison between average values of clusters and benchmark values for some indicators; (b) Comparison between average values of clusters and benchmark values for some indicators.

6. Conclusion

The whole study aimed at defining a set of indicators that, collected in a systematic way, allow significant improvement in planning and in the sustainability of urban transport systems od cities. The overall analysis, while not always linear and easily interpretable, has shown some interesting results. The environmental sustainability (in terms of pollution emissions) tends to improve in cities with an higher PT demand, in terms either of annual usage or urban modal share. Thus, "PT demand" could be adopted as a replaced indicator of sustainability. In addition, the "Bike lane length is correlated to bicycle mobility Regarding accident rate, no significant correlation emerged.

These results confirm the assumption that public transport is one of the most sustainable among urban transport modes; then, an increase of the use of this mode, together with pedestrian and bicycle ones, involves, as expected, an improvement of the level of environmental sustainability. So, each measure aiming at promoting the use of such modes or, alternatively, to penalize one of most competitive with those, that is private car, is, therefore, oriented to act in this direction. Afterwards, we proceeded to grouping surveyed cities according to the same characteristics previously identified, considering it effective for understanding intervention policies for urban sustainability. Comparing clusters by sustainability variables, it emerges that increasing the size of the city, the modal share of public transport increases while the modal share of private transport decrease. In conclusion, in order to improve environmental sustainability of cities, the most effective policies are those characterized by an higher PT Supply service, and an increase of bike lane length for all cities sizes. In particular, low population density cities, and large cities, needs to grow up the number of P&R slots, and the cost of street pay parking. Regarding smaller cities with high population density, the number of pay parking slots in city center must be reduced. In order to improve the road safety in medium size cities, the relation between accident rate in pedestrian areas and attraction share of PTW, should be more in-depth analysed. Finally, concerning pollution level, results were inconsistent.

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