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URBAN SUSTAINABLE MOBILITY. PART 1: RATIONALITY IN TRANSPORT PLANNING

Summary. The impact of the transport sector is in the range of 20%-40% in terms of consumption of fossil fuels and emissions of greenhouse gases and particulate matter. In this context, policies aimed at reducing these effects are very important. Many urban areas are trying to adopt planning strategies aimed to a sustainable use of resources often referred to as sustainable mobility. These policies are very different in terms of costs and expected benefits, and the effects of these policies and their combinations are difficult to anticipate on a purely intuitive basis and sometimes the end effect could be contrary to intuitive expectations (e.g. policies aimed to reduce pollution, ending up in increasing it). In this context, the concept of eco-rational planning assumes a central role. This means identifying the right mixture of interventions to be implemented on the transport system that is: rational for the transport system (e.g. reduction in terms of congestion, traffic accidents, travel time) and sustainable for people's health and for the environmental (e.g. emissions reduction) and requires minimal economic resources (e.g. lower monetary cost per unit of CO_2 saved). The paper discusses the importance of rational decisions in transport planning.

ZRÓWNOWAŻONA MOBILNOŚĆ MIEJSKA. CZĘŚĆ 1: RACJONALNOŚĆ W PLANOWANIU TRANSPORTU

Streszczenie. Wpływ sektora transportowego w odniesieniu do zużycia paliw kopalnych i emisji szkodliwych gazów oraz cząstek stałych jest w zakresie od 20% do 40%. W tym kontekście działania mające na celu zmniejszenie niekorzystnych skutków są bardzo ważne. Wiele obszarów miejskich stara się przyjąć strategie planowania zmierzające do zrównoważonego wykorzystania zasobów. Są one często określane jako zrównoważona mobilność. Zasady te są różne pod względem kosztów i oczekiwanych korzyści. Skutki tych polityk i ich kombinacje są trudne do przewidzenia na podstawie intuicji, a czasami rezultat może być sprzeczny z intuicyjnymi oczekiwaniami (np. polityki zmierzające do zmniejszenia zanieczyszczenia środowiska, powstrzymanie wzrostu zanieczyszczenia środowiska). W tym kontekście pojęcie planowania ekologicznie racjonalnego przejmuje główną rolę. Oznacza to określenie odpowiedniego zestawu interwencji, które są: racjonalne dla systemu transportowego (np. ograniczenie zatorów, wypadków drogowych, czasu podróży), zrównoważone dla zdrowia ludzi oraz dla środowiska (np. redukcja emisji), wymagające minimalnych zasobów ekonomicznych (np. niższe koszty za zaoszczędzoną jednostkę CO_2). W artykule omówiono znaczenie racjonalnych decyzji dotyczących planowania transportu.

1. INTRODUCTION

A city without oil is the general goal aimed at gradually reducing the use of fossil fuels and greenhouse gas emissions in different urban functions. Some observers see these interconnected functions in analogy with a living organism and speak of "urban metabolism" [16, 19]. These objectives are widely acknowledged both in the world (Kyoto and Cancun) and European (White paper and 20/20/20 strategy) levels. The impact of the transport sector is in the range of 20%-40% in terms of consumption of fossil fuels and emissions of greenhouse gases and particulate matter. In this context, policies aimed at reducing these effects are very important and have dual objectives at the global and local level.

At the global level, in recent years the worldwide energy demand has increased with the consequence increase of carbon dioxide (CO_2) emitted. Fossil fuels, especially oil, are at risk of extinction, their price is growing and subject on unpredictable fluctuations.

At the local level, greenhouse gas emissions and fine particles pollutants have adverse effects on human health; in addition pollutant concentrations exceeding the limit allowed by law can cause severe functionality problems for the cities and legal problems for public administrations.

To this end, many urban areas are trying to adopt planning strategies aimed to a sustainable use of resources often referred to as sustainable mobility (e.g. Travel Demand Management strategies, pricing policies, ITS technologies, new transit services and/or infrastructures, sustainable land-use policies). These policies are very different in terms of costs and expected benefits, both at the global and local level. Because of the well-recognized nonlinear interdependencies of urban transportation systems [8] the effects of these policies and their combinations are difficult to anticipate on a purely intuitive basis and sometimes the end effect could be contrary to intuitive expectations causing a "not-rational effects" (e.g. policies aimed to reduce pollution, ending up in increasing it).

Furthermore, the recent economic crisis has forced the public administrations in Italian cities and regions to cut investments for urban mobility projects, forcing planners to consider explicitly the problem of a rational use of economic resources.

In this context, the concept of rational planning assumes a central role. Starting from Elser's definition of rationality in decision-making [13], as acting in the best possible way considering the aims and the constraints, in this paper the concept of "*eco-rationality*" proposed in [7] was deeply developed as acting in the best possible way considering *eco*logical and *eco*nomic aims (pollution reduction; welfare improvement; congestion reduction; economic necessities) and constraints (e.g. budget; resources; levels of pollutants). Eco-rationality tries to mitigate the pitfalls of irrationality in "*acting in the best possible way*"; this means identifying the right mixture of interventions to be implemented on the transport system that is:

a. rational for the transport system (e.g. reduction in term of congestion, traffic accidents, and travel time),
b. sustainable for people's health and for the environmental (e.g. reduction of fuel consumption and emissions)
c. and satisfy the basic economic necessities (e.g. requires minimal economic resources ensuring basic social economic necessities like food, drinking water, shelter, and clothing).

Obviously, the concept of eco-rationality is necessary a fuzzy one, as no single value objective function can be referred to, and even non-quantitative objectives and constraints can be included in the decision-making process (the opposite occurs for the strong rationality as described in section 2).

One of the main element for pursuing eco-rationality are the quantitative methods (tools) for ex-ante and ex-post evaluations. The traditional role of quantitative methods in supporting transport-related decision processes is mostly oriented to "forecasting" the impacts of alternative options while little effort is dedicated to ex-post analyses of system performances and to the forecast reliability. On the other hand, monitoring and ex-post evaluations are crucial to support a "rational" dynamic decision-making process, as: a) they provide feedbacks to stakeholders and decision-makers for further stages of the process, b) they increase the credibility (and establish limits) of quantitative methods and c) they are the basis for fine tuning the models.

As an application case studies were considered two "conventionally sustainable" transport policies developed in Naples in last years without quantitative evaluations:

– regulatory incentives to the renewal of vehicle fleet,
– and new transit-point and light goods vehicles for urban distribution.

Starting from the transport simulation model implemented (see the compendium paper Part 2) and the results obtained in [7], an ex-post evaluation was performed to quantify the "non-rational effects" of these policies applied in Naples (Italy), underlining the importance of the ex-ante analysis for sustainable transportation planning. Finally the section 4 reports main conclusions and research perspectives.

2. RATIONALITY IN TRANSPORT PLANNING

Planning interventions on a transport system means making decisions (not deciding vs. alternative plans/projects vs. looking forward to new plans/projects). There are many ways to define collective choices or decisions according to the field we're referring to, economy, philosophy, social science etc. [2, 3, 21].

Several definitions of rationality have been proposed both for individual and group decisions. As said, a rational choice (rationality) in transport planning means acting in the best possible way considering the aims and the constrains [13]. This definition is in general enough to be compatible with different decision-making approaches. However these approaches should have of "*minimal set of requirements of rationality*". I propose the following requirements:

– *comparative* that means considering more than one alternative (e.g. not deciding, one of the available options, searching for other possibilities);
– *aware*; being informed about the options (features), the context (physical and decisional) and other related choices (internal, horizontal and vertical coherence) besides impacts evaluation through quantitative ex-ante/ex-post estimations (costs, benefits, risks and opportunities);
– *consistent* that means comparing options with aims and constraints and avoiding choices contradicting each other with respect to the achievement of the stated objectives or resulting in unnecessary waste of resources;
– *flexible*; choices can be changed due to cognitive constraints (limited information and estimated effects), the context (unpredictable) and the ad-vantages of not making a choice (postpone unnecessary decisions).

The introduction of the above requirements is intentionally "fuzzy" to be adapted to very different decision contexts.

The main theoretical models of rationality are two: the strong rationality and the cognitive or bounded rationality.

Strongly rational models assume that individuals and organizations choose the best action according to unchanging and stable preference functions and constraints. This approach implies the existence of one or more decision-makers with a unique system of preferences that allows the ordering of the possible choices. The homo economicus is able to evaluate all the possible alternatives and choose the one with the maximum utility satisfying all bounding constraints. Although the strong rationality is an "ideal" model, not completely achievable in the real world, it allows to evaluate the decisions in a clear and rational way.

The idea of an absolute rationality is not easily to apply in a real context. "Optimal" choices require that all the possible alternatives are perceived by all the decision-makers and all the criteria to evaluate the different options are clear to each of them and that decision-makers are agreeing on a set of trade-off among effects of alternative options.

Often the strongly rational models are not able to represent human behaviour at the individual level and even more so when several individuals interact in complex systems. In opposition to the strong rationality model, cognitive or bounded rationality models have been proposed.

Cognitive rationality explicates the dynamicity of the decision making process, ideally divided in subsequent stages, while keeping the realism and flexibility of bounded rationality within each stage. This model is inspired on the learning theory of dynamic decision-making processes [14, 15] and dynamic cognitive processes [25]. The model is "cognitive" in nature since actors learn about solutions and their effects, the achievable objectives, the possible trade-offs, during the decision-making process. It also includes the possibility of decomposing decisions in subsequent steps, implementing subsets of them and "learning" from their effects. Still the process can be rational insofar as the four requirements of rationality are met. According to the bounded rationality model, the decision-maker has limited time, capacity to express and compare objectives and budget resources and therefore he/she chooses an alternative which is satisfying. This model was proposed by Herbert Simon in 1955 [22] as an alternative for modelling the decision-making process; decision-makers haven't the capacity and the resources to achieve the optimal solution, but they apply their rationality only after having simplified the available alternatives. So the decision-maker is a satisfier who searches a satisfying solution instead of the optimal one [16, 17, 17, 24].

Differently from the homo economicus, the administrative man has a limited rationality and isn't able to analyse all the possible solutions and to consider them simultaneously but he evaluates them sequentially and chooses the first he finds satisfying [23].

The concept of satisfaction is necessary a fuzzy one, as no single value objective function can be referred to, and even non-quantitative objectives and constraints can be included in the process. The model is "cognitive" in nature since actors learn about solutions and their effects, the achievable objectives, the possible trade-offs, during the decision-making process. It also includes the possibility of decomposing decisions in subsequent steps, implementing subsets of them and "learning" from their effects. Still the process can be rational insofar the four requirements are met.

The conclusion is that a rational choice is not always (almost never) the best solution for different reasons: not clear aims and/or constraints, lack of consideration for all the alternatives, wrong evaluation of all costs, benefits, risks and opportunities of each alternatives. This means that rational choice is a multi-step decision process based on the outputs from previous decisions, monitoring and ex-post evaluations.

The decision-making process can be considered a learning process which is realized through continuous upgrading. In the transportation field, an example of decision-making process with a bounded rationality model should be the choice of an infrastructure (i.e. an highway or a railway). Although in theory there are infinite alternatives to connect the starting point with the arrival one (infinite paths), the designer chooses among a limited number of possible alternatives on the base of his/her previous experiences. The evaluation criteria considered could be: the construction and maintenance costs, users times and costs, the environmental impacts and so on. So the choice is made considering only few alternatives (not all) and using few parameters.

This model is particularly suitable for the collective decisions, where more decision-makers and stakeholders are involved, for which it isn't possible to identify a unique hierarchy for the different aims which allow to achieve the best solution.

In general, a rational choice, however bounded, which is comparative, aware, consistent and flexible is better than a-rational choices such as those represented by the garbage can model (e.g. [11]).

Rational decision making is more accountable and coherent with Public Engagement allowing to avoid some irrational effects such as [1]:

- *analogical effect*: the solution A has worked in a certain context and so it can work in this context too;
- *opposition effect*: the solution A has worked, so the solution B doesn't work;
- *random effect*: the solution A hasn't worked after an event B, so B caused the problem.

In this context, as said, the eco-rationality of transport choices could be defined as acting in the best possible for people's health (pollution/welfare), the environment's, global and local, benefits (pollution) and the economic necessities. Many transport policies (choices) are widely accepted as sustainable (ecological) but they aren't always eco-rational (not acting in the best possible way). An example could be:

- CHOICE: a vehicle restricted access area in the historical centre;
- EFFECT 1: rise in PT modal share and vehicle emissions reduction in the historical centre;
- EFFECT 2: increase in traffic congestion and vehicle emissions near restricted area and in other parts of the road network for diverted traffic;
- TOTAL EFFECT: increase in total urban emissions.

These transport policies could be defined as "*not-rational*" and can be identified applying a rational decision making process, using quantitative methods [20] and evaluations (Decision Support System - DSS).

In the next section, to underline the importance in using quantitative methods for ex-ante and ex-post evaluations (described in the compendium paper Part 2), two real case not-rational policies occurred in Naples are described.

3. APPLICATION CASE STUDY

3.1. The case study

The application case study is the city of Naples in southern Italy, occupying more than 117 km^2 with a population of about 960 thousand inhabitants and a population density of 8.2 thousand inhabitants/km^2. These socio-economics and territorial characteristics make this city particularly suitable for a public transport system based on railway (Transit Oriented Development [9, 10]). For over 20 years an integrated planning project based on the use of railways has been set out. Today Naples has 9 urban metropolitan lines and it is considered that by the end of the project, 60% of Neapolitans will have a metro station less than 500 metres close.

To estimate mobility characteristics within Naples, a specific traffic counts survey was performed in the period 2007-2011 (see also [5]). 131 the traffic count sections (see Fig. 1) were identified through a screen-line method and monitored for two average days: weekday (working day) and weekend (holiday). The reference period measured was 06:00-21:00 for the average weekday and 09:00-24:00 for the average weekend. The vehicles flows measured were divided by vehicle type: car, motorcycle, light goods vehicles and heavy goods vehicles.

For each traffic count section was possible to estimate the peak and off-peak hours for morning, afternoon and evening periods.

For data analysis, the study area was divided into four basins (Fig. 1): city centre; west basin; north basin; east basin.

The results of the survey show that, for the average weekday, the morning peak hours ($\subset$ [06:30-09:00]) for the outer band (west basin $\cup$ north basin $\cup$ east basin) are earlier than the central ones ($\subset$ [07:30-10:00]). This is explained because trips towards the city centre need more time to reach their destination and so have to anticipate their departure time. With respect to afternoon peak hours in the north-west basin, maximum flows occur between 16:30 and 20:00, during which there are presumably "work to home" trips. By contrast, in the north-east basin of the city, the afternoon peak hours are strongly anticipated and occur between 13:00 and 16:30.

As for the weekend, the most significant traffic flows occur after 12:00. In the afternoon, traffic flows are about 50% of those on weekdays. In the evening, the peak hour occurs at about 20:00. From this survey was possible to estimate network peak and off-peak hours.

Starting from these surveys and from the results obtained in [7], a simulation model (see the compendium paper Part 2) was implemented to simulates the relevant interactions among the various elements of the Naples transportation system and to estimate the performance of the system estimating some indicators (e.g. average speed; km/year travelled by vehicle category; fuel consumption, vehicles emissions) both related to the base scenario (2011) and referring to design scenarios.

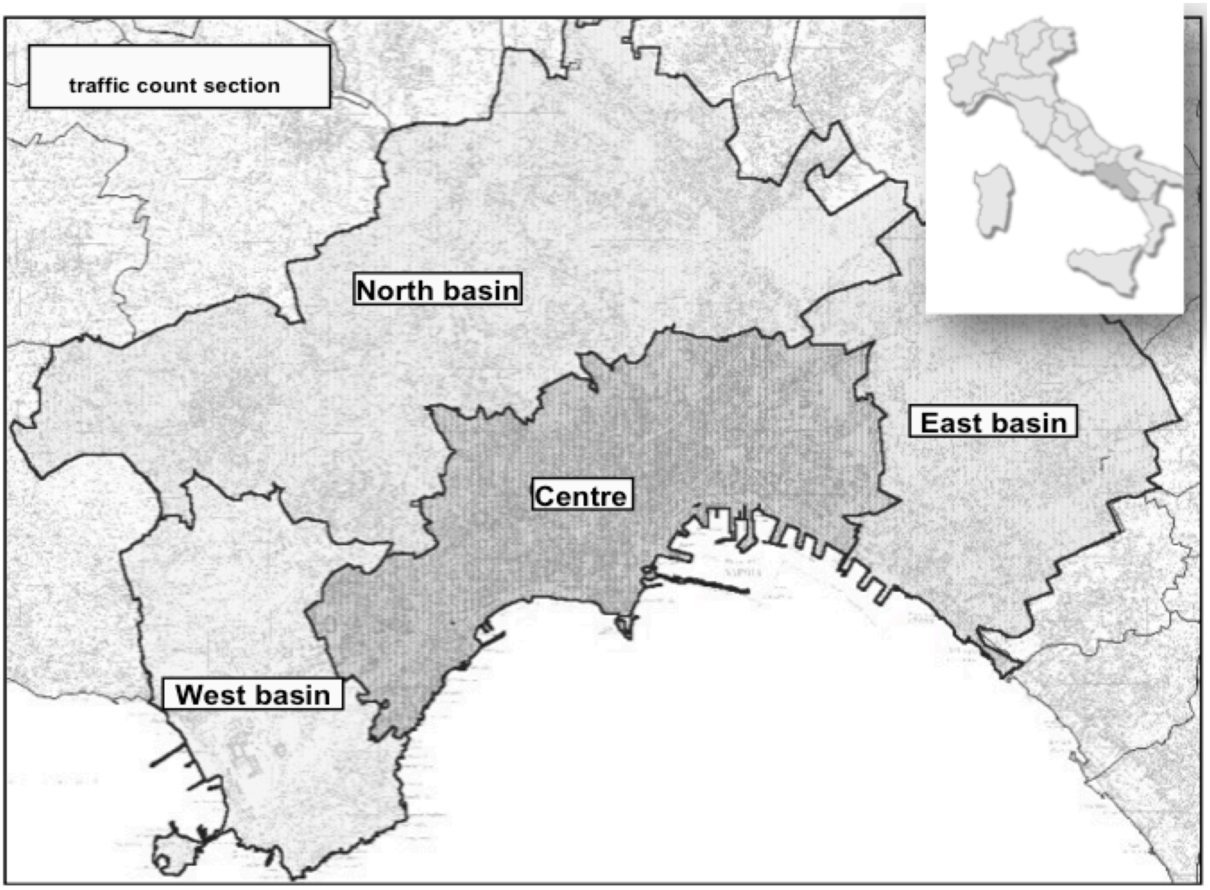

Fig. 1. Study area and traffic count section – Naples, Italy
Rys. 1. Obszar badań – Neapol, Włochy

Impacts of transport policies were estimated through Nested Logit models to take into account the influence of "lower" choice dimensions on "upper" levels (both for passenger and for freight). In demand model specification, several attributes were considered: socio-economic (e.g. resident population by market segments of the number; employers and firms in economic activity sectors), level of service (e.g. travel time, travel cost, waiting time) and dummy variables (e.g. geographic and accessibility attributes). With respect to the assignment model, stochastic user equilibrium assignment was considered for car passenger mode, while stochastic network loading assignment model was used for freight vehicles. For all the details on the data, models and calibration methods and sample see the compendium paper Part 2 and [4, 6, 12].

3.2. Some examples of non-rational policies implemented in Naples

As said, in the last years in Naples, two "conventionally sustainable" transport policy were developed without following the minimal requirement of rationality (in particular the quantitative analysis was not performed):

- regulatory incentives to the renewal of vehicle fleet,
- and new transit-point and light goods vehicles for urban distribution.

In this section, starting from the transport simulation model implemented and described, as said, in the compendium paper Part B, an ex-post evaluation was performed to quantify the non-rational effect of these policies applied in Naples, underling the importance of the ex-ante analysis for performing rationality in transportation planning.

3.2.1. Renewal of vehicle fleet

In the last 10 years in Naples city was observed a renewal of more than 30% of car fleet. This phenomenon has been caused also by some restrictive transport policies applied in the city; for three business days per week only cars with low emission can circulate. This policy has increased the natural renewal process of the car fleet, modifying also the percentage share of diesel vehicles. From the database of the Italian Motorist Association emerges that between 2001 to 2011 this percentage share is greatly changed (Fig. 2). In 2001 the 13% of the cars were diesel; the 82% were gasoline vehicles, while the 5% were Liquefied Petroleum Gas (LPG). By contrast, in the 2011 the 38% of the cars are diesel, the 60% are gasoline vehicles, while the 2% are LPG. The result is that in these ten years was observed the 12% increase of diesel car share caused by: the increase in performance and technology of diesel engine (e.g. common rail and multijet engine); the abrogation of the Italian diesel tax.

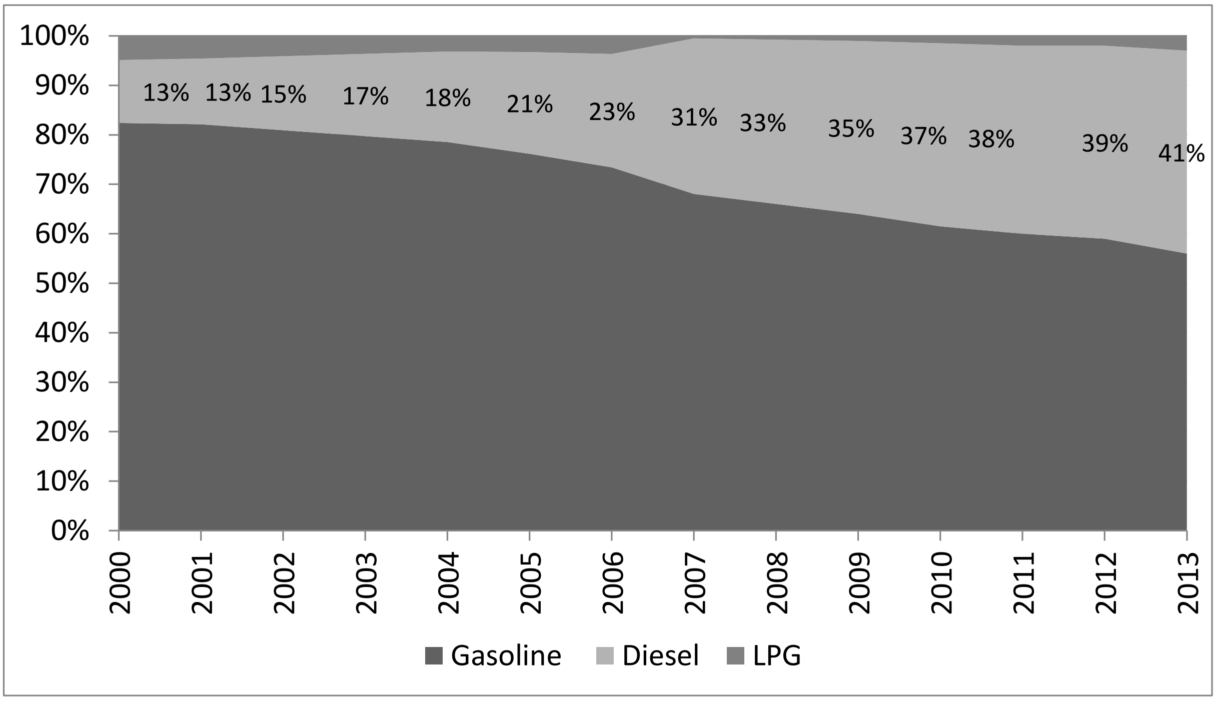

Fig. 2. Percentage share of the Naples car fleet
Rys. 2. Procentowy udział floty samochodowej w Neapolu

The environmental effects of this restrictive traffic policy have been estimated through the models implemented (beck-casting application). The simulation results show that in these 10 years, the increase of the diesel cars share has caused the increase of 5% of the PM10 car emission (+1% in total PM10 transport emission) while a decrease of 9% in car CO_2 emission (-4% in total CO_2 transport emission). This means that if the new vehicles are more efficient from an environmental point of view (the EURO 4 CO_2 car emission is 25% lower than of the EURO 0 CO_2 car emission), they are not sustainable from a men's health point of view (the EURO 4 PM10 diesel car emission is larger than the EURO 0 PM10 gasoline car emission).

Starting from these results, a design scenario was simulated testing the traffic restrictive policy jointly with some renewal incentive policies aimed at reducing overall emissions of pollutants. The simulation results (costs not included) show that a renewal of 30% of total vehicular fleet (cars, buses and good vehicles) produces:

- 38% reduction in total PM10 emission (-142 tons/year); the 70% of PM10 emitted in Naples are by buses and good vehicles (more than 90% of the buses and good vehicles are diesel);
- 7% reduction in total CO_2 emission (-74 thousand of tons/year); the 56% of CO_2 emitted are by cars.

In conclusion, the application results show that only a traffic restrictive policy for the polluting vehicles is not always eco-rational. By contrast, this policy combined with the design of policies to "control" the renewal of vehicles fleet can lead to an overall result of system eco-rationality.

3.2.2. Transit-point and light goods vehicles for urban distribution

The second kind of transport policy tested is the application of the City-Logistics Plan proposed for Naples which consists in:

- new transit-points in strategic location inside the city;
- new and more efficient vehicle paths (from a distribution point of view);
- no heavy trucks for urban delivery.

Through the simulation models the environmental effects of these interventions has been estimated. The results show that, against a traffic congestion reduction (5% reduction), the main impacts are

- + 10% in traffic fuel consumption;
- + 5% green gasses emission (equivalent CO_2);
- + 11% fine particles emission (PM10).

This was caused by the increase in trips length and number caused by the use of only light good vehicles for urban distribution.

As an alternative scenario has been estimated the effect of the application of the City-Logistics Plan jointly with the design of the renewal of light good trucks into electric vehicles. The simulation results show that a renewal of 35% in electric vehicles could decrease the total emissions:

- ≈ 0% in total traffic fuel consumption;
- ≈ 0% in total green gasses emission (equivalent CO_2);
- -3% in total PM10 emission (-11 tons/year).

In this way, this policy could be eco-rational even if the effects are very limited from the environmental point of view (the Napoli smokers emit 30 tons/ year of PM10). The estimation of the implementation costs is out of the scope of this paper.

4. CONCLUSIONS AND RESEARCH PERSPECTIVES

The paper discusses the importance of rationality in in transportation planning and in particular in using quantitative methods (tools) for ex-ante evaluations. According to the author, a rational choice (rationality) in transport planning means acting in the best possible way considering the aims and the constrains. A rational approach is not always the right alternative but is most probably nearer to the best solution also because is more acceptable (for Public Engagement) and follow some minimal requirements of rationality (e.g. quantitative method's evaluations).

The eco-rationality of transport choices was introduced as acting in the best possible way considering people's health, the environment's and the economic necessities. Standard transport policies are not always eco-rational because of these policies are very different in terms of costs and expected benefits, both at the global and local level. Because of the well-recognized nonlinear interdependencies of urban transportation systems the effects of these policies and their combinations are difficult to anticipate on a purely intuitive basis and sometimes the end effect could be contrary to intuitive expectations causing a "*not-rational effects*".

Starting from these considerations an ex-post evaluation was performed to quantify the "non-rational effects" of two transport policies applied in Naples (Italy), underling the importance of the ex-ante analysis for sustainable transportation planning.

One of the research perspectives will be to test the eco-rationality of other transport policies (e.g. vehicle restricted access area in the historical center). Furthermore the effects of the realization costs of some transport policies will be taken into account.

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