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Sustainable Development and its Implications for Regional Development. Accessibility as a Function of the Sustainable Transport System

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ABSTRACT

All large cities are confronted with rapid urban growth, most often combined with expanding urbanization. These trends generate increased mobility demands and a strong need for transport infrastructure. Although it is notoriously difficult to measure, the economic, social and environmental impact of this generalized urban sprawl is substantial: uncoupling of home and work, land consumption, loss of economic attractiveness, increased dependency on fossil fuels and, as we know, these factors produce important negative environmental externalities. These problems have heavy repercussions on the competitiveness and attractiveness of a Region. In this view, this paper analyzes, if ''sustainable transportation'' could be considered seriously as a pattern for achieving a "sustainable competitiveness". At the base is the idea that the choice of a destination is not linked to the distance but to its "accessibility". From the methodological viewpoint, accessibility has a long tradition, starting in the 1950's with Hansen, who defined accessibility as the potential of opportunity for interaction. In fact, accessibility may be used for investigating the (un)even distribution of economic activities, or the (dis)equilibrium in the development of different regional performances. In particular, the accessibility measure can be considered as a first exploratory step in the understanding of people's needs and behavior, especially in the framework of transport structures.

Keywords: *Regional development, transport system, accessibility, cost benefit analysis, sustainability, environmental quality, mobility.*

1. INTRODUCTION

It is universally recognized that transport infrastructures can be considered as an important factor of development, or that the level and the rate of development are positively linked with the amount and efficiency of infrastructures. It follows that an improvement of the equipment and the efficiency of infrastructures can help to promote the development of a economy. This link between infrastructures and development has been considered by academics of economic theory and from the history of economic development. Particularly, authors such as Kuznets, Rostow, Hirschman, Tinbergen showed in their analysis, the relevance of such link.

The purpose of this paper is to present some arguments on the role of transport infrastructures as a factor of growth and development of a regional economy.

Economists study the transport infrastructures in order to explain the performance of markets in all areas in which the territory and the spatial distance assume economic importance.

In general, the improvement of transport infrastructures determines a reduction of the interaction costs between economic agents located in different points of economic space, or, in other words, facilitates the overcoming of the barriers imposed by the space to the movement of people and to the exchange of goods, services and information. These direct effects affect the performance of the markets in which each agent exchanges goods and services.

In this context, the accessibility, understood as the facility or difficulty in making a journey from/to a particular location, is introduced to connect the generation and/or the attraction of the flows to the characteristics of the transport system.

It is a variable that can be very important, not only when the purpose of travel is not obligatory but, in some cases, it can determine the capacity of attraction of a territory, in terms of the availability of industrial and commercial services/settlements, or according the levels of production and employment offered by the region, with potential positive effects on the environmental management of the whole area.

2. THE CONCEPT OF ECONOMIC DEVELOPMENT

The classical economists attributed to the concept of economic development, the meaning of prosperity, not only economic but also social, cultural, institutional to a community.

In the most recent definitions, some authors identify it with economic growth, an increase over time in the level of gross domestic product, GDP, per capita. However, some researchers believe that this definition has an error of perspective. Since economic growth refers only to the GDP per capita it does not take into account the following issues:

- the distribution of GDP per capita among the population;
- the problem of externalities and non-tradability of certain goods and services;
- the valuation of assets in GDP reflects the distortions inherent in this mechanism.

2.1 The Physical Limits to Growth

The central paradigm of neoclassical economic theory considers the market as an allocation mechanism able to activates the necessary resources at the lowest prices. In other words, the economic system is an isolated system. The situation is different when we consider that the economic system is placed into a limited or "finite" natural system .

There are, in this case, physical limits to growth, of carrying capacity, such as pollution and the depletion of non-renewable natural resources and the excessive exploitation of renewable natural resources.

The concern about the progressive depletion of natural system determined by the development of modern economic systems has stimulated the search for effective solutions to the redefinition of the relationship among economics and environmental problems.

The solutions are placed on three assumptions:

1. The first one, less radical, proposes the reduction of production at the optimal level, i.e. the "zero growth" hypothesis;
2. The second hypothesis proposes the introduction of national accounts extended to the evaluation of ecological subsystems;
3. The third assumption, inspired by Georgescu-Roegen's bioeconomic paradigm, proposes to set up the economic systems on the basis of evaluation of solar energy embodied in human productions.

2.2 The Social Limits to Growth

The arguments against growth were supported by economic analysis that have tried to demonstrate the social costs and, in particular, the environmental costs.

The Esterlin paradox: "the data indicate that the material wealth and human happiness are not closely related", and the Scitovsky analysis, the so-called joyless economy, in which the emphasis is on the need of something that goes beyond the material wealth, are an example of what might be called the social limits to growth. However, as emphasized by the literature on the subject, we cannot tell of development of a society if there is not already a growing society, that is, development becomes real after a material growth of a determinate community.

A typical example is presented in the literature as the distinction between primary goods and positional goods: a society, in fact, will try to have primary goods if it is in poverty, and will seek to have positional goods if it has already satisfied its primary needs (such as industrialized countries).

2.3 The Sustainable Development

In order to take into account both the problem of the physical limits and that one of social limits to growth, it was necessary to develop a new paradigm relating to the interaction between socio-economic and natural systems: the sustainable development.

Sustainable development is a process of change in which the exploitation of resources, the performance of investments, the orientation of technological development and institutional change are considered harmonious and able to increase the possibility of meeting the needs of the present and the future generations.

3. THEORIES OF ECONOMIC GROWTH AND REGIONAL DEVELOPMENT

The territory and therefore transports play an important role in influencing the development of an economy. An aspect that emerges when studying the development of an economy (characterized by the spatial factor) is represented by the differences in which development involves and affects the areas and regions that constitute the economy. Imagine that the territory T is divided into two regions, A and B. Studying the economic development of the territory T in territorial terms means discuss the discrepancies and differences of development between the regions A and B.

The regional economists have provided many theoretical explanations of this phenomenon. For a brief presentation of these theories it is necessary distinguish between analysis of regional balanced development and analysis of regional unbalanced development [1] [2].

3.1 The Regional Balanced Development

The analysis of balanced development assumes that the market works as an efficient and effective allocator of resources both at social and at territorial level. In this sense, the differences between the two regions are seen as temporary disturbances, caused by exogenous shocks on the demand or on the supply side, compared to a long-run equilibrium in which the growth rates between the two regions are homogeneous.

The mechanisms that guarantees the return of each region on the path of convergence towards a balanced development are represented by the adjustment of prices and of the sectoral and geographical perfect mobility of production factors.

The prices reflect the net excess of demand for goods and factors, and the exchange flows of goods and factors will adjust until there are benefits from the regional and sectoral "exchange", or until the remunerations of the factors are equal on the whole economy [3].

From the point of view of the geographical distribution of production, the regional balanced development refers to a pattern of specialization based on a comparative advantage (Ricardo), or on the factorial intensities of equipment, according to the theory of Heckscher-Ohlin.

These theories explain only the intersectoral trade, i.e. the exchange among countries specialized in the production of goods commercially recognized as individual. Furthermore, due to the nature of their formulations, the theories of Ricardo and Heckscher-Ohlin are substantially agnostic with respect to the intraregional exchange.

Obviously the analysis of balanced development is based on the assumption of perfectly competitive market. A price adjustment according to the functions of excess demand and supply and the perfect mobility of factors are, in fact, the essential requirements of the model.

3.2 The Regional Unbalanced Development and Returns to Scale

A territorial analysis cannot ignore the role of the spatial concentration of production, i.e. the agglomeration and productive districts indicated by Alfred Marshall as the main source of external economies of scale [4]. In these circumstances, a region, that gains a small initial comparative advantage in the production of a certain good, can increase this advantage over time through the external economies of scale [5]. From another side the endogenous growth theory has indicated in its external effects (due to economies of localization and urbanization) the main drivers of innovation processes of the district and of the long-run growth. The long-run regional growth is possible where there is a favorable environment for innovation processes of individual operators, and the diffusion and imitation of such innovations is very easy [6].

The phenomenon of territorial agglomerations, however, should not be interpreted only as a function of external economies of scale. In fact, industrialization has led to relevant spatial concentration of production, originated by the development of technologies with high returns to scale. Technological development and space are, in this sense, in conflict.

The space is in fact an innate element of product diversification. The consumer is not indifferent between a neighboring supplier and another one distant from its ordinary location.

Territorial differentiation of the product leads to define a market where the competition takes place among "neighbors" [7] in a direct way, and is expressed in indirect way among remote competitors. The ability of each producer to expand their production is therefore more limited by the difficulty of attracting the demand than of the ability of reducing costs.

Krugman (1991) [8] has reviewed and synthesized these theories into a simple economic model of monopolistic competition. In that context, it is clear, that the development of a region can be caused by the occurrence of a pecuniary externality represented by the enlargement in the demand side. This effect allows the adoption of more efficient technologies and then to expand the productive base of an area through so-called "backward linkages" in the areas of input suppliers. As the overall demand is limited, the process of "circular cumulative causation (CCC)" concentration rewards one region to the prejudice of another one. These elements can produce structural differences that accumulate in the long run and in the space and lead to the divergence of the paths of development of the regions into a local economic system.

These considerations have found various expressions in the regional economic analysis. The principle of "Circular Cumulative Causation" of Myrdal and Hirschmann, to explain the persistence of regional divergences and which is closely bound up with increasing returns; the theories of hierarchical diffusion of development as the "Spatial Filtering-Down Theory" of Berry and the "Growth Pole" of Perroux, make reference to an economic model based on the elements described above.

The two interpretations, previously suggested, offer different interpretations of the role played by the transport infrastructure in the regional development process.

3.3 Transport Infrastructure and Regional Balanced Development

The Balanced Development Model supports the trend towards an harmonious distribution of activities in the territory, with respect to excess of productive concentration, and includes the assumption of a perfectly competitive market. According to this theory: the more transport system is characterized by high coverage of spatial relationships and of a good functional efficiency, the more should help to neutralize the spatial connotation that prevents the achievement of a regional balance pursued. According to Dugonjic (1989), any improvement introduced to the system should operate in favor of this objective.

In practice, however, it appears that everything is influenced by the types of the existing transport supply (or system) and by the reciprocal influence among the types of preexisting transport infrastructure and of the evolution of production processes.

In this sense, for example, the regional supply scarcity of a certain mode of transport will lead to a regional specialization in areas which require less intensive use of that mode of transport.

3.4 Transport Infrastructure and Returns to Scale

In that context it is easy to argue that the improvements in interregional transport infrastructure do not encourage the spread of development. Rather, on the contrary, they make even greater gaps in regional development by promoting the production concentration processes and regional specialization.

A reflection on these two interpretations regarding the role played by transport systems in the process of regional development, allows us to observe how the interaction between transport and development is not a phenomenon easy to interpret. It might be added, in order to examine closely the knowledge of these interactions, the concentration of human mobility that is developing everywhere, developing interpretative (and practical) issues very hard to solve.

With the consequence that, associated with a large and indecipherable problem of freight transport [9], there is an equally large and significant problem linked to traffic of people that makes very complex to carry out a theorization, and prevents the formulation of solutions harmonically conjugated with the rest.

4. THE ROLE OF TRANSPORT INFRASTRUCTURE IN REGIONAL ECONOMIC DEVELOPMENT

It is known that the role of transport in development process involves two basic elements: on the one hand, the geographical and functional accessibility, and on the other, changes in the production structure (processes, specialization, organization, distribution, etc.) and in the pattern of consumption deriving from a reduction of transportation costs. While among economists there has always been a broad consensus in considering infrastructure as a necessary precondition for a region's economic development, however, as evidenced, nothing can be said as regards the precise identification of their role in the development process [10]. These difficulties can be attributed to: complexity of the phenomenon of "development", due to the presence of material relationships, intangible assets and to the objective and subjective conditions; continuous evolution (quantitative and qualitative) of the need for mobility; different dynamic of "local effects" (or regional) of an infrastructural investment [11]; valuation of temporal intervals.

It's well known that one of the main factors that led to the Industrial Revolution was, also, the decrease in transportation costs due to the introduction of the railroad, through investment in the railway sector and the substantial reduction in journey times.

The decrease in transport costs (or times) is one of the most significant effect in a competitive framework. This decrease makes the existing firms able to serve a wider market allowing an increase in the level of output and consequently the exploitation of economies of scale. Furthermore, the increased accessibility, resulting from the introduction of one or more new connections, allows to consolidate the competitive advantage of a location, making it more attractive for other productive or residential activities. The favorable economic conditions realize, in this way, a multiplicative process. However, this "virtuous circle" may be triggered in the opposite way, or become "vicious", when, thanks to links generated by new infrastructure, the inefficient firms of a region can be replaced by more efficient ones of another region (with consequences in terms of investment, employment, income, etc.) [12].

The response in terms of economic performance is diversified among different regions, because different is the potential for development expressed by each one. A reflection focused on the development potential of a region is that "a better provision of infrastructure increases the productivity of private investments and reduces production costs" from this results, therefore, an increase in differential income and employment compared to a situation where are not planned infrastructure projects. According to what before shown, the spatial effects of investment in transport infrastructure may vary greatly depending on their location. The fig. 1 shows the three main ways in which transport infrastructure can influence the development of a region.

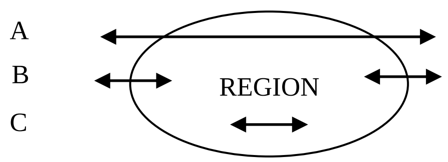

Fig 1: Influence of transport infrastructure on regional development

- **Effect A (crossing):** the infrastructure crosses the region as it has no access points.
- **Effect B (crossroads):** the infrastructure allows improvements in communications to and from the region (resulting in modification in the costs of procurement and in those of trade).
- **Effect C:** Infrastructure improves communications within the region (allowing an increase in internal efficiency).

The figure allows to specify the effects that the infrastructure determines on the region in which it is located, and on the other regions. The infrastructure modifies the competitiveness of the region by improving

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the accessibility (both as accessibility to a specified localization, both as interest that the localization arouses). To understand the impact on interregional flows of an improvement of the transport infrastructure is useful to refer to the "standard" model of interregional trade, assuming the presence of two regions (A and B), the production of a single good and the existence of commercial trade (A is the importing region).

Necessary condition for a flow of exports from the region B to the region A is that the price of the goods in the region B plus the cost of transport from B to A is less than the price of goods in the region A.

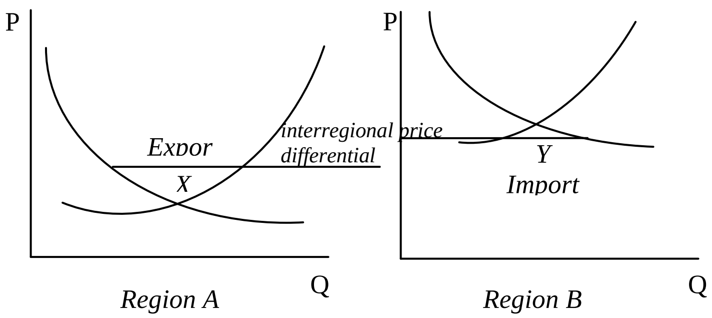

Fig 2: Supply and demand in a bi-regional system

As shown in Figure 2, compared to the situation of "no trade" there is a creation of additional benefit in both regions. In the region A this benefit relates to the consumers who pay a lower price than the situation in which there is not trade between regions, while in region B the benefits regard the producers, who sell their goods at a higher price.

5. ANALYSIS OF COST-EFFECTIVENESS IN THE IMPLEMENTATION OF A PUBLIC GOOD

In the contemporary States, the public sector carries out a wide range of activities that affect not only the economy, but entire society.

The public choice theory of goods and services studies the processes by which take form the "collective" supply, the demand of public goods, and of all those goods and services which, although "private", are subtracted, to some extent, to the domain of the market.

In the case of public goods, when a certain quantity is produced, the same quantity is available for the whole community. So if we want to identify the aggregate demand it is important to know what the community is willing to pay for various amounts of the public good. To do this, it is necessary to make a vertical sum among the prices/contributions paid by individuals for each amounts. Also for public goods, the general rule states that the optimal amount to be produced, that is the one that produces the maximum wellbeing for the community, is determined by choosing the level of production for which the marginal cost is equal to the marginal benefit [13].

The concepts of consumer benefit and the theory of well-being represent tools to evaluate the feasibility of a determinate project and are also the basis of cost-benefit analysis. Cost-benefit analysis allows to identify projects with positive net present value (the sum of discounted costs are subtracted from the sum of discounted benefits), by the formula, where:

n+1 = the number of years over which benefits and costs are analyzed
B_i = the benefits of the project in year i, i=0 to n
C_i = the costs of the project in year i
d = the discount rate

The discounted benefits of the project in year i are equal to

$$B_i/(1+d)^i \qquad (1)$$

The discounted costs of the project in year i are equal to

$$C_i/(1+d)^i \qquad (2)$$

Then, sum both the discounted benefits and the discounted costs over all years (0 through n) and subtract the sum of the discounted costs from the sum of the discounted benefits:

$$\Sigma\ (B_i/(1+d)^i) - \Sigma\ (C_i/(1+d)^i) \qquad (3)$$

summed over i = 0 to n.

In particular, the cost-benefit analysis can be defined as a set of rules to guide public choices among alternative hypotheses. To carry out the economic valuation of public projects it is necessary, first of all, identify the costs and benefits associated with a project for the duration defined as "economically relevant".

This initial phase is very important also to define the "boundaries" of the project. It is interesting to note that for a public project it is necessary to consider not only the monetary costs and revenues but also the social costs and benefits.

The difference generates the so-called "external effects". These effects can be positive (external economies) or negative (external diseconomies).

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From this point of view, the social cost of a public project is given by the sum of the monetary cost and the possible external diseconomies. Conversely, for the social benefit. However, an important issue is the extent to which take into account the external costs and benefits, because in any case, it is necessary to give them a monetary value [14].

For this reason, the definition of the "boundaries" of the public project is a basic problem for cost-benefit analysis. Given the complex nature of the investment project effects and their relationships with the economic environment, it is not easy to define which effects can be attributed to the project and those which may be excluded [15].

Since there are not clear indications for this type of problems and for the purposes of this study, which also regards the territorial impact of a project, it is necessary to combine the traditional cost-benefit analysis with a territorial impact assessment including, in addition to the external effects, also:

- microeconomic aspects;
- macroeconomic aspects.

In general, microeconomic analysis concerns the problems that affect the individual units, while macroeconomic analysis is devoted to investigate problems that affect the national and international economic mechanism.

When we analyze a project in microeconomic terms, it is necessary to evaluate the potential users of the work, its introduction in the local area, development plans; instead when we conduct an analysis of the project in macroeconomic terms, the attention should be paid to national parameters, to the level of employment, inflation, balance of payments performance.

6. COST-BENEFIT ANALYSIS AND PUBLIC CHOICE

A first approach to the problem is Pareto (also known as the traditional or efficient approach). According to this principle the well-being of the community is considered according to the well-being of individuals that constitute it. In this case the social function to maximize can be written as:

$$W = -W(U_1, U_2, ..., U_n) \qquad (4)$$

Where U_1, U_2, ..., U_n are the levels of individual well-being of each of the "n" members constituting the community, as a function of goods and factors of production owned individually. This expression is a

Pareto welfare function, because it is assumed that:

$$\frac{dw}{dU} > 0 \text{ with } h = 1, 2, \dots, n \qquad (5)$$

In graphical terms, considered only two individuals A and B, a shift in the figure from C to D is considered a Pareto improvement and thus an increase of well-being (fig. 3).

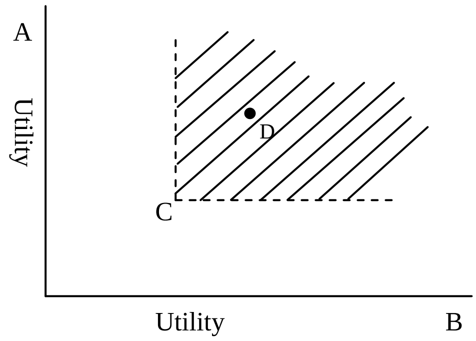

Fig 3: Interpersonal comparisons of utility

All points of the hatched area are potential Pareto improvements. A point, for example C, is called a Pareto optimal point if, given a state of the economy (defined by a given amount of resources), a state of technology and an initial distribution of income, it is impossible to find an another point to it preferable according to the criterion of Pareto.

However, the criterion of Pareto, is inadequate as a guide to public decisions.

This derives mainly from the fact that it is impossible to assign a numeric expression to the levels of individual well-being to obtain an order, consequently it is impossible to make comparisons of utility as: U_i <_>U_j. This limit can be illustrated with a graph.

The axis of the abscissa and the ordinate shows respectively the utility of individuals A and B. The curve indicates the utility possibilities frontier (fig. 4).

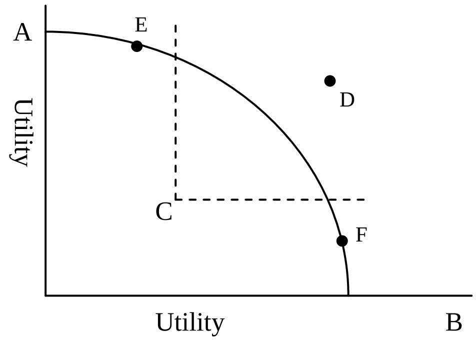

Fig 4: The utility possibilities frontier

If the choice was between C and D, as assumed in the previous figure 3 it would be unique. But between E and F cannot say what of the two situations, equally possible, is preferable for the two individuals with respect to C.

However, the choices in public spending lead almost always situations in which the "gainers" achieve an advantage at the expense of the "losers". For each public choice there are gainers and losers, a problem of which the Pareto criterion does not take into account. In order to allow the application of the Pareto approach to public choices and therefore to the cost-benefit analysis, additional criteria have been proposed to solve the problem between gainers and losers and are headed to the "new welfare economics". One of these is related to the assessment of the situation ex-ante and ex-post, respect to the decision and implementation of the project. In the classic prospective of the cost-benefit analysis, furthermore, the redistribution of income is not taken into account. For this it is impossible to conceive a situation that reflects the "Pareto optimality", according to which a project is acceptable if it increases the income (or welfare) of at least one individual, while leaving unchanged the situation of all the others, and not consider, in the analysis, the redistribution of income.

Moreover, it is very limiting neglect the redistribution of income when the planned work will have a direct effect on the economic and social growth. An infrastructure of transport is an intervention whose effects cannot be depleted in just benefits for users (changes in the cost of the journey). It is reasonable to think that this intervention will also be changing the image of a certain territory, influences the trend of economic and social development and its position (centrality, hierarchy and accessibility) compared to other territories. Unfortunately for the analysis of these aspects the cost-benefit analysis is inadequate.

It is known that "welfare economics" is a branch of economic theory that is specifically aimed at the comparison from the point of view of the social desirability of alternative economic situations. The social desirability of an economic situation will be evaluated according to two criteria, usually in conflict: the efficient allocation of resources among different potential uses, and the equity in the distribution of resources among individuals that are part of communities. From this approach derives a fundamental problem: the public transport infrastructure does not have a market price (because there is no market for public works), and also, each project involves side effects "indirect external effects". The effects can affect three categories: transport system; economic system and the environment. Also the regulation of demand is an instrument of transport policy useful to stimulate the market to reach a position of the "social optimum". The demand adjustment process was inspired by the necessity to reduce the level of production and consumption of a service (mobility) pouring on the collectivity the costs did not accounted by the price system (social costs). In this view, the regulation of demand is part of the theoretical framework of welfare economics and of the economics of public goods. In this context, this research has devoted specific attention to traffic control in a regional context, but not by developing aspects of planning and engineering management of flows, but with reference to evaluation and optimization of costs and benefits.

7. MOBILITY AND SOCIAL OPTIMUM

In this context, it is important to highlight the difference between the costs incurred and the prices borne by consumers of transport services. In particular, focusing on the system of individual car trips, it is easy to detect: on the one hand, the increase in external costs determined by the saturation of infrastructure and, on the other hand, the general absence of a congestion charges system and rationing of the individual demand for access to the road system (particularly in large cities and in their main access). It should be noted, in this way, first of all, the removal from the point of optimal allocation of resources and secondly the overconsumption of "mobility", precisely due to the existence of costs not borne directly by the individual users. Starting from these considerations, the demand adjustment process could provide the application of a tariff able to load on users the congestion charges and lead the balance at a lower level of mobility.

The share of demand reduced, by the increase of price, is the final section of the curve, i.e. the one with the lowest willingness to pay.

It is evident, therefore, that the regulation of demand is not simply a method to reduce congestion, but to attribute the costs to those who created them, and this has a greater effect the more is rigid the demand for mobility and the less is the cross elasticity between individual transport and public transport. All this does not mean that the funds generated cannot be allocated for interventions to decongest networks and transport services.

The introduction of forms of road pricing also determines a redistributive effect. It is clear that also the income affects the willingness to pay for mobility: consequently the adjustment of the demand would penalize the less favored groups of the population. At the same time, in large part of the studies about the theme, the ability to mitigate the effects of a perverse redistribution of funds is contemplated through operational measures.

For example:

- investing the resources generated by the road pricing in the financing of infrastructure and services in favor of the weaker sections of society;
- setting the management of pricing so that to choose between price and discomfort (i.e. differentiating the road pricing depending on the timing and on the traffic of the roads).

Improving, thereby, accessibility. In this regard, the congestion reduction could be also achieved through political measures different by charges: through creation of new infrastructural supply; addressing real-time traffic with adequate technological tools or through a coherent planning of urban functions (urban system) and land use. In general terms, accessibility is a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them:

$$A_i = \sum_j g(W_j)\, f(c_{ij}) \qquad (6)$$

where A_i is the accessibility of area i, W_j is the activity W to be reached in area $_j$, and c_{ij} is the generalized cost of reaching area j from area i. The functions $g(W_{ij})$ and $f(c_{ij})$ are called activity functions and impedance functions, respectively. They are associated multiplicatively, i.e. are weights to each other. That is, both are necessary elements of accessibility. A_i is the total of the activities reachable in areas j weighted by the ease of getting from i to j. It is easily seen that this is a general form of potential, a concept dating back to Newton's Law of Gravitation. According to the Law of Gravitation, the attraction of a distant body is equal to its mass divided by its squared distance. The gravity model of regional science is somewhat more general, it states that the attraction of a distant location is proportional to its size (for instance population) weighted by a decreasing function of its distance.

In the context of accessibility, the "size" are the activities or opportunities in areas j (including area i itself), and the "distance" is the spatial impedance c_{ij}. The interpretation here is that the greater the number of attractive destinations in areas j is and the more accessible areas j are from area i, the greater is the accessibility of area i. This definition of accessibility is referred to as destination oriented accessibility. In a similar way an origin-oriented accessibility can be defined: the more people live in areas j and the easier they can visit area i, the greater is the accessibility of area i.

Because of the symmetry of most transport connections, destination-oriented and origin-oriented accessibility tend to be highly correlated.

However, the generic equation of accessibility above is more general than the gravity model. Different types of accessibility indicators can be generated by specifying different forms of functions (for example in function of labor). We know, in fact, that the opportunity cost of factors of production (i.e. employment) in a local economic system also contains a component related to "spatial element". In general, the improvement of transport infrastructure leads to improvement of accessibility of markets. This can be measured as:

$$ACC_i\,(L) = \sum_j L_j\, f(c_{ji}) \qquad (7)$$

where Lj is the pool of available labor in the region j, c_{ji} is an index of the cost of transport between regions j and i and f(.) is the impedance function.

The question can be whether the accessibility models conventionally used in spatial-economic science are able to support the sustainable model in the transport system.

8. A FOCUS ON ENVIRONMENTAL ASPECTS

There is still uncertainty about the precise nature and extent of global interdependence between economic growth and environmental protection systems. In order to analyze this complex interaction it is necessary to assess the economic theories within the broader environmental paradigm. Faced with the complexity arising from ecological interdependences and uncertainties surrounding the resource management have been proposed two alternative approaches. Some authors support the adoption of cost-benefit analysis able to include monetary valuations of the uncertainty and irreversibility of many production processes. Others support an approach able to set fixed standards in order to achieve a macro-environmental policy. Some critics have tried to incorporate in the economic analysis the most innovative models of the materials balance, and to a lesser extent, the pattern of entropy. And while pollution is seen as a sign of market failure, it is also recognized that it is a widespread and unavoidable phenomena (due to the laws of thermodynamics), which requires the intervention of the State through a package of regulatory tools and incentives.

In principle, it is possible to define an optimal level of pollution (in the sense of economic efficiency) in which the marginal net private benefits (MNPB) (of polluter) is equal to the external costs of those who are damaged. But it is a static approach, a not feasible objective of economic policy. In this context and for the presence of uncertainties, we should consider the pollution control policy as a search process based on a principle of "acceptable" rather than "optimizing". In cases of probable locally irreversible environmental damage caused by economic growth has been proposed the idea of the Shadow Project Approach, on this bases the costs of the development project (responsible of such damages) should be increased in an amount sufficient to finance a project "shadow" able to replace the lost of natural heritage. Proponents of the extended cost-benefit analysis (as opposed to traditional CBA) have adopted an approach in terms of "sensitivity to values" trying to incorporate into the analysis, multiple criteria decision. Particularly, the traditional CBA is criticized because it does not fully capture the intangible impacts such as social costs or environmental damage that cannot be measured in monetary terms. Valuation techniques known as extended cost-benefit analyses have been developed to take these intangible impacts into account [16].

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Environmental problems on the border between the economic and the environmental system are complex and involve multiple aspects and disciplines, in addition, there is still uncertainty about the precise nature and extent of global interdependence between economic growth and environmental protection systems. The conceptual problems between economic analysis and environmental system affect also the modeling of transport. In particular, it appears that the "common root" of the problems is necessary to disconnect the "reality of facts" (on which we measure the project action and the related environmental impact studies) from the "interpretative hypotheses of reality" for modeling the Territory-Environment-Transport System. According to this view, the System as a whole, must lead on the one hand to the identification of the optimal route between different alternatives, on the other hand to the pre-assessment of impacts associated with the construction and operation of infrastructures. However, the economic and environmental research is still in a state of transition. The effort is to find a unique methodology that can be adopted both during the design phase and throughout the management period.

9. MAIN TYPES OF EXTERNALITIES

Transport activities cause a range of external costs. The level of these externalities depends on many factors, tab. 1 summarizes the main externalities and their drivers. About of these five externalities it is knew that air pollution and noise occur at the local level and can be contained to a substantial degree by fairly inexpensive technical solutions. Accident externalities are complex and heavily dependent on coordination of human behaviour. Congestion and climate change externalities are both strongly dependent on the volume of transport, but apart from that they are very different. With congestion there is a negative feedback loop (more congestion leads to higher time costs of travel, and higher costs discourage demand) [17]. Congestion derives from the concentration of volumes in time and space. If spreading demand over time and space were easy, there would be no congestion problem as there would be ample capacity to handle volumes. This basic observation suggests that policies to spread demand may be as effective as attempts to reduce overall demand.

Table 1: The main transport externalities

Types of externalities	Source	Nature of cost	Public abatement and supply type policies	Policies affecting demand and vehicle characteristics
Congestion	Volume of use approaches or exceeds design capacity per unit of time.	Mainly time and schedule delay costs.	Network capacity.	Congestion charges, fuel taxes, access restrictions, land use regulation, etc.
Climate change	Greenhouse gas emissions from fossil fuel use.	Wide-ranging and uncertain adverse impacts from climate change.		Fuel efficiency standards, CO_2 or fuel taxes, etc.
Traffic safety	High traffic density and heterogeneity in vehicle weight and speed, increase average accident risk.	Mainly health and loss of life; Material damage.	Adaptation of road infrastructure, emergency services, mandatory insurance,etc	Traffic rules and procedures, risk-dependent insurance premiums.
Air Pollution	Fuel combustion and exhaust.	Mainly health, loss of life, and environmental degradation.		Standards (vehicle equipment, fuel quality), access charges.
Noise	Engines and movement.	Health, discomfort.	Sound barriers, silent road surfacing, curfews,etc.	Standards, curfews, tradable permits.

10. DEFINING SUSTAINABLE TRANSPORT

The concepts of sustainability and sustainable development (as showed) originally focused on certain long-term environmental concerns, such as natural resource depletion and ecological degradation (including climate change), but have expanded to include other issues. Most current definitions recognize three main categories of sustainable development issues: economic, social and environmental and some incorporate other issues such as governance and fiscal sustainability [18].

Sustainability is a simple concept with complex implications [19]. It reflects a paradigm shift, a fundamental change in the way problems are defined and solutions evaluated. It maintains a distinction between growth (increased quantity) and development (increased quality). It focuses on social welfare outcomes, rather than on material wealth, and common economic indicators such as GDP that measure the quantity but not the quality of market activities can not be sufficient. Because sustainability strives to protect natural resources, it favors policies that minimize consumption of resources such as air, water and land.

It is knows that sustainability can be evaluated as weak standard, which allows natural capital to be replaced by human capital or a strong standard, which rejects such substitutions.

In this view, a weak sustainability standard allows transport to increase environmental impacts if required for economic development, or if negative impacts can be offset by other sectors, such as pollution reductions by heavy industries. A strong sustainability standard places more emphasis on impact reductions within the transport sector, and so places more emphasis on reducing motor vehicle impacts.

Transportation has significant economic, social and environmental impacts, and so is an important factor in sustainability. Sustainability supports a paradigm shift occurring in transport planning. Previously, transport was evaluated primarily in terms of mobility (physical movement), but increasingly it is evaluated in terms of accessibility. Many factors affect accessibility, including mobility, land use factors (such as the location of activities) and mobility substitutes (such as telecommunications and delivery services). Accessibility-based planning expands the range of solutions that can be applied to transport problems; for example, congestion can be reduced by improving land use accessibility or telecommunications, in addition to accommodating more vehicle traffic [20].

Several definitions of sustainable transportation have been proposed [21], usually a sustainable transport system may generally be considered to be one that allows the basic access and development needs of individuals, companies, and society to be met safely and in a manner consistent with human health. Sustainable transport supports a competitive economy and balanced regional development, and promotes equity, including gender equity, within and between successive generations.

Environmentally, a sustainable transport system minimizes the use of land and emissions, waste, and noise. It uses renewable resources at or below their rates of generation, uses non-renewable resources at or below the rates of development of renewable substitutes, and limits emissions and waste within the planet's ability to absorb them. In terms of cost, a sustainable transport system is one that is affordable and operates efficiently, taking into account requirements for investment in capacity and the need for maintenance [22].

11. SUSTAINABLE URBAN TRANSPORT: ACCESSIBILITY AND ENVIRONMENTAL QUALITY

The pillars of environmental sustainability (or stewardship), social equity and economic efficiency are identified as embracing all aspects of sustainability [23].
A key to sustainability in cities has been identified as all three pillars of environmental sustainability social equity and economic efficiency working together. Therefore an effective sustainability performance requires all three pillars to achieve complementary outcomes rather than simply individual outcomes.

Table 2: The pillars of environmental sustainability

Economic	Social Equity	Environmental
Accessibility	Equity/fairness	Water /Air pollution
Traffic congestion	Impact on mobility disadvantaged	Climate change
Consumer costs	Human health impacts	Noise pollution
Infrastructure cost	Affordability	Accessibility
Mobility barriers	Cohesion	Hydrologic impacts
Accident damages	Accessibility	Habitat and ecological degradation
Depletion of non-renewable resources	Livability	Depletion of non-renewable resources

Source: Adapted from Litman and Burwell, 2006

Furthermore the expansion of road infrastructure, in particular motorways, will add barriers to the migration of many species, reducing their viability and disrupting local ecosystems. Another important consideration regard the presence of the accessibility factor in all the Pillars as showed in the tab. 2.

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With the aim to apply these considerations to an urban framework able to drive it toward a sustainable paradigm it is necessary to introduce a new approach of sustainability analysis, in which a sustainability framework is formulated able to bring the three pillars together toward an holistic consideration of the urban system, of its dynamics and of the resulting sustainability performance [24].

Fig. 5 summarizes the framework, which lays out the frame points for ensuring that the systems elements and interactions that drive the sustainability performance are visible and measured.

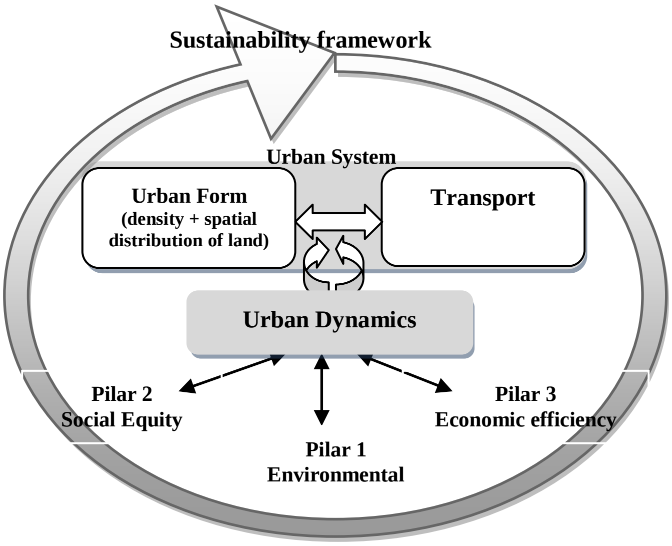

Fig 5: The urban "sustainability framework"

The "Urban System" includes the "Urban Form" and "Transport" elements that define the structural configuration of the city, in which are showed interactions and interdependencies between these two elements. "Urban Form" is characterized by density and spatial distribution of land-use. "Transport" on the other hand is characterized by the transport network spatial layout and the specific mode characteristics.

The system function is to provide for the needs of the community. Response of the community to the "Urban System" produces interactions that result in selection of location of residence and workplace, industry and trips and so on. These interactions are collectively known as "Urban Dynamics". It is an interactive process as indicated by the circular arrow having feedback effect between each element.

The resulting "Urban Dynamics" outcomes generate the sustainability performance in terms of the three pillars included as elements. Each pillar has a feedback to the "Urban Dynamics" and vice versa (as indicated by the double headed arrows in the figure).

In this system, we assume that, at base, transportation provides mobility and accessibility [25]. It enables people to move around and access various locations, and it serves as a basic factor input for commercial entities. Understanding the distinction between accessibility and mobility can be a critical aspect in creating a sustainable transportation strategy. Mobility can be defined as the ability to move around or to be mobile. Accessibility, on the other hand, is the ability to visit or reach specific locations (e.g. work and shopping places) or undertake certain activities, such as sightseeing and shopping [26].

In this context, the relationship "environmental quality - accessibility space" indicate e.g. the accessibility to jobs for workers from their place of residence (in a city reality) but can be helpful also for understanding commercial trade and passengers among different regions or at whole Area level (economic efficiency) and to improve quality of life through repercussions in environmental terms. In which, environmental sustainability and economic efficiency focused on accessibility (the first and third pillars of sustainability) are considered as important factors to promote sustainable transport and competitiveness, as showed below (see fig.6).

The figure 6 illustrates this spatial concept and the performance goal. A city's sustainability performance in relation to the optimum (environmental quality and accessibility goals) can be analytically quantified and simply visualized in a scheme for assessing the three pillars of sustainability in cities and consequently in the urban mobility.

The figure shows a positive relationship between environmental quality and accessibility space, in which transports (in the shape of mobility) for achieving sustainable goals, have to combine these two aspects.

The environmental sustainability measure (Pillar1) can be formulated from many different parameters (e.g. traffic noise generated, ecological stress, particulate emissions, resource usage). For example, are developed indicators to calculate CO_2-footprints for motor vehicles[i]. Accessibility can be identified as a useful measure of social equity (Pillar 2) and economic efficiency (Pillar 3) equally aspects of sustainability.

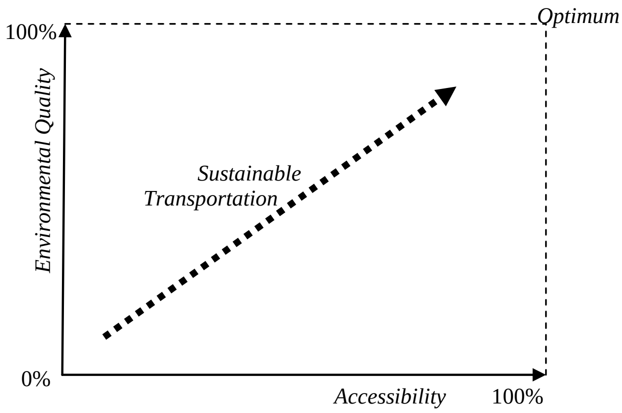

Fig 6: Transport as a function of environmental quality and accessibility space

On the basis of this function, we can observe that transport can become sustainable if its development is sustained by an adequate accessibility space (in terms of easily to reach a point, but also in terms of provide information to citizens, of developing new services and enhancing projects to improve the quality of life in the cities) and respecting the environmental quality.

12. CONCLUSIONS

The goal of this study was to guide transport system toward productivity and opportunities to build an enduring prosperity in order to promote "accessibility" as a tool to achieve "sustainable mobility". To realize this purpose it is necessary to project a smarter, naturally friendly, more innovative and enterprising transport system, including also the transport networks. Addressed towards urban models less dependent on roads and cars in which town planning and public transport networks are intimately linked within a reticular metropolisation-based approach. Through urban amenities structured around rehabilitated public areas, likely to be instrumental in improving the quality of life in dense urban areas, allowing better road sharing in favour of soft modes and integrating essential intermodal centres. Towards the full integration of informal transport within global public transport provision, in order to optimize existing resources, and taking account of the inhabitant and user. Using a dimension based on the "territorialisation" of public policy, aimed at encouraging approaches which are systematic and integrated rather than sectorial, with the aim of an effective strategic planning. Finally and more generally speaking, the emergence of urban contracting authorities with the competence, own resources and capacity to arbitrate over local players is one of the conditions for the successful implementation of more sustainable urban policies.

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[i] A number of factors in urban transport contribute directly or indirectly to the potential growth in energy use and CO_2 emissions. Energy use or emissions by urban transport, E, can be described by the following identities, and where i is the mode of transport. Since CO_2 emissions are directly proportional to energy use, the same identities apply but with a different coefficient for the carbon content of the fuel, in particular, the emissions of CO_2 and quantity of fuel consumed are very closely correlated because the carbon content of the most common transport fuels does not vary greatly. For instance, identity (1) below is defined by the number of vehicles, the vehicle use or vehicle kilometers traveled (VKT), and the vehicle efficiency and fuel content (E/VKT). Identity (2), however, is defined by the number of person-trips, the distance of the trips, the number of persons in each vehicle (i.e., occupancy), and the energy or emissions content of the fuel per VKT.

$$\Sigma E(i) = (vehicles)i*(VKT/year)i*(E/VKT)i \qquad (1)$$
$$\Sigma E(i) = (trips)i*(trip\ distances)i*(1/vehicle\ occupancy)i*(E/VKT)i \qquad (2)$$

These identities and others “Schipper, et al. (2000)” are useful in characterizing the potential urban transport characteristics driving changes in energy use or emissions.