Sustainable Public Green Transport to Face Sprawl. Geodatabase for Impact Valuation and Alternative Choice

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Abstract
First objective of the research is to conduct a meta-analysis concerning the relevant relationship between "urban sprawl and economic growth". Second objective of the research is to derive possible systematic interventions to re-direct the urban sprawl phenomenon that is consuming all the scarce and costly natural resources of the Planet. The same themes are investigated at international geographic scale as well as at territorial scale, by experimenting Case Studies in which the general framework is compared to specific local situations. Also, research designs and tests a new set of criteria for multidimensional valuation of one possible policy responses to urban sprawl *i.e.* the integration of settlement system with public green urban transport.

Riassunto
*Primo obiettivo della ricerca che si presenta è di condurre una meta-analisi circa il rilevante rapporto tra "*urban sprawl *e crescita economica". Secondo obiettivo è derivare possibili sistematici interventi per mitigare il fenomeno dello* sprawl *che sta consumando le scarse e preziose risorse naturali del Pianeta. I temi sono investigati sia a scala geografica e sia scala territoriale, attraverso la sperimentazione con Casi di Studio in cui la struttura generale è comparata con le specifiche situazioni locali. Inoltre, la ricerca progetta e testa un nuovo* set *di criteri per la valutazione multidimensionale di una possibile* policy response *per la mitigazione dello* sprawl *e del traffico veicolare, ovvero l'integrazione tra sistemi di insediamenti e trasporto ferroviario sostenibile.*

1. Research general framework and specific focus

The general research here introduced deals with the complexity of European (and not only) urban system and namely with urban sprawl phenomenon.
By performing meta-analyses and analyses at different scales, research aims to: analyze sprawl trend overtime and assess its magnitude; try to understand sprawl causes, finding out the eventual causal relationship (or not) of localized sprawl with population increase as well as observed economic growth; search and detect mitigation measures as policy responses to sprawl, relaying on some benchmarks;

design and test new sets of criteria for multidimensional valuation of policy responses; integrate geographic information system with valuation tools creating a Spatial Decision Support System (SDSS). The concentrated focus of the specific study here presented (as a part of the general research concerning sprawl) is about one possible planning and management approach of policy response to urban sprawl *i.e.* the integration between settlement system and its urban revitalization and public green urban transport. This approach is well known as Transit Oriented Development (TOD).

2. Infrastructures and sprawl

As starting point, a specific and preliminary question should arise about sprawl: why public green urban transport and TOD can help facing sprawl?

Continental researches and territorial localized studies observed that, among many negative impacts of sprawl, one common consequence is particularly damaging. The spread-out of dispersed housing causes: disintegration of original urban functional mix; decrease of structural accessibility; zoning producing the need to move frenetically; increase of frantic individual mobility by private cars and related side effects. In alternative to wild urban expansion, the connection of transport services to consolidated urban system might make a difference by enhancing existing dense settlements and improving their structural accessibility, and in so doing, helping to lower the frantic individual traffic and the consequent congestion. It constitutes a new approach to rebuild a positive relationship (disappeared in recent contemporary age) between settlements and structural accessibility, namely the above introduced TOD, which also fosters-up a new valuation approach in broad transport field.

3. Valuation approach and new set of criteria

TOD is a new settlement-transport framework that might enhance the valuation approach, because until now, transport system has been seen as a separate sector and valuated under specific and insular aspects, often adopted as solely leverages to make choices for investments in transport infrastructures, such as: just initial cost of investment, as input; transport cruise speed, as output.

Research experience suggests shifting from just two assessments aspects for choice in transport infrastructure field, to multiple dimensions, including new relevant criteria, for valuating alternatives.

Criteria assess the fulfillment of important requirements by transport alternative in the framework of TOD approach to accessibility.

	TOD objectives to face sprawl (requirements)		**Criteria (and measures \ indicators) to assess fulfillment of objectives**
a	Settlement and urban centers should be directly served by urban railroad, train-tram, *Stadt-schnell-Bahn*	Ca	Settlements crossed by transport infrastructure and services (number of)
b	Larger number of residents\inhabitants should be served by railroad	Cb	Residents \ inhabitants served directly by infrastructures (number of)
c	Tracks and organization of accessibility infrastructures should get social consensus	Cc	Level of social consensus toward accessibility infrastructures (yes \ no)
d	Infrastructure and accessibility should not only be admitted by plans but also shall help to implement planning	Cd	Convergence of planning tools toward the greenest alternative in accessibility and transport (how many)
e	Accessibility and transport alternatives should contribute to reducing CO_2 emissions	Ce	Potentiality of each alternative for CO_2 reduction with respect to *status quo* (degree)
f	Accessibility and transport alternatives investments \ interventions should minimize landscape injuries and soil \ land consumption	Cf	Measure of soil consumption for transport investments \ interventions, and consequent injuries to landscape (soil \ land square meters; number of injuries; degree of injuries)
g	Accessibility and transport alternative must maximize both: population directly served; best possible connection with corridors as TEN, national, local and other strategic nodes	Cg	Networking connection with other strategic nodes and corridors as Trans European Network (TEN), national, regional, local (yes \ no)

Table 1 – Accessibility and infrastructures. Criteria for evaluation of transport alternatives in TOD framework

These criteria are logically connected to a new way of considering transport system as "integrated" to urban system accessibility framework and therefore able to face urban sprawl.

Then, valuation main task should be to assess comparatively effectiveness of transport alternative projects by applying the new sets of criteria adopted in multidimensional valuations.

4. Research Case Study in the narrowest part of Italy

General research has been called-on through a specific study and application to help the regional community of Calabria analyzing and, hopefully, facing an overwhelming sprawl phenomenon.

This region is the Southernmost of continental Italy, theater of the applied Case Study where objective analysis of regional sprawl has allowed to estimate in m^2 (unit of measurement) (Massimo, Barbalace, 2009; Massimo, Musolino, Barbalace, 2009) the impressive magnitude of soil consumption, *i.e.* land yearly destroyed by disordered and wild urban over-expansion in farm land, and coast land. Research has therefore investigated sprawl at local level by implementing a Case Study and focusing on the central isthmian area (the narrowest part of Italy: 40 km) where the second (Catanzaro) and third (Lamezia Terme) towns of the region are located (Massimo, Musolino, Barbalace, 2009). One paramount consequence of fragmented housing location, observed after 1954 when the Country heavy industrialization started and the welfare state begun, is the skyrocketing of individual daily mobility of dispersed and scattered population and individuals. It is performed mainly by private cars with related inefficiency in social life, time wasted driving, road congestion, parking shortage, fuel consumption and dependence, heavy air pollution, increase of CO_2 emission, difficult parking in destination towns and central business districts, abandonment of a clever railroad system conceived in 1864 in a very "modern" way, *i.e.* connecting as many settlements as possible.

All these impacts call-on specific study to analyze and evaluate possibilities of mitigating future sprawl by revamping and re-vitalizing existing settlements, and in particular historic centers, today more often abandoned and neglected, by serving them as much as possible with public green transport to: enhance objective structural accessibility in the area for people and places; create a shifting option (not existing at the moment) from individual mobility by private cars to collective accessibility.

Both urban revitalization and public green transport are complementary structural investments because they contribute to change the intrinsic characteristics of urban space and economy.

5. Surprisingly under estimated alternative

Then, research looked-up to roads with the worst car traffic congestion of the region constituting the Case Study, to pre-figure selected structural interventions and alternative investments. In the central area of Calabria, research has detected the largest and most congested corridor of individual mobility by private car, on the road, in the region, by daily and periodical commuters. It is a main road between the barycentric part of the region and the capital city, where an average of 28.000 cars pass each day.

It has been really surprising to detect that besides the main road corridor of car traffic, there is a parallel railroad corridor, connecting: many settlements having over 250.000 residents; the second and third towns of the region, of which one is the region capital; several scientific technological poles; University Schools; general hospitals. Moreover, this railroad corridor, part of the original railroad structure of the region, is a potential bridge between other paramount transport infrastructures such as the two main national and continental railroad corridors to Trans European Network (TEN), as well as to international airport, the busiest and growing of the region (over 1.500.000 passengers each year).

This important potentiality is illogically neglected, depriving people and daily commuters of modal option and conserving bad and costly (in private as public budget) inefficiency with the only car-route modality to commute in the general system. All this generates a Pareto non-optimality condition.

6. Transport alternative in the Case Study Area

First step must be to analyze and test the propensity of commuters driving car for\to modal shifting from individual to collective public transport both for inter-city and intra-city commuting. Encouraging results of interview polls concerning propensity, willingness and readiness of private car commuters (some of them in the Case Study area) to modal shifting toward public transport, foster-up and encourage to focus on transport planning to be connected with urban system management. Results also address to take into account all the existing and future designed alternatives for commuting in the area and to perform valuation through several criteria, not just two. Doing the census inventory of existing and future commuting alternatives, within a very helpful geographic information system, it has been

surprising to discover the existence of a hypothetical blueprint (sketched by a railroad management public company) that conceived and designed a total new alternative railroad corridor in the same area. It is located in the Southern part of the area, outside and not included in any transport planning acts and tools, and it does not connect any settlements being just the conjunction between the region capital town (namely its historic center) and the international airport.
In such a way three potential alternatives exist in the settlement-transport structure of the area:

- *Alternative 1 (A1)*: *status quo*, with prevalence of a main road for individual inter-city commuting by private car, and doing nothing for the railroad;
- *Alternative 2, (A2)*: enhancement of existing railroad (parallel to Alternative 1); today this railroad is badly neglected even if it is a strategic asset for future spatial and economic planning and management of the area;
- *Alternative 3,* (*A3*): new blueprint (before unknown) for a new railroad on a farther South alternative and totally new itinerary, outside all transport planning acts, not serving settlements and inhabitants.

Research has then tried to understand which of the above alternatives is likely to represent the best policy response to mitigate sprawl and road congestion. For it has performed a multidimensional valuation integrated to geographic information system, to detect the preferable alternative according to the new set of criteria. The first stone has been laid for a Spatial Decision Support System:

> "A spatial decision support system can be defined as an interactive, computer-based system designed to support a user or group of users in achieving a higher effectiveness of decision making" (Malczewski, 1999).

7. Spatial decision support system: integration between Geodatabase and multicriteria valuation

Present research aiming to achieve better and more effective result, detected the need of a tool that could integrate GIS-based data processing and decision supported by multicriteria analysis.
It shall allow users\appraisers to perform integrated multicriteria valuation (MCA) approach on a unified single platform *i.e.* within ArcGIS environment. Therefore, a first prototype MCA-GIS tool has been designed, programmed, and then tested on the Case Study above presented.
The analytical valuation model set-up for the experimentation is based upon the Dominant Regime Method (DRM) by Nijkamp and Hinloopen (Hinloopen, 1985; Hinloopen, Nijkamp, 1986), because it better suits the data collected that are a mix of ordinal and cardinal data. In fact, among the different information layer of the main Geodatabase there are data concerning settlements, historic centers, population dynamics, sprawl measurements, economic data, regional topographic basemap (Massimo, Barbalace, 2009). To all this, a specific information layer has been designed, created and added to the main Geodatabase: it contains the spatial representation of the different transport alternatives censused along with the related alphanumeric information. A new independent Feature Class is created, and therefore the selected criteria can be scored. Then, the tool processes all the selected data giving back, as output, a vector representing the ranking of the alternatives, valuated with the DRM integrated to GIS.

8. Application of criteria for valuation

In updated transport valuation approaches, new variables are taken into account in additional to traditional costs and speed data, such as the number of inhabitants \ residents served directly in their settlements and, also, the double consensus toward the infrastructure investment: first, social consensus; second, the convergence with transportation planning tools and acts. Each criterion is comparatively applied to each alternative (*status quo*, doing nothing; enhancement of existing railroad; project of new farther South railroad) in a range of 1 (lowest) to 5 (highest). At present time criteria don't have reciprocal weight, therefore the neutral scenario is adopted.
Crossed settlements. A2 crosses all settlements (score 5) of the focus area. A1 is not a railroad and it is far from all settlements (2), while A3 is even farer (1). Only A2 gets the goal. Scores: A1:2, A2:5, A3:1.
Served population. A2 serves over 250.000 residents and other not resident inhabitants by urban railroad (5). A1 serves only indirectly (3) the area through car road network. A3 does not serve population at all (1). Only A2 gets the goal. Scores: A1:3, A2:5, A3:1.

Social consensus of grass root organization. Public activities and media reports show the pro-active and unanimous consensus of social organizations toward the A2 (5) which costs 140 million of Euro. They oppose against A3 (1) which needs the huge public cost of 250 million of Euro but leaves all the settlements of the area without inter-city\intra-city railroad service, with a double damage. Social consensus calls for a change: not to keep the *status quo* of A1 (2). Only A2 gets the goal. Scores: A1:2, A2:5, A3:1.

Planning convergence toward an alternative. All six planning acts examined converge clearly toward A2 (5), in explicit alternative to and against A1 (1) and not mentioning at all A3 (2). Only A2 gets the goal. Scores: A1:1, A2:5, A3:2.

CO_2 lowering down. A2 leads to CO_2 reduction in the whole sector of transport in the area (5), both in its lifecycle (including management) and in the initial investment step where no totally new track must be built-up. A3 impacts positively in its lifecycle but it requires the construction of a brand new infrastructure (2) far from the existing one then (A2) must be dismissed with consequent disinvestment of an existing capital. A1 will leave the present level of pollution without mitigation and does not improve the *status quo* (1). Only A2 gets the goal. Scores: A1:1, A2:5, A3:1.

Landscape impact. A1 does not bring any change on landscape (4), because it does nothing. A2 makes minor and not relevant change with injuries on landscape because it is just an enhancement of an already existing track (3). A3 is a new construction and the impact on landscape will be relevant, sometimes heavy (1). Scores: A1:4, A2:3, A3:1.

Networking. Global-local. A2 connects the pan-European (I; VIII), national (Tyrrenian; Ionian-Adriatic) and inter-regional corridors with the local services to all settlements, implementing the *Stadt-schnell-Bahn* approach (5) of train-tram. A3 connects only the long-distance corridors (4) but does not serve local communities at all. A1 is not a railroad (1). Only A2 gets the goal. Scores: A1:1, A2:5, A3:4.

The performance of criteria application gives the following ordinal qualitative effect matrix.

			Criteria						
			Ca	**Cb**	**Cc**	**Cd**	**Ce**	**Cf**	**Cg**
			Crossed settlements	Served population	Social consensus	Planning convergence	CO_2 lowering down	Landscape impact	Networking TEN corridors
Alternatives	**A1**	*Status Quo*. Modality through road by private cars	**2**	**3**	**2**	**1**	**1**	**4**	**1**
	A2	Enhancement of existing railroad	**5**	**5**	**5**	**5**	**5**	**3**	**5**
	A3	Project of farther South new railroad	**1**	**1**	**1**	**2**	**2**	**1**	**4**

Table 2 – Ordinal qualitative effect matrix for valuation of transport alternatives in Case Study area.

Intuitively, looking at the Table, the second Alternative A2 seems to match the goal of sustainable transport and train-tram approaches able to integrate commuter service in the larger railroad system, like the *Stadt-schnell-Bahn* benchmark. The third Alternative A3 seems to fail some key goals, first of all the lack of service to residents and the lack of connection between all existing settlements of the area.

In the strategy for spatial management of this area the valuation is performed to detect among three possible alternatives the preferable.

In fact, the MCA-GIS tool has been run on the above alternatives and criteria. Then, the model has also been tested by considering a further criterion *i.e.* the initial cost of investment. According to data of A3 and estimation of A2, costs are: A1, nothing; A2, estimated € 140 millions; A3, € 250 millions. It represents a new column in the matrix (0; 140; 250) and a new ranking.

Ranking	*WITHOUT cost criterion*		*WITH cost criterion*	
	Alternative	**Scores**	**Alternative**	**Scores**
1st	Alternative 2	0,999	Alternative 2	0,999
2nd	Alternative 1	0,374	Alternative 1	0,329
3rd	Alternative 3	0,127	Alternative 3	0,172

Table 3 – Ranking of alternatives through Dominant Regime Method analytical model integrated to GIS.

Alternative 2 achieves in both valuations the 1st place, and it is the preferable alternative among the three considered.

9. First results and considerations

Research detected in the Case Study Area the coexistence of greatest sprawl, private car traffic congestion, potential but not yet treasured alternative transport modality with urban rail. In particular, in the Lamezia-Catanzaro corridor the already existent green railroad is a potential alternative, today under-used and inefficient, *versus* congestion generated by daily transit of 28.000 private cars on Route SS280.

The enhancement of green public rail transport, as already successfully experimented in other countries, might represent a way to: strengthen the existing and consolidated cities; create a polycentric structure to effectively mitigate sprawl; reduce vehicle traffic congestion and consequent pollution\emissions.

In this framework, research has: analyzed and valuated three different alternatives concerning settlement-transport integration and connection to face future sprawl of a region; designed a new set of criteria; designed and programmed a prototype tool to perform multicriteria valuation integrated to GIS; laid the basis for a Spatial Decision Support System; applied and tested all this.

Alternative valuation and selection in the Case Study has been performed with a neutral scenario where each criteria have the same weight in the valuation matrix.

Multicriteria analytical model integrated to GIS tool can help to put it in future valuations.

Valuation outcomes leads to preferability of the second Alternative A2 *i.e.* the enhancement of existing railroad *versus* the third Alternative A3, *i.e.* the newly designed railroad, located outside all settlements of the area and not planned in any accessibility-mobility plan, program or act.

The preferable alternative has the effective potentiality to serve, with public collective railroad transport, over 250.000 residents and at the same time to connect two main national corridors, Tyrrenian and Ionian, that are part of pan-European mega-corridors I (Palermo-Berlin) and VIII (Skopie-Varna) and of general Trans European Network. It plays the longed and virtuous double function international-national and local, like the *Stadt-schnell-Bahn*, *i.e.* the urban fast railroad and train-tram benchmark.

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Figures

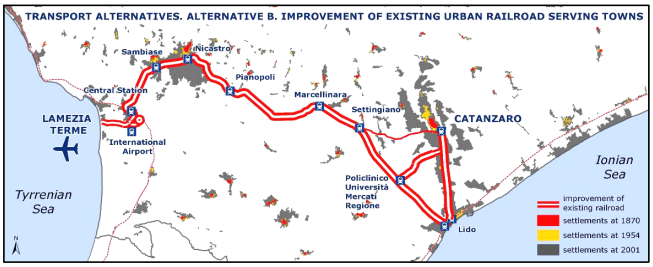

Figure 1 – Central area of Calabria: Sambiase – Nicastro – Catanzaro. Transport Alternative 2: improvement of the existing urban railroad crossing urban settlements and serving 250.000 inhabitants. Geodatabase.