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A TRAM-TRAIN SYSTEM TO CONNECT THE URBAN AREA OF COSENZA TO ITS PROVINCE: A SIMULATION MODEL OF TRANSPORT DEMAND MODAL SPLIT AND A TERRITORIAL ANALYSIS TO IDENTIFY ADAPTED TRANSIT ORIENTED DEVELOPMENT PROSPECTS.

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Abstract

The purpose of this paper is to study possible prospects of regional development and of public transport demand evolution, resulting in the implementation of a new tram-train service to suburban and an urban tramway for urban area of Cosenza and Rende and for municipalities in the valley of the river Savuto, in the southern Italian region of Calabria.

This is an area that in recent decades has seen significant phenomena of urban de-population, with consequent problems of urban sprawl into neighbouring small cities and land consumption.

The mobility system is heavily focused on the use of private cars as the main and often the only way to travel; causing obvious problems of traffic congestion and poor urban quality of life for citizens.

The modern tram-way system project, next to be realized, will connect the urban area of Cosenza and Rende with the University of Calabria. It is a first important structural intervention that will hopefully help to significantly increase public transport modal share and to promote implementation of Transit Oriented Development policies, properly adapted to that specific territory.

The decision to adopt such a narrow gauge tramway line, allows to consider the prospect of actually integrating this service with a tram-train system linking Rogliano and municipalities of Savuto valley, with the urban area, using existing narrow gauge railways of Ferrovie della Calabria (regional train operators).

With this purpose was developed a transport demand simulation model, using the Tranus system, to estimate the evolution of the transport demand modal split in that area, caused by such changes in the mobility system. Through a spatial analysis were showed some areas that might be interested by interventions of urban renewal and regeneration, with greater access to public transport services and Transit Oriented Development policies.

Results of this analysis and the simulation model will be presented and discussed in detail in this paper.

1. Interactions between transport and land use

In the first part of this work we will consider characteristics and potentialities of simulation models related to integration between transport systems and land use.
To evaluate properly and with a long-term prospective, impacts on transport demand due to supply changes, it must be considered effects of such changes on land use.
It's a well-established principle to consider land-use changes and evolution of transport systems such as phenomena that influence each other and therefore require an analysis more and more connected and integrated.
The concept of "land use" includes several variables and activities related to urban economic system. The number of residences and offices in a given area, as well as values of the property market, are factors that influence land use and that in turn are strongly influenced by transport supply affecting these areas and therefore from potential changes related to it.
Growth of number of trips is caused by an intensification of land use, in the same way as growth and redistribution of residences and activities evolves according to transport system's changes, and more precisely on the basis of increased levels of accessibility to these areas.
For these reasons it should be useful an analysis of interventions on the transport supply always considering effects on the integrated transport-land use system.
A representation of such a close correspondence between location decisions and travel behaviours can be found within the concept of "*feedback loop of land use-transport*"[1].

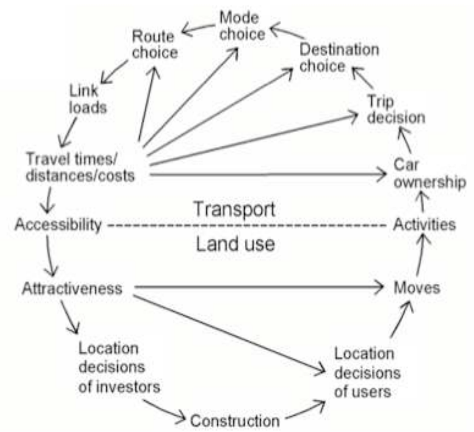

Fig. 1: feedback loop of land use and transport. (Michael Wegener, 2010)

That representation shows how improvements in a transport system leads to an increase in accessibility of some places, which, in turn leads to a change (usually an increase) of the value of land. This is a two way process, circular, continuous and repeated, that links land use with the location of activities; distribution of activity with needs of spatial interactions; needs to travel with the infrastructure facility in the system; level of accessibility with decisions that change the system of land use.
It can be inferred that the set of relationships between transport system and land use, is both complex and dynamic, or rather constantly changing, with interference and mutual dependencies.

[1] Overview of land-use transport models - Michael Wegener, 2010

Several studies confirm that increase in residential density has an inversely proportional effect to the average length of trips[2].

Residential and employment density, as well as large agglomerations and rapid access to transit in a specific area, was shown to be positively correlated with the modal share related to public transport.

Level of accessibility is also directly proportional to the number of trips generated and attracted in a particular area, as well as an accelerator factor in economic development processes. In particular the concept of accessibility is a significant part of the processes that govern a territorial system, where we can distinguish three sub-systems: sub-system of the residences, sub-system of economic activities and sub-system of available land in each zone, by type and relative market prices[3].

Number and types of residences in a given area depends on the sub-system of economic activity in that area, which in turn depends on the distribution of sub-system of the residences. Both of them depend on the availability of land and also on ease utilization of activities and functions in the area; that is the accessibility of these sites. Accessibility is therefore linked to needs of travel, to levels of service of transport system supply, but also to the activity system[4]. In particular, we define two different types of accessibility[5]: active and passive[6].

Active accessibility is a measure of the ease with from a given area *o* it can be reached an activity localized in any other zone of the study area, for a given reason. Passive accessibility means the measure of the ease with the activity present in a given area *o* may be reached, for a given reason, from others zones of the study area[7].

Value of accessibility is therefore influenced by both land use and transport factors, and in turn participates to the mutation of the integrated land and transport system.

2. Integrated land use and transport models

Simulate the interaction between a transport system and land use is a complex and difficult operation, which must take into account numerous factors and variables[8].

Mainly there are three families of methods that are used to achieve these simulation models and forecasting the impacts of changes on transportation system and land use.

A first method is represented by surveys and interviews with users (stated preference), to record their reactions to any changes. The disadvantage of this method is due to the subjectivity of answers that does not guarantee reliability.

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[2] Testi PORTAL, Trasporti ed uso del territorio. Portal, materiale didattico sui trasporti, 2003.

[3] Marco Tucciarelli, Assetto territoriale e sistema dei trasporti: modellazione delle scelte di mobilità, Tesi di Laurea Specialistica , 2009.

[4] Testi PORTAL, 2003.

[5] E. Cascetta, P. Coppola, A. Nuzzolo, Territorio, economia, logistica e trasporti, analisi e previsione della mobilità delle persone, TEXMA T.

[6] *Active accessibility* of residents of zone *o*: *Acc_att(o)* = $\sum[E(s,d)^{\alpha_1} * \varepsilon\xi\pi\ (\alpha_2 * C(o,i))]$

where: E(s,d) is the number of employed in activities *s* in zone *d*; C(o,i) is travel cost between *o* and *d* ; α1, α2 are parameters to calibrate.

Passive accessibility of economics activities in a zone *d*: *Acc_pass(d)* = $\sum[Res(o)^{\beta 1} \cdot \exp(\beta_2 \cdot C(o,d))]$

where: Res(o) is residential population in zone *o*; C(o,d) is travel cost; β1 ,β2 are parameter to calibrate.

[7] P. Coppola, A. Nuzzolo, Regional accessibility and socieconomic activities location: from empirical evidences towards a modelling framework, Department of Civil Engineering, University of “Tor Vergata” (Rome).

[8] Marco Tucciarelli, 2009.

Another method is based on empirical observations of users behaviour (revealed preference). This method provides more reliable results, but certainly valid only for current situations and therefore not reportable to possible impacts due to future changes. A third method is based on mathematical simulation models of human behaviour. These models also rely on data coming from empirical studies and observations of user's actual behaviour, for a given transport system; they are also well suited to simulate effects of future scenarios, as well of situations with similar characteristics to those for which parameters were estimated.

In particular it is possible to distinguish three categories of models designed to simulate the interaction of land use and transport: predictions model of transport demand, predictions models of land use and integrated transport and land use models[9].

The first are used to predict effects on transport demand in an area that presents a particular supply levels; so they simulate the process of choice made by users about the possibility of making a trip, when, why, by which transport mode and following which path. The most common mathematical model used in these cases is the *four-stage model*; which in turn contains the emission or generation model, distribution model, modal choice model and path choice model[10]. For this kind of model, data related to land use are provided as exogenous.

Prediction models and methods of land use are used to simulate the economic, social, demographic and housing changes in a given area and are inputs to the decision-making processes related to spatial and transport planning. Part of these models are territorial plans and other land use regulations tools, but also methods based on the subjective judgement of experts (*panel of experts, the Delphi method*), which after an iterative process come to a shared consent.

Statistical methods use linear regression models to estimate effects of a given variable, fixed values of other variables of the system. Discrete choice models (Logit) are used to estimate the probability to make a choice in a particular system, depending on the characteristics of individuals performing the choice and on the choice features.

Input/output models instead offer a representation of economic relations between the components of a given production system (purchases and sales, imports and exports), and therefore among the various sectors in which it is articulated.

Finally, the econometric or mathematical or statistical models are used to represent and simulate relationships between different economic variables, and can be used to predict employment and demographic changes.

A further approach is referred to the combination and integration of land use models with transport systems simulation models, trying to pair and connect functions of demand forecasting with those of land use and then to predict reciprocal effects.

These kinds of models can be classified in different categories. They differ from each other as in the manner in which variables of the model are defined (continuous or discrete spatial variables), as in the way in which these variables are specified and also if they are endogenous or exogenous.

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[9] Ibidem

[10] Emission model: provides the average users number of category *i,* moving al time *h,* for the reason *s,* leaving from the zone *o*. Distribution model: provides the average users number of category *i,* moving al time *h,* for the reason *s,* leaving from the zone *o*, towards the destination area *d.* Modal choice model: provides the average users number of category *i,* moving al time *h,* for the reason *s,* leaving from the zone *o,* towards the destination area *d,* with the transport mode *m.* Path choice model or assignment: : provides the percentage users number of category *i,* moving al time *h,* for the reason *s,* leaving from the zone *o,* towards the destination area *d,* with the transport mode *m,* using the route/path *k.*

In integrated land use an transport models it can be distinguished an operational approach, based on the theory of spatial interactions (Lowry, 1964), or on the theory of entropy maximization (Wilson 1970), in which land use models have the aim to study relationships between different activities in a localized area, based on analogy with Newton's gravitational theory and physical principles of maximization of entropy.
A further approach refers to the already mentioned econometric input/output models; it's the case of the Meplan models (Echenique, 1990) and Tranus (De La Barra, 1989). The whole structure of these models is based on integrated economic models where transport demand is obtained as a result of all the relationships that occur between activities present in a given area. These models can simulate effects of transport policies on various socio-economic and territorial components and for that purpose require a large amount of data.
Other approaches related to integrated land use and transport models depends on the way it is studied the evolution of the analysed system. Statistical models study a variable in a fixed period of time, keeping unvaried the other variables of the system, while dynamic models simulate explicitly the evolution of the system considering different reference periods affected by changes in the transport system. Other dynamic models are based on utility maximization (Meplan and Tranus) or on different transformation processes that influence activity and space consumption. In particular Meplan software can be used to estimate effects of changes in transport on land use and their potential development; it incorporates an economic evaluation that provides economic costs and benefits of different decisions[11]. Urbansim is an open source simulation platform, designed to maximize reality, thus increasing its usefulness for assessing the impacts of alternative transport a land use policies[12].
Implementation of this model requires input data such as exogenous population, number of jobs, regional economic forecasts and plans for land use and transport.
Tranus model simulates the residential system; land use, property and transport system. The system can be applied to any scale and is very flexible; uses discrete choice Logit models. The general theoretical framework of this model will be treated more extensively in subsequent paragraphs[13].

3. Territorial analysis of the study area

The territory considered in the present study includes city of Cosenza, in the north-western part of region of Calabria, in southern Italy. In particular, in addition to the city of Cosenza, analysis extends to the conurbation that includes the adjacent municipalities of Rende, Castrolibero and Montalto, as well as the territory of Savuto (a zone of 17 municipalities which includes a total area of 393, 73 km^2, all classified entirely mountain[14] and with an average population density of about 162 inhab/km^2).
To serve the urban area of Cosenza and Rende will be soon realized a new transit service which will correspond to the type of a modern tramway, narrow gauge, compatible with that of the regional lines of *Ferrovie della Calabria* (950 mm), a company that performs regional bus and rail service. This system will cross the

[11] Testi PORTAL 2003
[12] http://www.urbansim.org/Main/UrbanSim
[13] http://www.tranus.com/
[14] http://www.cmsavuto.it/Profilo/Comprensorio.html

central areas of the urban area and will be strongly connected, by interchanges nodes, with regional railway and bus lines that converge on the area.
The urban area affected by this operation and which is the basin of influence of the new line, is formed by the towns of Cosenza and Rende, which now form a homogeneous conurbation, with many other smaller municipalities, for a total population of 280,876 inhabitants[15].
This conurbation is spread over an area of approximately 107 km^2, with an average density of 1,061 inhab/km^2. Over the past two decades there were a significant reduction in the number of inhabitants, as a result of a migration of many residences to the hinterland; especially in the city of Cosenza, in the period between 1981 and 2001, has been a reduction of residential population of about 35,000 units[16].
The aim of this work is to analyse possible effects on transport demand and modal split between private car and public transit, following implementation of a new service of modern tramway (light rail), next to be realized, and an additional tram-train service to integrate with it. The idea is to connect area of Savuto to the conurbation of Cosenza and Rende and the University of Calabria, with an high quality rail service, efficient, without break and sustainable for the environment.
Regarding the spatial structure of the studied area, it is significant the polarizing role of the city of Cosenza, the provincial capital. Considering the increased presence within it of work activities, educational and commercial, office and administrative structures, can be observed as a result to occur, compared to a continuous decrease in population during recent decades, a steady increase in daily traffic flows into and across the town.
In particular, as major attractors of traffic flows within the conurbation, there is, in the municipality of Rende, at north-west the campus of the University of Calabria, at north-east an industrial area and a commercial area in the central zone. About Cosenza instead main attractors are the city centres, where there are commercial activities, offices and business centres, the historic zone of the town, located at south of the conurbation, and also the local hospital.
In particular, greater density of settlements, activities and services are located in the strip of territory bounded on the north by the University campus and on the south by the old district of Cosenza, and extended for a length of about 8 km.
Even the municipality of Castrolibero in the south west and of Montalto in the north, have a strong proximity with the conurbation, being completely part if it[17].
University of Calabria covers an area of 250 hectares and has a student population of approximately 32,000 students and 2,000 staff, including administrative and teaching staff. Currently is in place a further expansion of residential facilities on the campus, which will soon be offering a total of about 4,200 beds for students and teachers.
As stated previously even the urban area of Cosenza and Rende, over the past twenty years has been affected by significant phenomena of migration to the surrounding areas and therefore of urban dispersion or sprawl[18].

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[15] Carbone, D.C. Festa, Nulli, Lo Feudo, Zinno, Un tram treno per l'area urbana di Cosenza, 2010.
[16] Ibidem
[17] Ibidem
[18] Definitions of urban sprawl:
"Diffuse and low density development which is typically localized at the edge of an existing settlement to the vast rural areas. Characterized by segregation, land consumption and dominated by car. "(National Trust Historic Preservation dor);
"Specific form of urban growth expansion with low population density, car dependence, with negative repercussions for the environment and society in general "(Hasse y Lathrop 2003).

However, these phenomena were recorded unevenly over the entire area affected by the conurbation. In fact the particular orography of this territory, which stretches along the river Crati valley and surrounded by hills and mountains of Sila to the east and southern coastal mountains to the west, has resulted with an urban growth mainly evolved in a linear axis, which starts from the historic district of Cosenza up to the campus of the University of Arcavacata and at the gates of the town of Montalto.
The substantial linearity that characterizes the shape of the urban conurbation that includes the towns of Cosenza and Rende, is even more evident if we consider the main roads on which the system of mobility of that area is based (A3, ss107, ss19, ss19bis), which pass through all along the north-south axis.

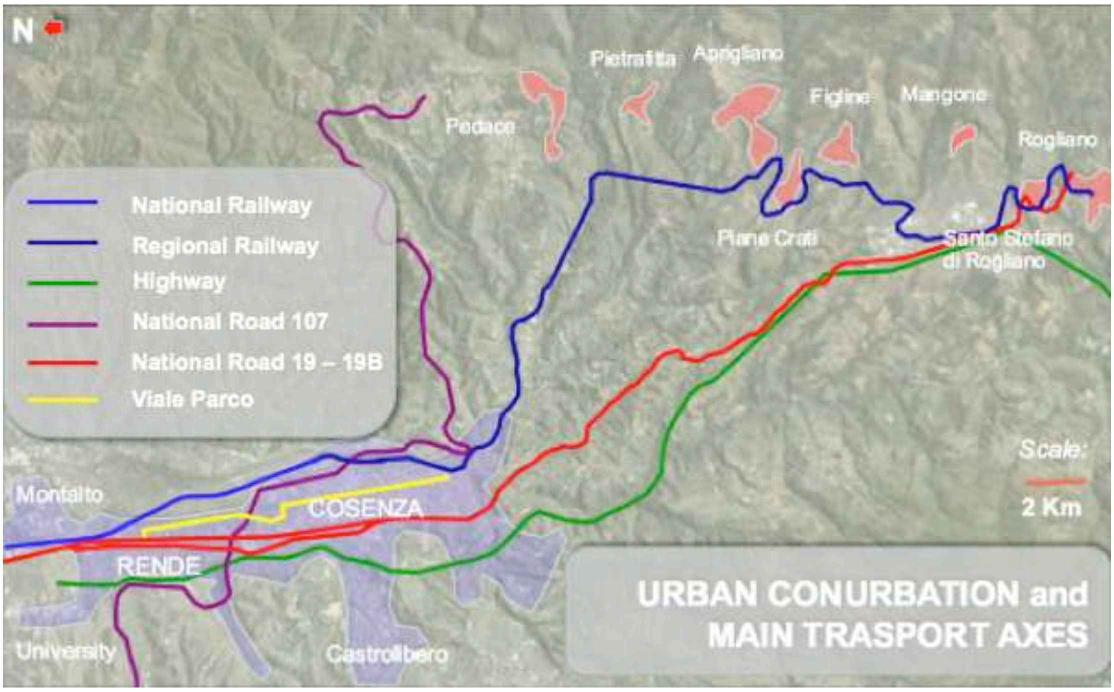

Fig. 2: Urban conurbation of Cosenza and Rende, municipalities of Savuto river valley, with main transport infrastructures axes. (Lo Feudo Fausto 2012)

It extends along this axis also the new road infrastructure in the urban area, known as "Viale Parco", with a strategic importance related to the mobility system and to the future urban asset; in fact, in recent years along this road there has been a considerable increase of new residential constructions.
This is probably a number of new residences disproportionate related to real residential demand and to local property market. Certainly characterized by a use of structural criteria that show a lack of attention to parameters of quality and urban sustainability; with particular reference to the creation of green spaces and aggregation areas, as well as homogeneity about constructive and aesthetic criteria (heights and facades of buildings, courts, common areas etc.).
Such very intense construction activity but at the same time not sufficiently monitored, is opposed to the situation of the neighbouring area of the city's historical district. This is an area with a high historical and artistic value, which represents one of the most beautiful historic districts of Italy. Nevertheless from almost a decade it is affected by a continuous phenomenon of de-population and the deterioration and degradation of the building stock. This shows a political will mostly aimed to creating new housing and to consume land without a special interest in recovery and consolidation of the existing building stock.

Fig. 3: Photo of Viale Parco (Via G. Mancini) in Cosenza.

Through the study of maps provided by the National Geo-Portal (GN) of the Ministry of the Environment, Land and Sea[19], can be observed that during the period between 2000 and 2006 there were some areas of conurbation that more than others have reported a greater thickening of the urban fabric, with consequent problems of increasing population density. That is the case of area surrounding the campus of University of Calabria and the area located in the north extremity of Rende, along the ss19 road, which leads to the town of Montalto.
Urban sprawl can be identified in the village of Rende Saporito and at the south - west (Vadue Carolei, Laurignano) and south - east (Zumpano) extremities of the city of Cosenza.

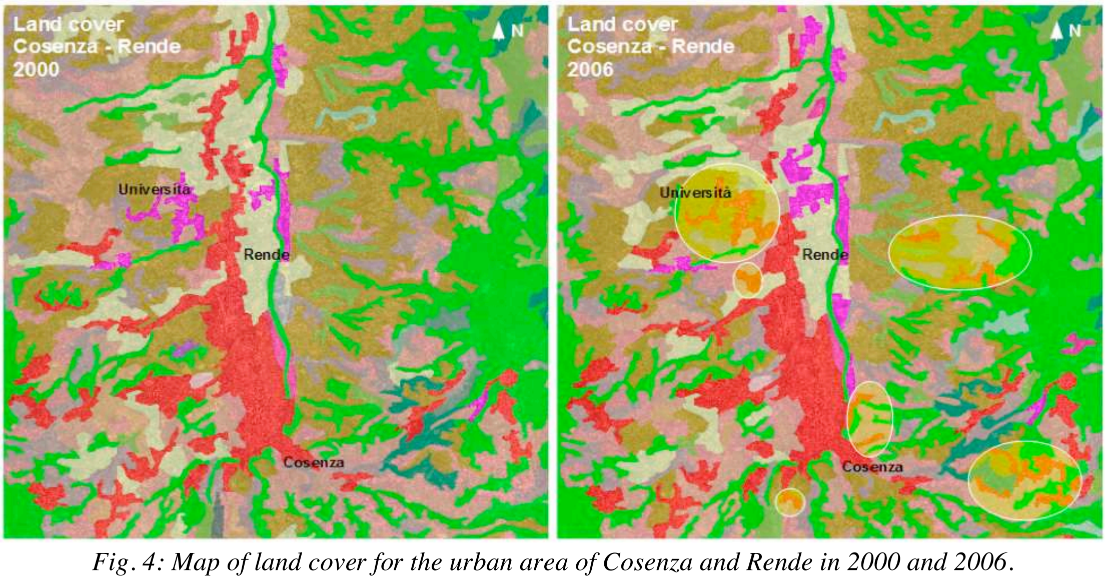

Fig. 4: Map of land cover for the urban area of Cosenza and Rende in 2000 and 2006.

[19]www.pcn.minambiente.it

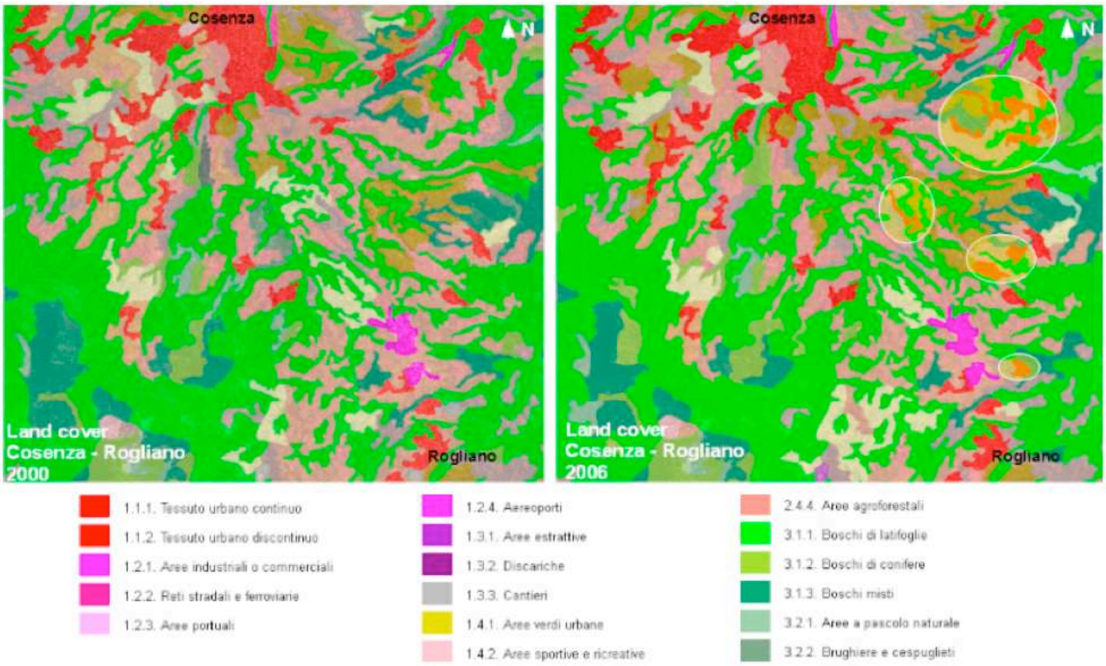

Fig. 5: Map of land cover for the urban area of Cosenza and in the area of Savuto municipalities in 2000 and 2006.

If analysis is extended to the territory of Savuto, that will be involved in the transport model which will be explained later, can be clearly seen how during the same period (2000 - 2006), several towns of this zone have registered a strong intensification of their urban fabric. It is therefore confirmed the constant phenomenon of de-population concerning the urban area of Cosenza and Rende, in favour of his hinterland.

In particular, this phenomenon is common to both municipalities closest to the extreme south - east of the city of Cosenza (Casole Bruzio, Trenta, Pedace), and next to area of Savuto as Donnici, Aprigliano and Piane Crati.

It is a non-homogeneous phenomenon of urban sprawl of nor really high intensity, attenuated and slowed down mainly by geography configuration of the area, but that in any case needs a constant and continuous monitoring action.

From this analysis on spatial asset evolution of the urban fabric in recent years, it can be deduced that the study area will continue to maintain, in the next future, her substantially linear structure, with a predisposition to urban expansion and densification especially in the north of the conurbation, near the University of Calabria and Castiglione Cosentino railway station and along the new “Viale Parco” road, which recently opened to traffic and a further part, inside the municipality of Rende.

4. Mobility and transport systems in the study area.

Urban area including towns of Cosenza and Rende is, in terms of mobility and transport, a crucial and strategic node in the region.

In this area in fact the highway A3 *Salerno-Reggio Calabria* is connected with ss107 road, which leads to Paola, on the Tyrrhenian cost side, and to Sila Mountains and Crotone, on the Ionian coast side.

This situation results from the elevated volumes of traffic that cross the area, especially on the Tyrrhenian and Ionian coasts director (west - east) and on the north - south axis on the highway; that must inevitably overlap with the local traffic, creating many different critical points inside the urban area. Cosenza is also an important railway junction from which starts the *Sibari – Paola* railway line, which would serve the connection between the rail lines operating along the Tyrrhenian and Ionian coasts. In addition, the stations of Cosenza City Centre and Vaglio Lise, branch narrow gauge lines of Ferrovie della Calabria to San Giovanni in Fiore, and to the city of Catanzaro.

4.1. Road network

The A3 highway *Salerno-Reggio Calabria*, through the urban area of Cosenza and Rende along the direction north-south has two exits which serve both the territories (Cosenza Nord - Rende and Cosenza Sud). Territory of Savuto is instead served by A3 highway through the Rogliano's junction.
The road ss107 links the ss106 on the Ionian coast and the SS18 along the Tyrrhenian coast and colleague Paola and Crotone crossing the urban area of Cosenza.
In particular next to the junction that connects ss107 road to the University area there are most high congestion problems. Municipalities of the area of Savuto, are also served by the provincial roads 242 (ex ss535) to Rogliano and 244 (ex ss178), which starting from Donnici arrives to the mountains of Sila. The roads ss19 and ss19bis are fundamental for the mobility system of the entire conurbation Cosenza-Rende. The opening to traffic of the new "Viale Parco", also in a north - south axis, will contribute to reduce congestion on urban road system, currently involved in a massive traffic of cars and lack of road links in the transversal direction.

4.2. Rail network

The railway system in the urban area of Cosenza and Rende is articulated around the lines of Rete Ferroviaria Italiana (RFI) *Sibari - Cosenza* and *Paola - Cosenza*.
The line *Cosenza - Castiglione Cosentino - Paola* connects the urban area with the national line *Battipaglia - Reggio Calabria*, on the Tyrrhenian coast.
The line for Sibari is ongoing electrification, it connects the Ionian coastline to *Taranto - Catanzaro - Reggio Calabria* and currently is registering a considerable decline of daily trains supply by Trentalia.
The two mentioned lines are joined near the rail station of Castiglione Cosentino located in the municipality of Rende, to converge with a double track line towards the station of Cosenza Vaglio Lise.
Railway services on these lines are subject to the Central Control of Traffic and Central Operations Manager, with a capacity that can be estimated at 70 trains/day both direction. From the station of Cosenza Vaglio Lise starts the railway line of Ferrovie della Calabria, with a narrow gauge of 950 mm, direct to Catanzaro.
So railway infrastructures facilities are actually not sufficient to respond to transport demand and to compete, at an urban as a regional scale, with car mobility.

4.3. Rail supply

Rail services are performed by Trenitalia and Ferrovie della Calabria, that operate on national and regional connections.
Trenitalia offers regional and interregional services and operates from Cosenza. These services operate in the station of Vaglio Lise (not well connected with the city centre,

even if served by numerous taxis and some bus lines) and in the station of Castiglione Cosentino (situated in the north extremity of the urban area). Current supply is around 70 trains in 24 hours. Ferrovie della Calabria instead operate regional connections from Cosenza to Rogliano, from Catanzaro city centre to Catanzaro Lido and Soveria Mannelli and also operate a sort of underground service between the stations of Cosenza Vaglio Lise FS and city centre station, with nearly 70 daily trains between tin both directions, but with very low levels of demand[20,] due mostly to the significant distance of rails and stops from residential area. Train supply of *Cosenza - Catanzaro Lido* line is around 880.553 trains x km/year.

4.4. Bus supply

Bus services represent the main transit mode in the urban area of Cosenza. Supply, in fact, in terms of numbers of vehicles x km, is around over 20 million bus x km/year.
Transit demand for the city of Cosenza is covered by AMACO (Azienda per la Mobilità nell'Area Cosentina), with 6 urban lines and 24 suburban lines.
In the town of Rende, beside AMACO, which performs the connection with the railway stations, the company Consorzio Autolinee operates express lines connecting the hinterland with Rende tries and the University of Arcavacata.
Territory of Savuto is connected to the urban area by several bus lines, of different companies, but with the problem, frequent in the area, of lack of integration and connections of lines, with overlap of routes and schedules and with the prevail of the costly logic of only direct connections. This policy leads to the vicious circle whereby lack of users during low demand hours, leads to reduced services, and poor quality of services causes further declines in the levels of transit demand[21].
The number of buses that run through the conurbation is very high, area around the bus station in Cosenza, located right in the city centre, result in systematic traffic congestion in various times of the day and delays and disruption for users.
The area of the University of Calabria is finally the main transit flows attractor and at the same time a point of high critical congestion situations, due to high levels of private vehicles circulating in the area and to the lacks of evening and night links to the rest of the urban area.
In conclusion, there is a poor and ineffective integration between rail services and bus transit supply, as inside the conurbation, as in the suburban area[22].

4.5. Characteristics of mobility

A recent study made by the Department of Territorial Planning of University of Calabria[23], provides a precise analysis of general characteristics of mobility, in reference to the area affected by the conurbation of Cosenza and Rende, as well as levels of demand for public transports, which is estimated around 70 million passengers x km/year.
This study provided the average number of daily trips made by each inhabitant, equal to 0.850 and the total number of trips made throughout the day (239.431) and at peak

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[20] http://www.ferroviedellacalabria.it
[21] Marco Tucciarelli, 2009.

[22] Carbone, D.C. Festa, Nulli, Lo Feudo, Zinno. 2010
[23] Ibidem

hours (30.282). Modal split identified by this study is strongly oriented towards the private car, that is used for approximately 70% of total trips, with average travel distances ranging from 20 km by car to 7 km by bus.

5. Urban renewal perspectives and Transit Oriented Development.

The urban planning theory of Transit Oriented Development (TOD) was born in United States, with the aim of promoting a sustainable urban and regional transit oriented development[24]. It is particularly aimed at dense and compact urban forms, to combat phenomena of dispersion and urban sprawl, pollution and car dependence[25], to promote policies that encourage use of public transport and soft mobility (pedestrian and bicycle mobility), as well as quality of life in modern urban areas. These are not entirely new and recent concepts; the idea of a compact city, built up around public transport nodes and that should encourage soft mobility, can be found in urban planning principles of the early 900'. The innovative challenge today is then try to develop methods and practices to support decision-making actors for the implementation of such principles[26].

Principles of urban design, which supports the theory of TOD, are called of the "*four D*": *Distance, Density, Diversity* and *Design*. We refer, in fact, to a high density and mixed urban development, giving priority to pedestrian mobility and providing a system of easy connections and accessibility to transit stops[27]. Pedestrian accessibility, urban connection, functional and residential mix, architectural and design quality, density, sustainability, public transport efficiency and quality of life are key factors included in that theory[28].

It's however important to precise that simple implementation of densification policies, can not be considered sufficient to success on decrease of car dependence, in favour of transit use. It should be definitely considered the problem of how to put into practice, how to manage and what other interventions needs to apply to assist more density policies[29]. The issue of urban density, in fact, is quite complex and influenced by numerous factors. Starting from concept of urban density itself, which is often associated with an image of concrete and high tower buildings of questionable architectural quality, when it is calculated that in a plot of one hectare, 15 individual houses can offer the same density a tower of six floors. So the height of buildings is not an indicator of true density; at the same time as more density of a settlement does not automatically stop urban sprawl, and this because the market demand refers to dense or dispersed areas does not correspond to the same type of customers.

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[24] Robert Cervero, A Panorama of TOD Principles & Experiences – University of California, Berkley, International Seminar on Urbanism Oriented to Rail & Intermodality, Ecole Nationales des Ponts et Chaussés, Paris – 2011.

[25] Gabriel Dupuy, Towards sustainable Transport: The Challenge of Car Dependance, 2011.

[26] Thomas Leysens, Reconfiguration des réseaux de transport & Renouveau urbain, l'enjeu d'un urbanisme orientè vers le rail, 2011.

[27] Transit Cooperative Research Program sponsored by the Federal Transit Administration – www.trb.org

[28] www.transit-oriented.com

[29] Robert Cervero, 2011.

However, since for a fact that in large urban areas, higher density corresponds to a smaller number of displacements, this does not occur in rural areas and small towns, which, being interdependent by nearby cities (because of work, trades and services), even if subject to greater more density, do not register any significant impact on the amount of daily travel distance. Another exception is about price of land, which if destined for greater more density, inevitably record strong increases, which will benefit mainly landowners[30].

TOD policies are then preferably applicable in certain conditions, specifically when they are accompanied and supported by a strong political will, by a stable economic situation and, above all, by an intense coordination between different levels and actors involved, both during the strategic and operational planning, until the phase of funding seeking and of implementation.

They must also be well adapted to different local contexts; taking into account socio-economic and cultural needs of each territory. It is risky think to identically bring and reproduce such practices, even if proved that potentially virtuous in other contexts, such as the United States, in very different contexts such as Italy and southern Italy in particular.

However, TOD as urban planning theory in support of integrated transport policies and territorial government and as opportunity to develop urban regeneration has already been applied with some success, in several cases in Europe. Also in Italy, where was taken just an "architecture" type approach, mainly oriented to the redevelopment of railway stations buildings. Examples of this are the "Medium Stations Project" promoted by the Italian Railway Network (RFI), with the Region of Emilia Romagna or the “Hundred stations plan” sponsored by the City of Napoli[31], and complemented by the project of regional metropolitan system of Campania.

With reference to the case study object of this work, the implementation of founding principles of the TOD theory, if properly adapted to socio-economic and environmental circumstances, is hoped and to promote.

As shown previously, the territorial structure of the study area is characterized by a strong linearity; this refers to urban concept of linear city, designed by engineer Arturo Soria y Mata Spanish (1844 - 1920), as a radical alternative to the traditional development model of compact city, which grow around the original centre. In the "*lineal Ciutad*" of Soria y Mata mechanized transport infrastructure (primarily rail) becomes the "matrix" of urban settlement and even if Soria was oriented mainly to a city of isolated homes with low density, an element not much "sustainable" of his theory/utopia, the centrepiece is an axis of infrastructures composed of roads and a double-track tramway, joined by walkways and cross walks. This is a concept of urban development that appears also in the definition of "*complete street policies*".

Notion of *complete street* means the street as a place not only for cars, but open to intermodality, with sufficient space and security conditions for all types of users (pedestrians, cyclists, etc..), giving priority to transit modes (tram, bus, tram, etc..)[32].

The north - south axis on which will be developed the new tramway system in the city of Cosenza and Rende is a transport corridor that is well suited to the application of integrated policies between transport, land use and urban renewal. The hope is to

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[30] CERTU – Département Urbanisme Habitat, L’essentiel – La densité urbaine, 2010.

[31] Enrica Papa, Governo integato trasporti-territorio: Transit Oriented Development in Europa e nell'area metropolitana di Napoli, 2007.

[32] Robert Cervero, 2011.

move from a corridor currently characterized by a largely "car-oriented" mobility, to a "transit–oriented" condition; accompanied by not only interventions of urban more density, which are already largely in place, but also of urban renewal and modernization, in order to assist the walking priority and accessibility to transit networks.
This should be expected not only for buildings located in immediate vicinity of transit stops, but also considering at least the adjacent areas, with a radius equal to the potentially walking distance in period of at least 10/15 minutes. A good similar example is that of *Disques de Valorisation des Axes de Transports* (DIVAT) applied to various French cities. The DIVAT is an ideal disk with radius of 500 meters and centred on a rail station or on a public transport stop, considering a time walk of about 10 minutes. The interest is to be able in this way to well-direct the analysis and the monitoring activity by public institutions, with the purpose to exploit this land potential and to reflect on interventions of urban renovations and regeneration, mixed, dense and functional, well adapted to characteristics and forms of each urban area. It is one of many tools that can be used for observation and monitoring of land use, a practice now urgently needed for local communities, in order to preserve land consumption and to promote policies of land regeneration, renewal and "recycling".
In the case of the Urban Community of Lille, a DIVAT represents an area of approximately 78 hectares.
It is important to emphasize that pedestrian mobility and accessibility are a key element to close more users to transit systems. From studies carried out in France about that it was shown that 80% of displacements directed to a metro stop are made on foot, more than 65% to get a tram or 50% to railway stations[33].
Pedestrian mobility is demonstrated amply favourites up to 1000 meters; for displacements above 1500 m is transit that becomes more relevant[34].

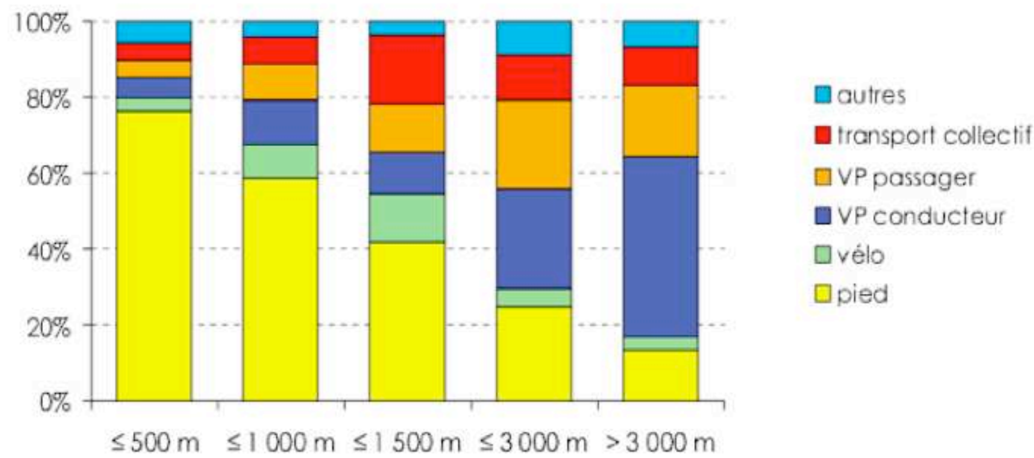

Fig. 6: Graph of modal split in function of distance from railway station in Strasbourg (France). (Bahn-Ville2 – 2010)

In the context of such an operation of implementation of a new tramway service, with the perspective to integrate and extend it to the province, through an integrated tram-

[33] Lille Métropole Communauté urbaine, Le DIVAT, Disques de Valorisation des Axes de Transports, 2009.
[34] S Bozzani-Franc, T Leysens, A L'Hostis, C Soulas, B Vulturescu , Un Urbanisme orienté vers le rail illustré par le projet Bahn.Ville 2010.

train system (as the case treated in this study and as will be detailed later in this document), can not be ignored the idea of promoting policies to improve accessible, safe and well connected pedestrian mobility to transit stops, with the application of a contemporary politics of traffic calming and a decrease in available parking spaces within these areas.

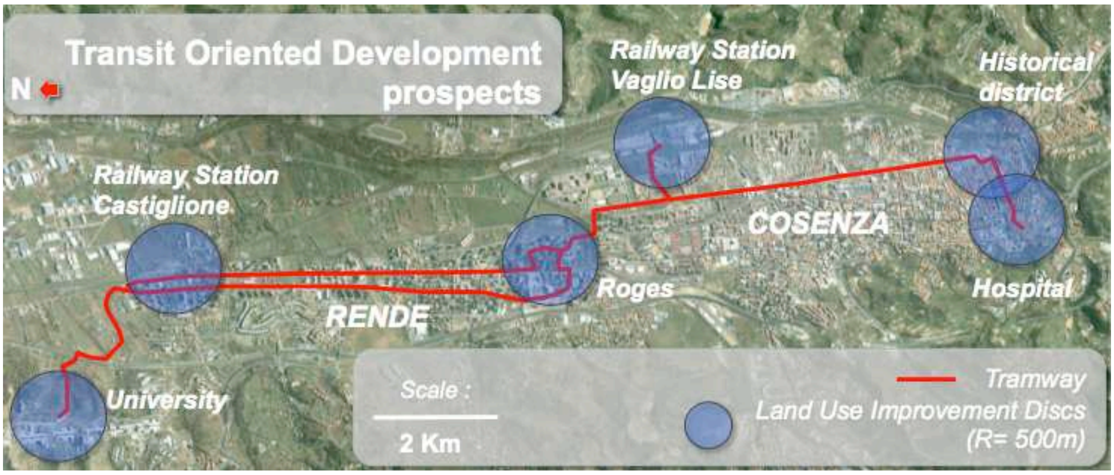

Fig. 7: Tramway itinerary in urban area of Cosenza and Rende with map and localisation of "Land use improvement discs". (Fausto Lo Feudo 2012)

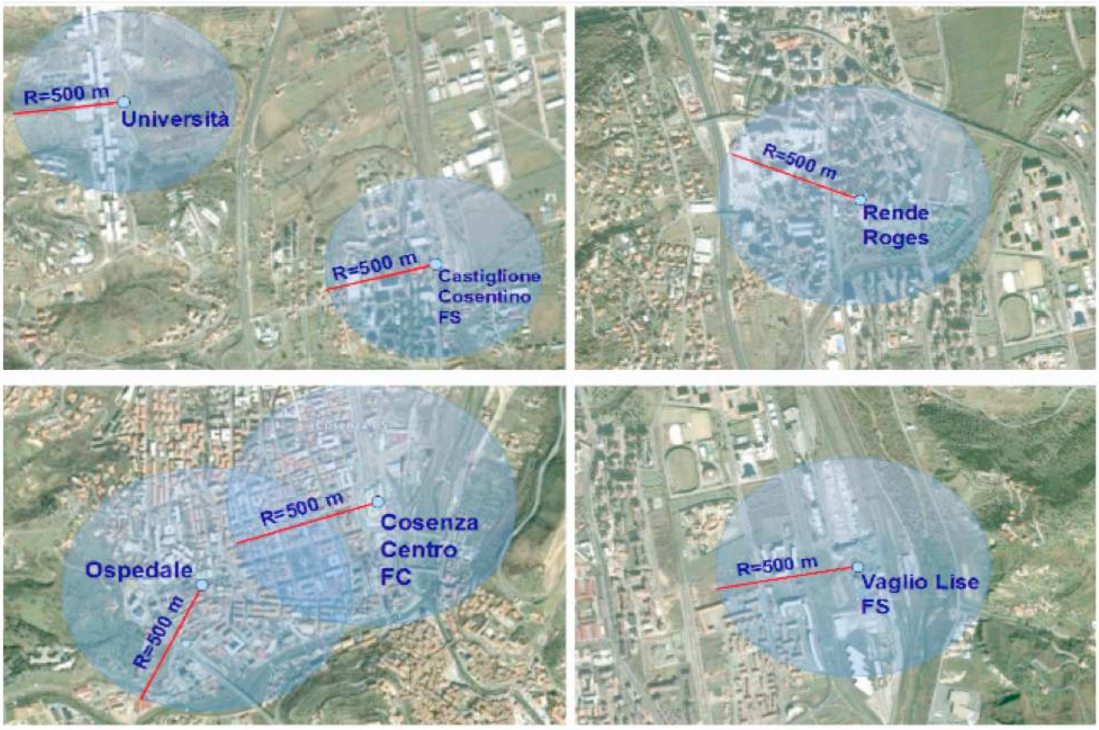

Fig. 8: Particular of six "Land Use Improvement Discs". (Fausto Lo Feudo 2012)

5.1. Land Use Improvement Discs

A spatial analysis was done to identify, among areas covered by new tramway (tram-train) line, those that may lend itself to operations of more density, renovation and urban regeneration, in line with principles of a Transit Oriented Development and at the same time that will require further land use monitoring and control. Six strategic points in the urban area were identified: the Civil Hospital, the intermodal hub

situated between the shopping centre I Due Fiumi and the city centre rail station, the rail station of Vaglio Lise, the bus stop near the shopping centre Metropolis in Rende, the rail station of Castiglione Cosentino and the bus terminal at the University of Calabria. On these strategy points were cantered imaginary discs, called "Land Use Improvement Discs", with radius of 500 meters, which represent the foot distance travelled in about 10/15 minutes. The interest of this exercise is to identify in which areas exhibit a greater potential for more density (residential and services), regeneration and urban renewal (of land use), as well as having a simple and direct representation of the potential territorial "cover" that this new transit system should have in a context mainly characterized by a linear urban form.
About the station of Cosenza Vaglio Lise, it is located in a position rather isolated with respect to the urban central area, not facilitating thereby the uptake of interventions that could improve pedestrian access. In the municipality of Rende, are near the Metropolis shopping centre, is already affected by a high level of residential density and a fair level of pedestrian accessibility. In the case of the railway station of Castiglione Cosentino, while the city side (west of the railroad) is characterized by a strong urbanization, the back-station territory is almost empty of building elements and affected only by small settlements and agricultural activities and small industrial activities. This situation suggests that a possible transformation, more density and redevelopment intervention must be translated mainly on the backside of the station[35], associated with interventions of functional regeneration of the station itself and to connect the two sides, so to limit the railway barrier effect. Finally it results evident that the area with greatest potential for more density and for urban development is the district of "Gergeri", located at the foot of the historical district of Cosenza and beyond Crati River (east bank side) compared to the city centre rail station. This is an area of more than 9 hectares, which in the past, despite its proximity to downtown, has been strongly affected by phenomena of degradation. This area if subject to future intervention, attentive to the principles of sustainability and TOD, could afford to facilitate the connection between the city centre and the neighbourhood located on the east bank of the river Crati and to enhance even more the potential of the new tramway service and tram-train directed to the area of Savuto. It should be noted that any action implemented in the area located on the right bank of the river, should not in any way reduce the surface of the bed of the river Crati and obstruct its natural path, but instead could help to recover and enhance the aesthetic and highly distinctive value of that natural element compared to the urban layout of the city of Cosenza.
The historical district of Cosenza finally, is surely an ideal area to put in practice redevelopment and urban renewal interventions, supported by intensification in transit supply levels represented by the new tramway. The particular conformation typical of many urban historic centres, imply inevitably that the majority of medium and small journeys, into and out of such areas, are carried out by foot. So it is hoped to put in place policies of urban fabric renewal and regeneration for this neighbourhood, as well as a strengthening accessibility to the new tramway stops.
This may allow breaking the isolation of this area compared to the rest of the urban area and begin a policy of re-population and of sustainable mobility practices promotion, to characterize this as a "transit oriented" neighbourhood.

[35] Fausto Lo Feudo, Una proposta di riqualificazione della stazione ferroviaria di Castiglione Cosentino nel contesto del sistema dei trasporti dell'area urbana cosentina, Graduation thesis, 2005.

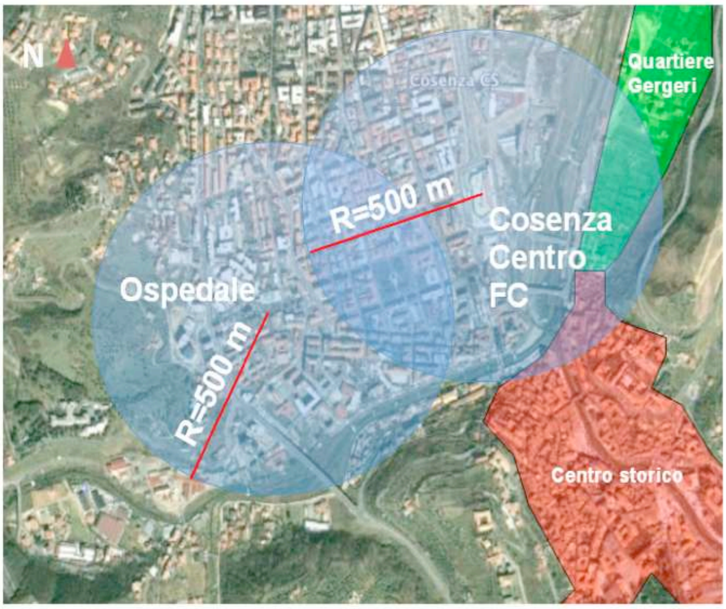

Fig. 9: District of Gergeri (green) and historical district of Cosenza (red): areas identified with most opportunity of densification, land use regeneration and urban renewal. (Fausto Lo Feudo 2012)

6. The project of a tramway system for the urban area of Cosenza and Rende.

The approval of tramway projects for the urban area of Cosenza and Rende arrived after a long cultural debate and a lengthy decision, started in the Eighties; until approval by Calabria Region of the final project ("Connection System between metropolitan Cosenza - Rende and University of Calabria"), which involves the construction of a modern tramway, narrow gauge (950 mm), compatible with the gauge of Farrovie della Calabria. The cost of whole project will be funded for the full amount through the European Union POR found 2007/2013, for a total cost of 160 million euros[36].
Track develops along the north – south axis between the historic city of Cosenza and the University of Calabria, with a total length of about 21Km. Regarding the connection with the existing rail network, it will be connected with the city canter railway station of Ferrovie della Calabria in Cosenza, through the tramway South Terminal, and with the Vaglio Lise train station, through the branch located in the middle position of tracing and then with the train station of Castiglione Cosentino through the north terminal.
From the tramway south terminal will grow another branch directed to the Civil Hospital of Cosenza, while the north terminal will extend a branch directed to the University of Calabria.
Despite the initial investment costs greater than other transport systems, choice of such a railway system was motivated because it is believed to ensure good capacity levels and efficiency, comfort and security characteristics, commensurate with the served territory. In the final project 91.35% of the route results in separate track (78.40% green covered), and only the 8,65% in shared track (on-street).

[36] *To access this funding projet will have to be completed by December 31, 2015.*

Moreover, as regards the narrow gauge, it will be used to allow the integration of service and interoperability with the network of Ferrovie della Calabria, to permit to envisage the implementation of a tram-train service, which connects the urban area to the Savuto valley.

7. Scenarios of development of rail transport with the hinterland: a tram-train service to connect Savuto valley.

As shown in the previous paragraphs, the tramway system that will affect the urban area of Cosenza and Rende will be strongly connected to the existing rail network and rail stations of Ferrovie dello Stato and Ferrovie della Calabria, via stops and interchanges nodes. In particular is extremely interesting link already provided by Ferrovie della Calabria to Rogliano. Although this rail line currently fails to adequately compete with car mobility, that thanks to the fast highway link between Cosenza and Rogliano, which is widely preferred to public transport. In this context, interoperability between the urban line (tramway) and suburban rail (train), would create an important continuous rail link between Rogliano, the urban area and the University of Calabria. Moreover, these services could be made quickly, even without the electrification of the FC lines, using the new diesel tram-train, already available on the market and used in other contexts[37].

From a study made to estimate trips realized in the conurbation Cosenza - Rende and area of Savuto was recorded that for a total of approximately 24,000 daily trips, about 88% are made by car, 11% by bus and only 1% by train. So there is surely an excessive disproportion concerning use of cars and at least further confirms of the large amount of potential demand that an efficient and attractive transit service could attract; also considering the fact that the majority of users who travel from Savuto area to the conurbation is made up of commuters and students[38].

The tram train technology is widely used in many European and American reality, and allows to integrate tramway services with urban suburban and regional rail services, often realized recovering existing railway lines, with low levels of traffic or in disuse. The ability of such a rail system as tram-train, to be a part of a local context in such a structural and incisive way, allows it to be considered as a system able to stimulate transport demand, in particular when accompanied by a bus service that performs the function of collect and distribution on the rest of the territory.

The main purpose is essentially to eliminate transfers of commuters from train to tramway that cause loss of time, making transit journey more comfortable and convenient instead of private car.

This is a technology that provides higher initial investment costs compared to other systems[39], but that presents a greater life of service of rolling stock, a greater capacity and lower maintenance requirements; all factors that compensate the increased initial

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[37] D.C. Festa, Un nuovo sistema di trasporto per l'area urbana cosentina, 2011

[38] D.C. Festa, S. D'Elia, L'efficienza del sistema dei trasporti fattore di sviluppo della regione Calabria: proposte ed interventi – Centro editoriale e libraio dell'Università della Calabria, 2004.

[39] Cost of investment: 2 million to 10 million euros per kilometer (2008 values excluding taxes) for the Rapid Transit Bus systems (Bus high level of service); 13 to 22 million for tram-train systems (rail or road system). Operating costs: from 3.5 to 5 euros per vehicle x km (2008 values excluding taxes) for BRT, 5 to 7 euros per vehicle x km for tram –train system. Energy use: 0.11 x kWh per passenger mile for tram; x 0.56 kWh per passenger mile for BRT. Source: "Il trasporto urbano in Italia: situazione e linee di sviluppo all'avvio del nuovo decennio", ISFORT, 2011.

spending investment. Other advantages of tram-train technology can be referred to a better comfort and a regular exercise, especially in cases of service realized in separated track. At this regard the technical literature agreed that, in general, tramway systems are convenient in area of at least 250,000 inhabitants, but are also convenient in city of 100,000 inhabitants, with some conditions: a linear spatial structure, with the tram as a cornerstone, and the presence of strong centres of demand (such as hospitals and universities) and terminals of suburban transport next to the track: all of these conditions occur in the urban area of Cosenza. In fact estimated demand from planners, 40,000 passengers/day at 2014 in the low scenario, 49,000 passengers/day in 2020 high scenario, 5,300 to 6,400 passengers during pick hour, fully justifies the action[40].

Implementation of a tram-train system in the context of the Province of Cosenza is a proposal that fully correspond to current plans and strategies of development and enhancement of rail transport and mobility system hoped for this area.

In particular, the *Territorial Coordination Plan of the Province of Cosenza* proposes to replace, with a standard gauge track, one of the two narrow-gauge tracks, currently used by *Ferrovie della Calabria* on the link Cosenza city centre station to Vaglio Lise station. It proposes as well the realization of the electrical traction airline and the installation of equipment for rail circulation control, besides some necessary changes on rail track inside both stations. Those interventions are proposed to permit to bring to Piazza Matteotti (city centre) at least local trains coming from relationships with Tyrrhenian coast, Ionian coast and the Crati valley; leaving to the station of Vaglio Lise only long-distance national traffic. The *Plan* also proposes the enhancement of the rail line to Sibari by an increase in the number of stations; thus providing a fast and efficient transport service for the valley of Crati[41].

After these considerations it results clear that proposed tram-train system could represents an excellent opportunity to enhance the existing service, which is that of *Ferrovie della Calabria*, and at the same time to exploit the full potential of the new urban tramway system next to be realized. It would permit to create a network of railway transit services, complete and efficient, intended to meet both urban demand and suburban commuters demand, coming from the municipalities of Savuto.

The renewal and strengthening of the rail line to Sibari would also help to activate the implementation of a regional (at least provincial) railway service and to better exploits the line *Cosenza Centro - Cosenza Vaglio Lise - Quattromiglia - Montalto – Sibari*, now unsuitable for urban service, because marginal to the conurbation and currently poorly utilized.

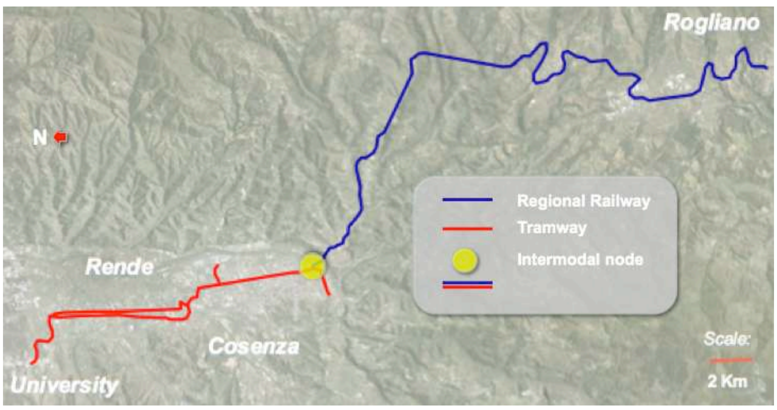

Fig. 10: Tracks of tramway and tram-train line. (Fausto Lo Feudo 2012)

[40] D.C. Festa, Un nuovo sistema di trasporto per l'area urbana cosentina, 2011.

[41] Piano Territoriale di Coordinamento Provinciale della Provincia di Cosenza, 2008.

8. General Description of Tranus system

"Tranus simulates the location of activities in space, land use, real estate market and the transportation system. It may be applied to urban or regional scales. It is specially designed for the simulation of the probable effects of projects and policies of different kinds in cities and regions, and to evaluate the effects from economic, financial and environmental points of view.
The most worthy characteristic of the Tranus system is the way in which all components of the urban or regional system are closely integrated, such as the location of activities, land use and the transport system. Movements of people or freight are explained as the results of the economic and spatial interactions between activities, the transport system and the real estate market. In turn, the accessibility that results from the transport system influences the location and interaction between activities, also affecting land rent. Economic evaluation is also part of the integrated modelling and theoretical formulation, providing the necessary tools for the analysis of policies and projects.
With a system of this kind it is possible to evaluate the effects of transport projects and policies on the location of activities and land use. It is also possible to assess the effects of urban regulations or housing projects on the transport system. The system may be used also as a stand-alone transport model, especially to evaluate the short-term effects of transport projects.
In terms of the scale of applications, the Tranus system may be applied to: Detailed urban areas; metropolitan areas; metropolitan regions, states or provinces.
In Tranus applications it is also common to make full use of the input-output structure of the activities and land use model to make an explicit representation of the spatial economics involved, also evaluating the combined effects with the multimodal regional network"[42].

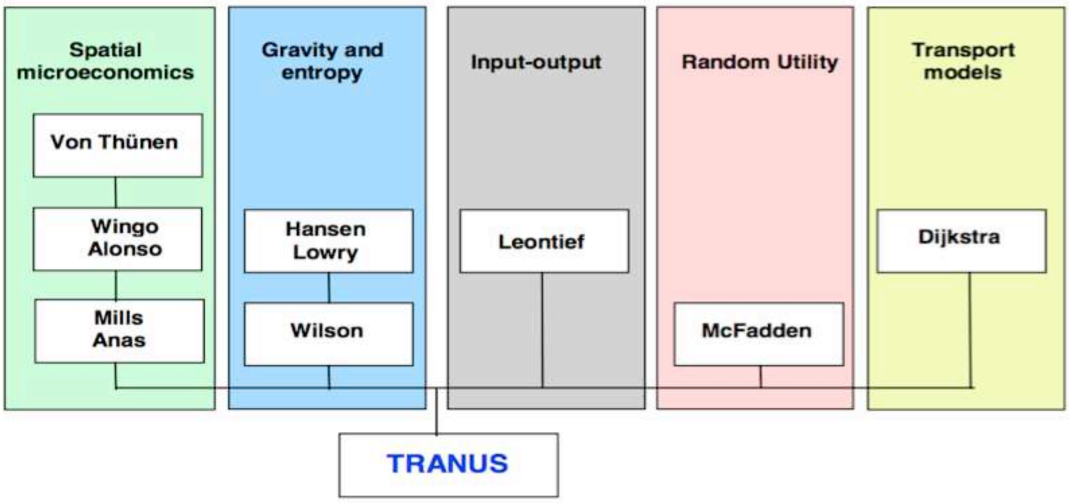

Fig. 11: The family tree of the Tranus system. (www.modelistica.com)

[42] TRANUS: Integrated Land Use and Transport Modeling System, General Description – Modelistica.

8.1. Main components of the modelling system

"The main components of the integrated land use and transport model are shown in Figure 12. The two main subsystems are presented: activities (land use) and transport. Within each subsystem a distinction is made between demand and supply elements that interact to generate a state of equilibrium.
The location and interaction of activities represent the demand side in the activities subsystem. Activities such as industries or households locate in specific places and interact with other activities to perform their functions. Activities also require land and floor space in order to perform their functions. Such spaces are provided by developers in the real estate market, thus representing the supply side.
Interaction between these two elements must lead to a state of equilibrium. If demand for space is greater than supply in a specific place, land rent will increase to reduce demand. Consequently, land rents or real estate prices are the variable elements that lead the system to a state of equilibrium.
In turn, the interaction between activities generate travel requirements. In the transport subsystem demand is represented by the need for travel, that may take the form of people traveling to their places of work or services, or goods that are produced in one place and consumed in another. A distinction must be made between the physical supply and the operative supply. The physical supply is made of roads, railways, maritime routes or any other relevant component. The operative supply is made of a set of transport operators that supply transport services, such as bus companies, truck companies, airlines, or even automobiles and pedestrians. The operative supply uses the physical supply to perform its functions.
Demand/supply equilibrium in the transport subsystem is achieved in two ways: prices and time. If demand becomes greater than supply for a particular service, the price of the service may increase, but it is mainly the travel time that increases to achieve equilibrium. For instance, if the number of boarding passengers for a bus service is greater than the spare capacity of the service, waiting time will increase. Similarly, if the number of vehicles along a road gets close to the capacity of the road, congestion is generated, thus increasing travel times.
The result of such equilibrium is synthesized in the concept of accessibility, that because it is a cost function, may also be called transport disutility".

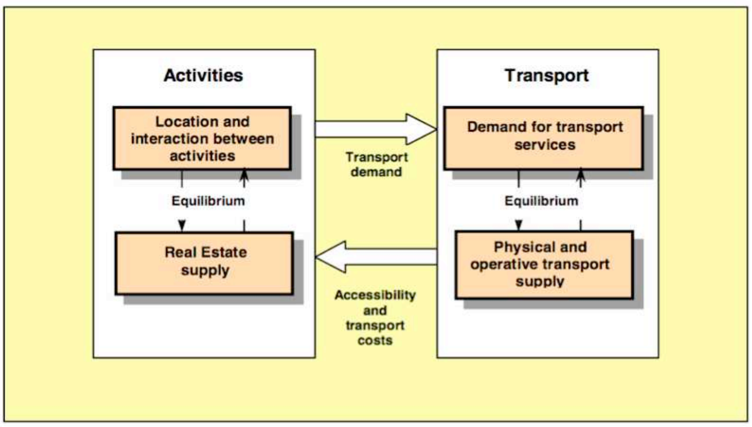

Fig. 12: Main elements of the land use-transport system. (www.modelistica.com)

"As may be seen, activities and transport are conceived as fully interrelated components with mutual dependencies. The interaction between activities gives rise

to travel demand, and transport equilibrium, in turn, affects activity location and interaction and the real estate system. The two main components, land use and transport, relate to each other in a dynamic way through time as shown in Figure 13, on the basis of discrete intervals t1, t2, t3, and so on. In this scheme, the interaction between activities in space generates functional flows, from which travel demand is derived. Demand is assigned to transport supply in the same time period. Transport demand/supply equilibrium determines accessibility between locations and influence economic flows. This feedback, however, does not occur in the same time period, but after a time-lag has elapsed. Consequently, accessibility in period t1 affects the distribution of flows in time period t2. As there are several inertia elements in the location of activities, changes in the transport system may take several time periods to fully consolidate. In this way, a change in the transport system, such as a new highway or a mass transit system, will have an immediate or short term effect in travel demand, but will only affect economic flows in the following time period. Changes in the activities system, such as increments in the production of some sectors or a new supply of buildings and land, will have an immediate effect on the transport system"[43].

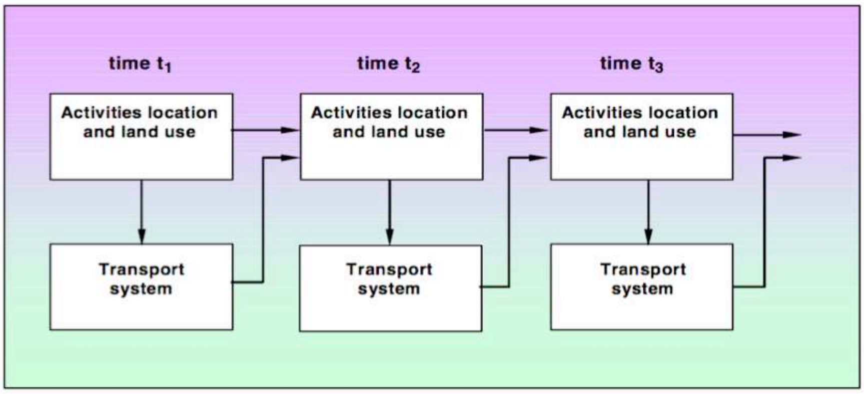

Fig. 13: Dynamic relationships between activities and transport. (www.modelistica.com)

"Figure 14 shows the main stages in the calculation sequence of the modelling process. The description begins with the activities system. The first stage is the location of final demand or exogenous production, followed by the location and interaction of induced production. One all activities have been located, the model checks for the demand/supply conditions in each location, especially land and floor space. If demand is not equal to supply, prices are adjusted accordingly, thus initiating an iterative process until equilibrium is reached. At the end the land use model outputs the location of activities, consumption of space and land rents. The model also outputs a set of origin-destination matrices with the economic flows by activity sector. These matrices are an input to the transport model.

Transport related calculations begin with a procedure called multipath search. The model reads the data on the transport network, transport services supply, and a number of additional parameters such as fares, operating costs, values of time, preferences, and so on. On this basis the model estimates several paths or travel options for each origin-destination pair. Each path is a combination between physical links, modes and transport services or routes. The next stage in the series of calculations, is the estimation of transport costs and disutilities for each intermodal

[43] TRANUS: Integrated Land Use and Transport Modeling System, General Description – Modelistica.

travel option or path. The number of trips is calculated as a function of the economic flows and an elastic function of transport disutilities. The number of trips thus generated may be split by mode, but this is an optional procedure because the multimodal assignment may do this. The purpose of multimodal assignment is to distribute travel demand among the several travel options or paths. The result is the number of person trips or freight assigned in each possible combination of physical link and route, as well as the number of vehicles. The final stage is capacity restriction, in which travel times are adjusted according to the relationship between demand and supply. As the number of vehicles in a link gets close to capacity, speeds are reduced, increasing travel time. A point may be reached in which queues are formed, generating delays not only in the congested link, but also spreading congestion upstream into incoming links. It is worth noting that congestion affects all vehicles sharing a link, such as passenger cars, trucks or transit vehicles. Capacity restriction is also applied to boarding passengers of public transport services. If the number of passengers gets close to the capacity of a specific route, the model increases waiting times, making the route less attractive in the following iteration. The model also calculates the time taken by transit vehicles at stops, as a function of the number of boarding or alighting passengers. Congestion and waiting time change the transport costs and disutilities that were calculated at the beginning. For this reason the calculation sequence returns to calculation of costs, repeating trip generation, (modal split) and assignment, generating an iterative process that ends when the system reaches equilibrium"[44].

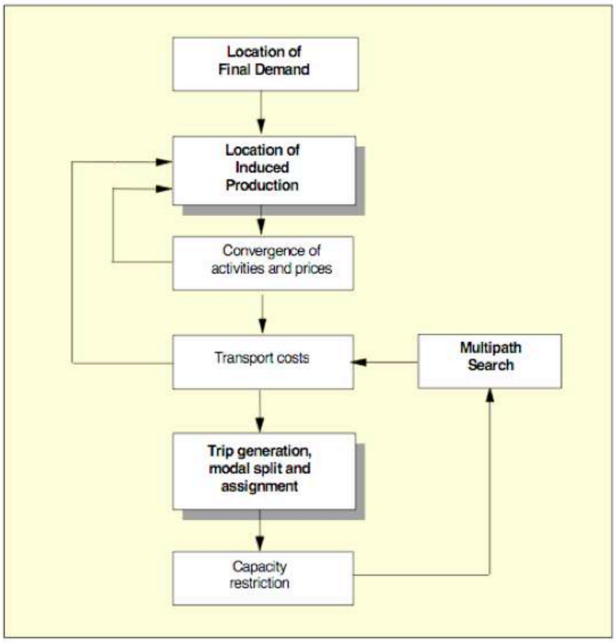

Fig. 14: Sequence of calculation in the Tranus system. (www.modelistica.com)

[44] Ibidem

9. Model to simulate the distribution of transport demand.

9.1. General description of the model

Based on the considerations previous reported, we proceed by presenting a simulation model of the transport system inherent the study area already described (the conurbation Cosenza - Rende and the close area of Savuto), developed using a software of integrated transport and land use modelling called Tranus.
The program Tranus provides a graphical interface that allows representing in a schematic way the network, and is controlled and managed by defining a set of parameters, which characterize its operation and the creation of different scenarios of study.
In particular in this case was developed and expanded a model created as part of a previous work of thesis, developed at the Department of Territorial Planning of University of Calabria[45], adding a further scenario to the model to consider the addition of a new tram-train service.
Then was made a simulation, for a peak hour, to estimate transport demand and the modal shift distribution, as a function of substantial changes to the transport system of this area and a strong increase in transit supply levels.
Then following the approach previously defined, study area was divided into nine Internal zones, corresponding to municipalities, and in four External zones, created to take into account also journeys originate outside the study area. Such an approach makes it possible to take into account all the different forms of mobility: domestic travel, crossing mobility (outside - outside) the exchange mobility in output (internal - external), the exchange mobility incoming (external-inside).

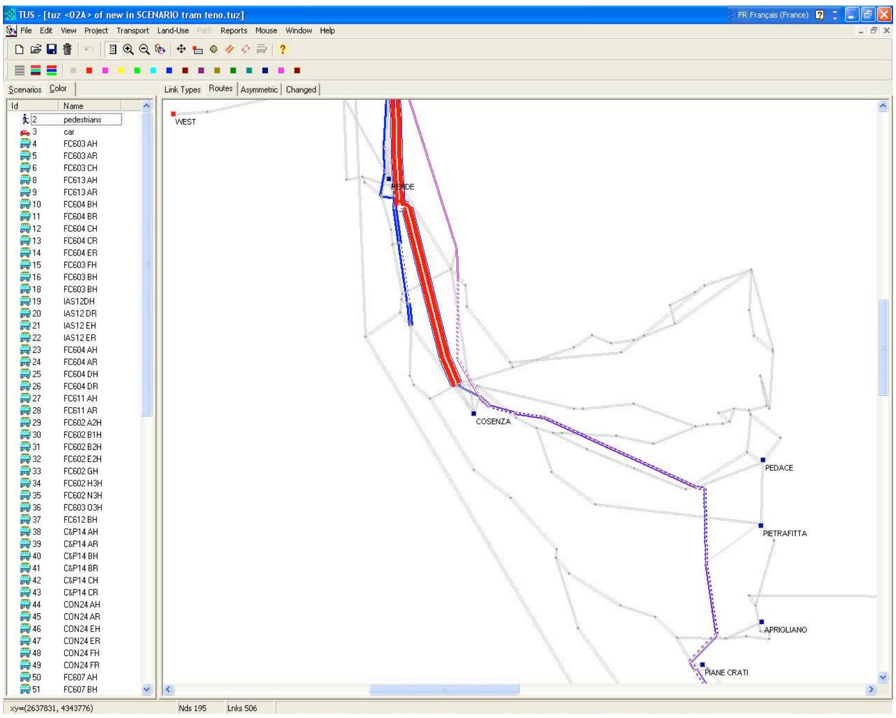

Fig. 15: Graphical interface of Tranus system with transport network.

[45] Marco Tucciarelli, 2009.

Internal Zones	External Zones
Aprigliano	*North*
Cosenza	*South*
Figline	*Est*
Mangone	*West*
Pedace	
Piane Crati	
Pietrafitta	
Rende	
Rogliano	
Santo Stefano di Rogliano	

Fig. 15: Internal and external zones created to set up the model.

9.2. Definition of the model

Tranus software allows the insertion of exogenously data concerning the activities system of the model area, and therefore proceeds to generate the corresponding O/D matrix. This is possible since for Tranus interactions between components of a given activities system, generates economic and functional flows that consequently results in transport demand.
In particular system of activities reported for this model consists of eight sectors: agriculture, industry, retail, wholesale, private, public services, education and health. For each of these sector were derived the numbers of employees, provided from the General Census of Population and Housing and the Services and Industry Census, products by Italian National Institute of Statistics (ISTAT) and dated 2001[46].
Once retrieved information related to the activities system, we proceeded to create the transport network and to define parameters required to run the model.
To import the network in the program it must be first created some databases that are used to define nodes, links, turns and routes that affect the studied network. These archives can be created using Geographic information system (GIS) programs or technical design programs such as Autocad; the latter option was used in this case to draw arcs and nodes of the network, then to exporting the data referring to the coordinates of the network on a normal spreadsheet.

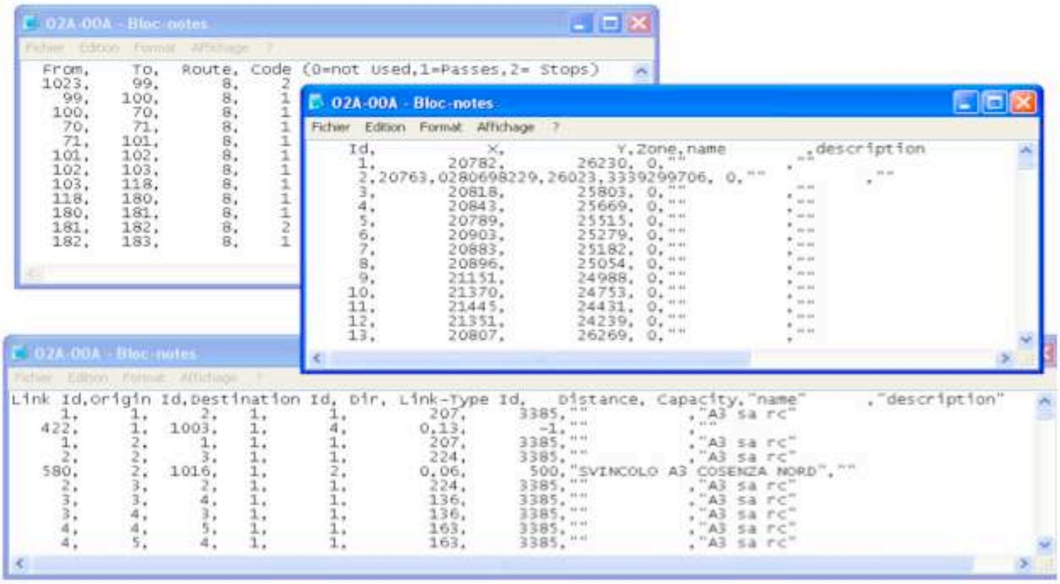

Fig. 16: Examples of database to create transport network in Tranus system.

[46] http://www.istat.it

After had imported network data on the graphical interface of the program, were defined functional characteristics of the network, starting from the definition of categories of users of the transportation system. In this study we considered a single category: Inhabitants. For that category was defined value of time, equal to € 1.39 / h, as estimated in a previous study[47].
In the Modes section it is possible to define type of transport modes operating in the network. In the present case were defined only one Transit typology, and was specified the value of the parameter Maximum Number of Path, which represents, for each movement from one zone to another of the network, the maximum number of paths that the model will calculate.
In the network may operate different operators (operating transport supply), and for each of them should be specified several features, whether if it be of operators non-motorized (pedestrian), whether motorized operators. In the present study were fixed the following transport operators: pedestrian, car, bus, train, tram, tram-train.
Information relating operators are divided into six sections: Basic Tariff, By Category, Energy, Cost and Stop. Energy Section is used to specify the costs of fuel, which is represented in Tranus system by a mathematical expression that defines relationship between consumption of fuel and speed of vehicles[48]. Values of minimum and maximum energy consumption reported in this study, entered into that equation, were obtained through formulas of the National Research Council (CNR)[49] created to calculate fuel consumption for vehicles[50] in suburban roads.
For each transit route loaded in the network, are finally fixed some parameters: minimum and maximum frequency of service; target occupancy parameter, which indicates the desired reached capacity by the operator (a low value of this parameter allows operators to easily vary their frequency); the option Follows Schedule, that if enabled indicates that the route follows a specific time and known by users.

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[47] D.C. Festa e A.Vitale, Simulazione di strategie per orientare la domanda di mobilità verso i modi collettivi.

[48] $CopEner$ = min + (max - min) exp (-x par Vel) x cost
where: $CopEner$ = operating cost of energy, min = minimum energy whit high speed and vehicles operating under optimal conditions, max = maximum power consumption whit speed close to zero; par = parameter adjusts the shape of the function; cost = cost of fuel.

[49] Vehicle fuel consumption in suburban roads: $C = [((v-v^0/a) + b) * (1 + c * i)]$
Where: C is fuel consumption in l/km; v is average speed of vehicles (km/h); I is slope express in %; v^0 speed corresponding to minimum consumption; a, experimental parameter for calibration; b, c are parameters of calibration of speed and slope

[50] Marco Tucciarelli, 2009.

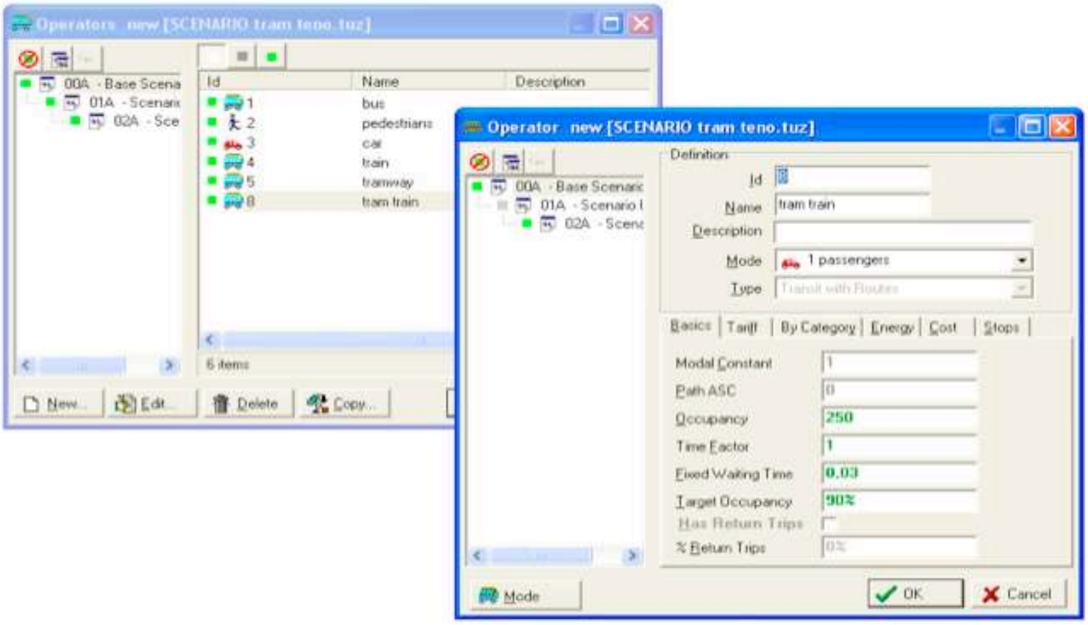

Fig. 17: Set up of transport operator's parameters in Tranus system.

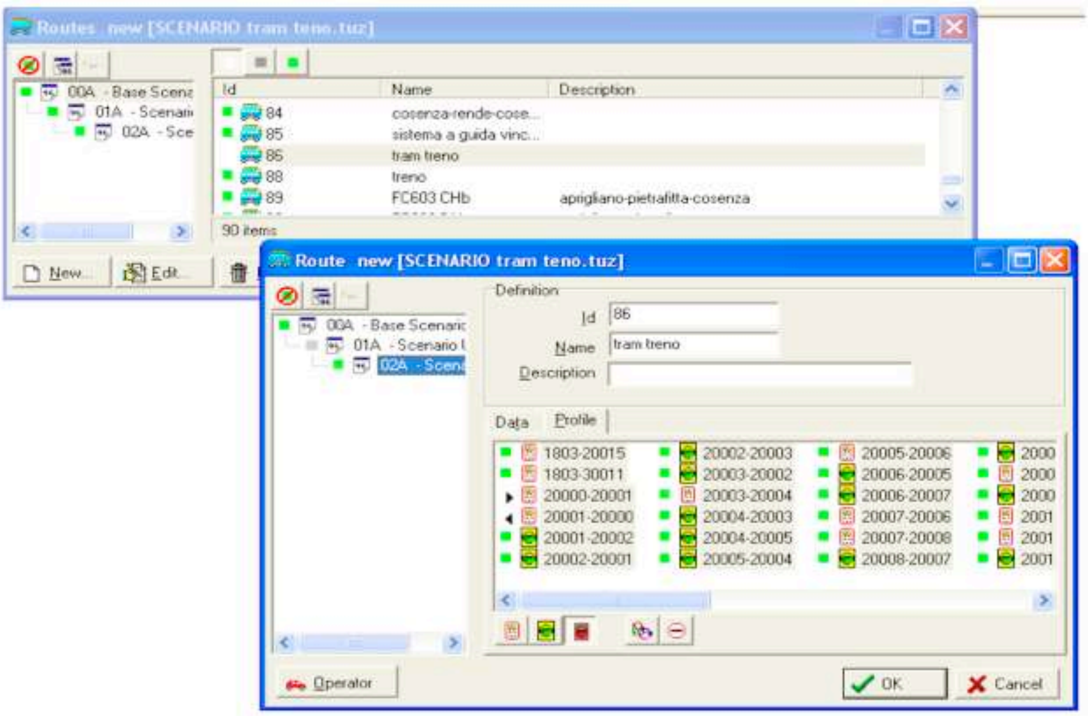

Fig. 18: Definition of a transit line itinerary in Tranus system.

9.3. Scenarios of the model

Three different scenarios were considered for this model, referred to the same study area. In particular was defined a Base Scenario representing the actual situation, in which are loaded all urban and suburban bus services, performing in the conurbation Cosenza - Rende and connecting area of Savuto.
Scenario One considers the starting of a tramway service connecting the centre of the city of Cosenza with campus of the University of Calabria.

Finally the last scenario (Scenario Two) considers the further increase in the amount of transit service, through the activation of a tram-train system, that starting from the rail station Rogliano, may come to the city centre rail station of Cosenza, and continue without disruptions, using the tramway network, to serve to the terminal of the University of Calabria.
For each of these scenarios has been calculated the percentage of modal split between car and various transit operators.

9.4. Running the model

Once loaded the data and defined characteristic parameters of the network, we proceeded to the execution of the Tranus program, for the calculation of results for each scenario. To obtain that, is necessary to activate the *Run* function, which allows performing in series all calculation modules that make up the program, and then returns as a result different types of files, containing all information pertaining to the model.
In our case it was used only in the module that refers to the transportation system, from which is generated, for each scenario, the o/d matrix of displacements, caused by the system of activities loaded exogenously in the model and values of transport demand modal split.
More specifically, once run the model, to proceed to the generation and extraction of results, is required to manually and individually run a series of programs provided by Tranus system. Among this list of programs in this case was used MATS to extract the o/d matrix generated by the system, and IMPTRA to extract all indicators related to the transport system that represented the objective of our research.

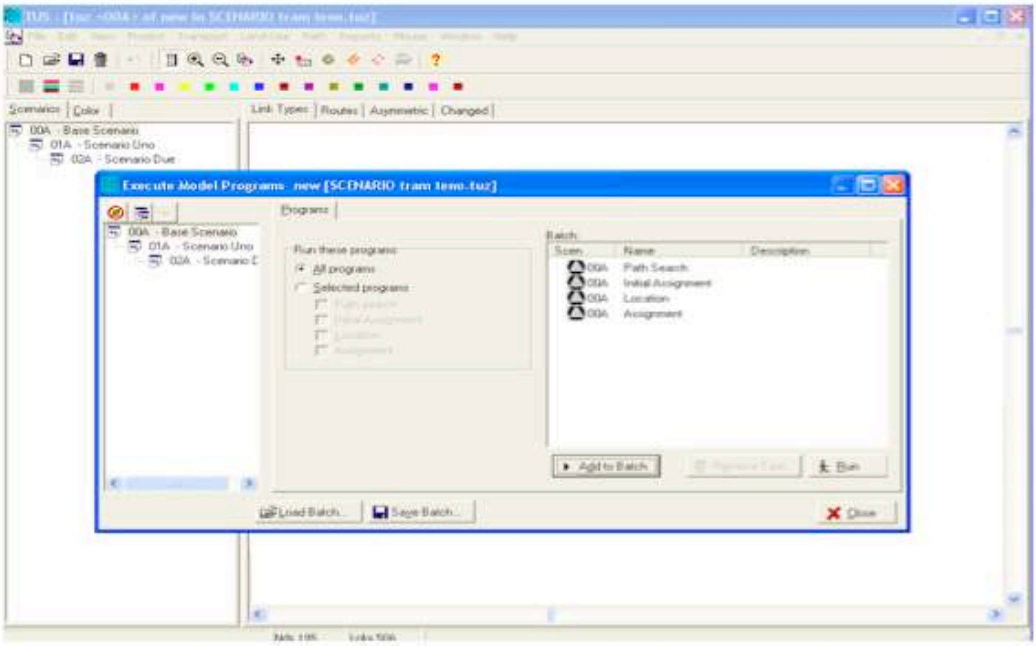

Fig. 19: Simulation execution by using the run function.

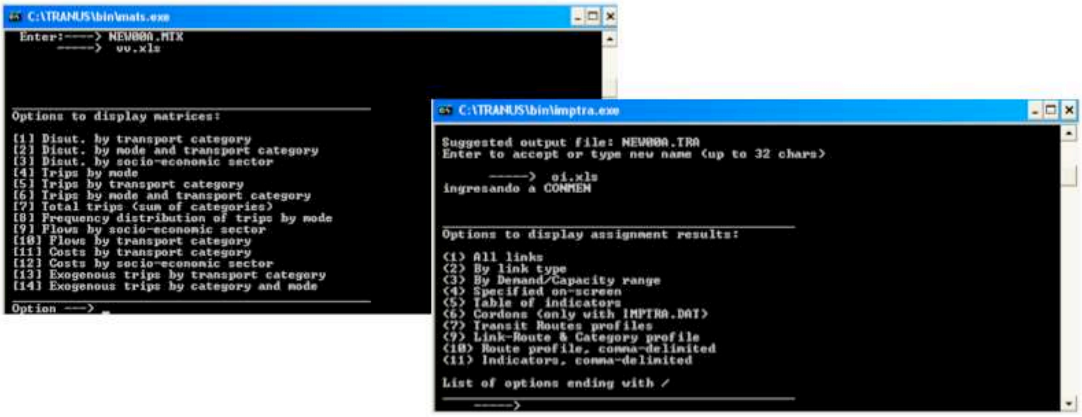

Fig. 20: Execution of calculation programs MATS and IMPTRA with reports options to display.

9.5. Generation and verification of results

As reference values to verify simulation results, were chosen those relating to the 14th General Census of Population and Housing made by ISTAT and dating 2001; in particular was used the O/D matrix related to the Province of Cosenza. Actually, as regards the present model, was considered only transport demand relative to systematic *home – work* journeys.

This choice is related to the fact that this type of trips represents the majority that occur, during peak hours, between the municipalities of Savuto area and Cosenza, Rende and the University of Calabria, and so it is sufficiently representative for the validity of the simulation.

To verify the acceptability between simulation outputs and observed measurements, on the basis of some literature examples of simulated O/D matrix calibrations[51], three different measures of goodness-of-fit were used to evaluate errors amplitude and results acceptability of the model[52].

The Percent error (PE) is normally applied either to a single pair of observed-simulated measurements or to aggregate network wide measures. For the present study it results of the order of 26,9 %. This difference, relative to the total number of displacements in the study area, is still acceptable considering the aim of the present study.

The normalized root mean square (RMSN) error and the Theil's coefficient were used as goodness-of-fit statistics to further calibrate the O/D matrix generated by the Tranus model. The first measure depends on the squared difference between simulated and observed measurements and penalizes large errors at a higher rate than small errors; while Theil's inequality coefficient is a measure of relative error.

Where N is the number of observations, Y^o_n and Y^s_n are an observation and the corresponding simulated value, respectively.

Theil's inequality coefficient U is bounded between 0 and 1 (where $U = 0$ implies perfect fit between observed and simulated measurements).

Concerning in particular the present case of study, calculations were made without considering intra-zonal flows, due both to the scale of the study area, that refers to a

51 *Jaume Barcelò EDITOR - Fundamentals of Traffic Simulation, Springer 2010.*

52 Yaron Hollander Æ Ronghui Liu - The principles of calibrating traffic micro simulation models, Springer 2008.

large conurbation of many municipalities end to the fact that Tranus doesn't supplies this kind of values.
Therefore normalized root mean square (RMSN) error measure results of the order of 1,6 and the Theil's inequality coefficient U of the order of 0,35.
These are values sufficiently acceptable for the present study and they represent a satisfying level of verification.

Percent Error (PE)

$$\frac{x_i - y_i}{y_i}$$

Root Mean Square Normalized Error (RMSN)

$$\text{RMSNE} = \frac{\sqrt{N \sum_{n=1}^{N} (Y_n^{\text{s}} - Y_n^{\text{o}})^2}}{\sum_{n=1}^{N} Y_n^{\text{o}}}$$

Theil's inequality coefficient U

$$U = \frac{\sqrt{\frac{1}{N} \sum_{n=1}^{N} (Y_n^{\text{s}} - Y_n^{\text{o}})^2}}{\sqrt{\frac{1}{N} \sum_{n=1}^{N} (Y_n^{\text{s}})^2} + \sqrt{\frac{1}{N} \sum_{n=1}^{N} (Y_n^{\text{o}})^2}}$$

MATRICE O/D ISTAT											
ZON	10001	10002	10003	10004	10005	10006	10007	10008	10009	10010	
	APRIGLIANO	COSENZA	FIGLINE VEGLI	MANGONE	PEDACE	PIANE CRATI	PIETRAFITTA	RENDE	ROGLIANO	SANTO STEFANO	TOT
*** APRIGLIANO	247	176	7	10	5	3	3	27	11	3	492
*** COSENZA	23	11720	47	52	13	14	11	1771	75	6	13732
*** FIGLINE VEGLI	0	32	0	0	0	0	1	6	0	0	39
*** MANGONE	3	90	59	160	0	1	0	27	31	8	379
*** PEDACE	4	158	0	0	173	0	7	21	3	0	366
*** PIANE CRATI	6	165	20	10	0	89	1	19	10	0	320
*** PIETRAFITTA	16	114	0	1	7	0	91	27	2	0	258
*** RENDE	7	3353	11	14	2	1	0	4256	24	0	7668
*** ROGLIANO	5	225	66	54	0	3	1	44	740	38	1176
*** SANTO STEFANO	6	77	18	31	0	0	0	14	38	105	289
TOT	317	16110	228	332	200	111	115	6212	934	160	24719

Fig. 21: O/D matrix from ISTAT for the home - work reason.

TOTAL TRIPS											
Iteration Area Pol Date/time simulation TRANUS Version											
16 NEW 00A 21- 2-2012 12:42											
ZON	10001	10002	10003	10004	10005	10006	10007	10008	10009	10010	
	APRIGLIANO	COSENZA	FIGLINE VEGLI	MANGONE	PEDACE	PIANE CRATI	PIETRAFITTA	RENDE	ROGLIANO	SANTO STEFANO	
*** APRIGLIANO	0.00	64.42	61.53	150.97	2.12	18.99	2.41	20.22	2.34	0.75	323.74
*** COSENZA	54.22	0.00	35.00	684.99	110.00	20.23	35.59	4884.04	70.58	17.39	5912.03
*** FIGLINE VEGLI	61.60	45.68	0.00	220.76	3.39	202.63	5.61	26.26	66.08	18.90	650.91
*** MANGONE	145.78	551.26	215.76	0.00	21.90	174.57	27.53	301.84	1068.99	387.87	2895.51
*** PEDACE	1.82	117.19	3.31	23.91	0.00	0.11	36.09	17.83	0.48	0.08	200.81
*** PIANE CRATI	19.63	34.58	202.92	180.84	0.31	0.00	0.32	17.60	4.80	3.31	464.31
*** PIETRAFITTA	2.37	40.05	5.55	28.81	36.23	0.16	0.00	24.95	0.36	0.09	138.57
*** RENDE	16.48	4923.08	22.00	361.99	14.96	10.85	22.15	0.00	31.23	7.29	5410.03
*** ROGLIANO	1.92	112.48	64.81	1092.71	0.85	3.18	0.48	56.00	0.00	138.06	1470.48
*** SANTO STEFANO	0.98	30.34	18.94	395.37	0.16	3.17	0.20	12.30	141.09	0.00	602.55
TOT	304.80	5919.08	629.82	3140.34	189.92	433.89	130.36	5361.03	1385.96	573.73	18068.94

Fig. 22: O/D matrix generated by Tranus system for home – work trips.

In succession of last paragraph are shown all results of simulation for three different scenarios.

9.6. Results interpretations

The proposed simulation model was applied to evaluate choice modal values trend, according to some changes made on the transport system and on transit supply levels.
Using the program Tranus was then performed a simulation for the pick hour, in order to estimate the evolution of transport demand, for house to work trips, and the modal split. Beyond scenario representing the current state, were considered two other scenarios characterized by the insertion of new collective transport services.
In particular, through this simulation, it was found by the model that the current situation is characterized by a high prevalence of car use, in the order of 90% of trips.
These results are largely adequate because exactly correspond to the real actual modal split situation. In the next scenario, in which it was placed in service a tram-way line, characterized by frequencies of service ranging from a minimum of 10 to a maximum of 12 passages per hour (equivalent to a maximum waiting time of 6 minutes and a minimum of 3 minutes), the modal share referring to private car becomes equal to 72.8%, that of transit respectively 5.9% for buses, 0.3% for the train and 21% for the tramway.
The last scenario takes into account the insertion of a tram-train system, integrated with tramway network; in this case the model provides as a result a percentage of modal split by car of 54.6% and equal to 45.4% for all transit services (bus, tram, train, tram-train).
Below are reported more detailed results of the simulation for each of three scenarios.

BASE SCENARIO	Actual Situation			
TOTAL TRIPS BY CATEGORY AND MODE				
Category	Modes....			
CatId	CatName	passengers	TOTAL	
1	inhabita	18069.	18069.	
	TOTAL	18069.	18069.	
STATISTICS BY TRANSPORT CATEGORY (TOTALS)				
CatId	CatName	Distance	TravTime	
1	inhabita	134721.	3317.	
STATISTICS BY TRANSPORT CATEGORY (AVERAGES)				
CatId	CatName	Distance	TravTime	
1	inhabita	7.46	0.18	
STATISTICS BY TRANSPORT OPERATOR				
OperId	OperName	Trips		% Modal Split
1	bus	1783		9,7
2	car	16576		89,7
3	train	114		0,6
	TOTAL	18473		

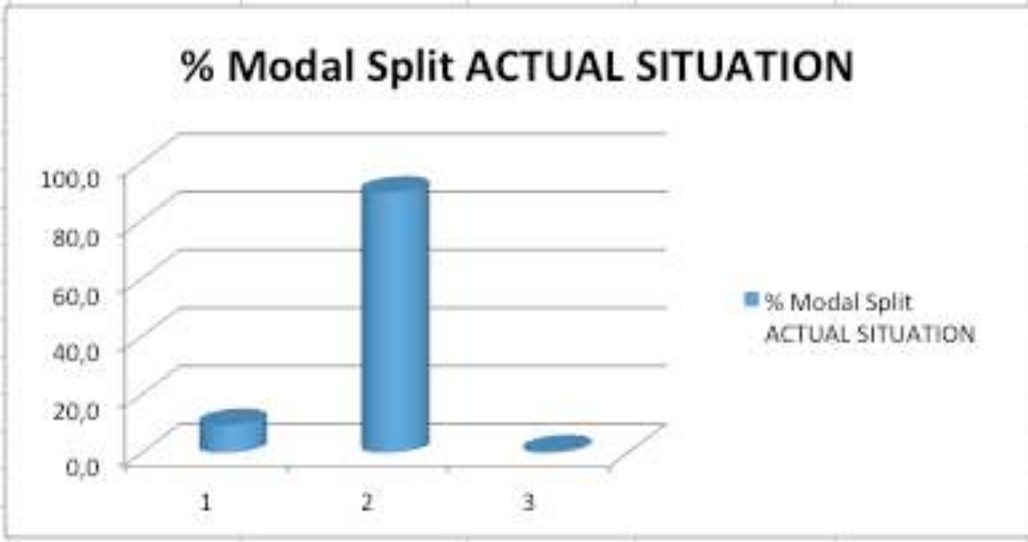

Fig. 23: Results for Base scenario, corresponding to actual situation.

SCENARIO 001 Tram-way				
TOTAL TRIPS BY CATEGORY AND MODE				
Category	Modes....			
CatId	CatName	passengers	TOTAL	
1	inhabita	17446.	17446.	
	TOTAL	17446.	17446.	
STATISTICS BY TRANSPORT CATEGORY (TOTALS)				
CatId	CatName	Distance	TravTime	
1	inhabita	111409.	3934.	
STATISTICS BY TRANSPORT CATEGORY (AVERAGES)				
CatId	CatName	Distance	TravTime	
1	inhabita	6.39	0.23	
STATISTICS BY TRANSPORT OPERATOR				
OperId	OperName	Trips		% Modal Split
1	bus	1044		5,9
2	car	12986		72,8
3	train	54		0,3
4	tram-way	3745		21,0
	TOTAL	17829		

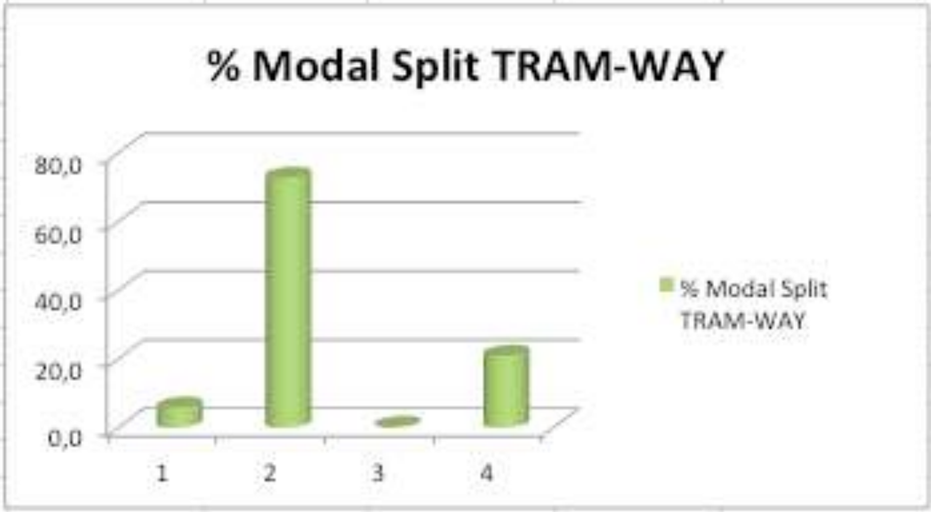

Fig. 24: Results for Scenario One, corresponding to implementation of the tramway system.

SCENARIO 002 Tram-train				
TOTAL TRIPS BY CATEGORY AND MODE				
Category	Modes....			
CatId	CatName	passengers	TOTAL	
1	inhabita	14711.	14711.	
	TOTAL	14711.	14711.	
STATISTICS BY TRANSPORT CATEGORY (TOTALS)				
CatId	CatName	Distance	TravTime	
1	inhabita	102982.	5006.	
STATISTICS BY TRANSPORT CATEGORY (AVERAGES)				
CatId	CatName	Distance	TravTime	
1	inhabita	7.00	0.34	
STATISTICS BY TRANSPORT OPERATOR				
OperId	OperName	Trips		% Modal Split
1	bus	2046		11,6
2	car	9628		54,6
3	train	41		0,2
4	sistema	4584		26,0
5	tram tre	1340		7,6
	TOTAL	17639		

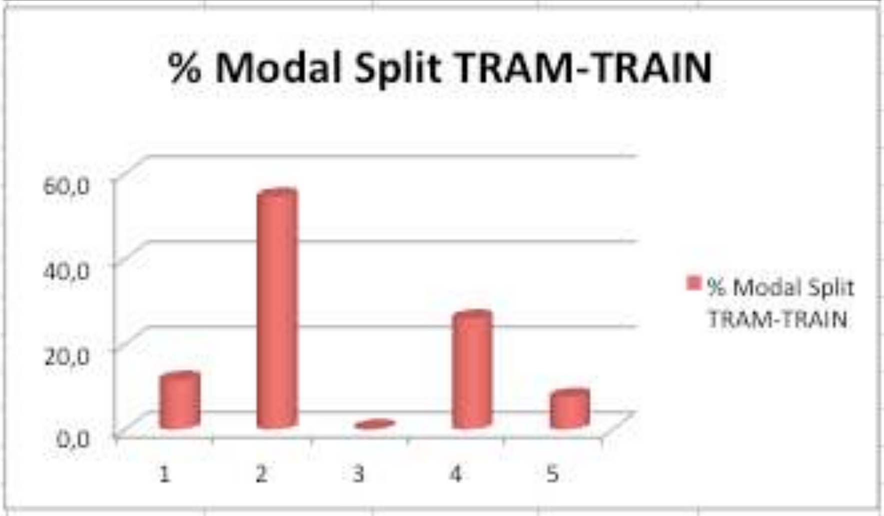

Fig. 25: Results for Scenario Two, corresponding to implementation of the tram-train system.

Conclusions

This study would be a contribution to decision making and planning of integration policies of land use and transport, for the territory of the province of Cosenza.
After introducing topic of interaction between land use and transport and the feedback loop that binds these issues, were described main methods and programs currently used for integrated transport and land use modelling and simulation.
Then was presented a territorial analysis of the study area, with particular attention to the definition of current levels of infrastructural facilities and public transport supply and to an analysis of the historical evolution of land use and land consumption.
As soon will be implemented a tramway system for urban area of Cosenza and Rende, which will heavily impact on the territorial system of the area; so were identified 6 strategic points along the planned track of the line, related to the most attractive areas of the conurbation.
On these points, corresponding to main stops and to the north and south terminals of the tramway, were centred discs of radius of 500 m (corresponding to the average distance travelled on foot in 10/15 minutes), defined *"Land use improvement discs"*. This operation was made in order to check levels of pedestrian accessibility to these areas, the urban renewal, regeneration and densification potential.
The idea is to promote and encourage the application of Transit Oriented Development policies, adapted to the socio-economic and spatial area; actually characterized by particular problems of lack of infrastructure and by strong car dependence. At this regard, two areas were identified that could be affected, as a priority, by such interventions. The first is the area of "Gergeri", an area of several acres, which registered degradation in the past and that even if very close to the city centre, is extremely isolated from the rest of the city.
The other area identified is that of the historic district of Cosenza. This is a neighbourhood of high historical and artistic value, which for decades had a steady and continuous phenomenon of de-population and of housing and social decay.
This neighbourhood is also accessible by foot from the tramway south terminal and this makes it an ideal place to promote regeneration policies of existing buildings to re-densification and to promote pedestrian mobility and transit use.
The simulation model created using the software Tranus, was applied to evaluate the evolution of transport demand modal split, according to three different scenarios.
The first scenario represents the current situation; the second scenario considers the commissioning of the tramway system between Cosenza, Rende and the University of Calabria; the third scenario considers the further implementation of a tram-train service between Rogliano and Cosenza, to be integrated with the railway network of Ferrovie della Calabria and with the urban tram-way.
This tram-train system represents an important opportunity to connect, through an efficient and quality transport system, municipalities of Savuto river valley, with Cosenza and the University of Calabria. A virtuous perspective view for enhance existing rail infrastructures in the province, such as the *Cosenza – Sibari* rail line, and promoting the development of a new regional railway system.
The results show a significant demand shift from private car to public transport, compared with the significant discrepancy related to car use present the current scenario (89.7%), reaching in the last scenario a substantially an equal ratio (54.6% car, public transport 45,4%).
In the present work was used only in the transport module of the Tranus software.

Actually Tranus allows to model and simulate even effects of such changes in transit supply, on residential sub-system, activities system and on land use.
This potential development of the created transport model, thanks to Tranus potentialities, represent real prospects and opportunities for deepening and expand of this research.
The objective is to estimate in advance effects of interventions proposed in this document, and thus to provide a complete and concrete support tool to the decision-making sphere and to public institutions involved in planning management of transport systems and of land use in that territory.

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