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Its aim was providing the audience with the basic problems, the latest developments and the ultimate strategies, by defining methods, models and procedures for the evaluation of each element of the transport network, particularly in the context of transportation planning.

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- Arc and Node Performance Estimation of each Transport Mode;
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6
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6

The accessibility produced by a local transit network

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Abstract

This research sets some accessibility indicators referred to a road intercity transit system for commuting users within a district. The aim is to make available some accessibility measure tools by which evaluate the effects, on this performance, of the actions designed for a local transit network.

Keywords: accessibility, measure tools, public transit

1. Introduction

Accessibility is one of the most important targets to pursue by the local transit supply as well as the one of the most required performances to this system in the weak transport demand areas. In fact, in not densely populated regions the local transit services, mostly or entirely produced by road vehicles, rarely lack in capacity; opposite in these environments we must arrive to an hard compromise between the achievement of fair levels of accessibility and the respect of the budget of the local governments subsiding public transit services. The measurement of the accessibility by reliable indicators is an effective support to set the actions to execute on the transport supply.

In this work we referred to a road intercity public transit network serving mostly commuting users within a district. We have built the accessibility indicators, taking into account what arises from international literature, with the purpose to disclose different aspects of the same performance. Particularly we built, besides more simple indicators based on the travel distance and time, also indicators allowing for the amount of the supplied services and for the generalized cost perceived by the user in the travel. Every indicator measures the accessibility produced by the public transit service related to the personal car one. The relation to the same performance produced by the private transport involves two important advantages: the first one lies in refining the accessibility produced by a bus service network from the effect of the routes supply amount and standards; this last ones can change from a zone to zone in the

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same analyzed area and are counted invariant; the second advantage lies in making the accessibility not an absolute parameter, and therefore with limited relevance, but a relative one to the choices in competition with themselves, that is the public transport and the personal one, and so connected to the modal spilt. Particularly the set indicators measure, for the road public transit related to the private one, the relative space and time accessibility, the relative supply accessibility and the relative generalized one, using properly adjusted formulas.

The indicators have been tested on a transit network of a district traffic area analyzing the most important origin – destination relations, within the observation area. These relations are the travels between the district capital and the gravitation centres of the district sub-areas and also between the municipalities included in every sub-area and their gravitation centre.

Since the executed tests highlighted a lower accessibility in some traffic sub-areas with respect to other ones and the likely factors of this difference, we successively changed the transport supply by targeted actions to reduce the arisen criticalities. Then we calculated again the accessibility by the set indicators to test for these last ones the responsiveness and the ability to measure the performance in question.

Finally we connected the accessibility measured by the different indicators to the modal split only for the work travels, to highlight the responsiveness of the users to this performance in choosing the transport vehicle.

After the present introduction, this paper reports a bibliographical analysis on the topic of the accessibility and its measure (section 2), a portrayal and discussion about the indicators adjusted by the authors (section 3), the performed experiment and the derived results (section 4) and finally, in the section 5, some concise remarks.

2. State of the art

Many researchers dealt with the accessibility mainly in '70s and '80s. Unfortunately they did not reach a one and exact definition of the accessibility because this attribute has various aspects, each of them closely related to the use and the context. Nonetheless common aspects to all accessibility concepts exist; these aspects can be summarized by the facility to arrive at every territorial activity from a remote place by a set transport system (Dalvi e Martin, 1976). The consequence of this definition is that every accessibility measure must appraise, by suitable parameters, the following elements:

1 location and socio-economics of the individual or of the individual homogeneous groups with reference to we want to measure the accessibility;

2 available opportunities in a given area to satisfy the different needs of the individual or of the individual homogeneous groups that we are considering;

3 type and attributes of the transport system connecting, across the space, the individual to the area activities.

The international research has produced a lot of indicators by which we can make functional the accessibility concept and measure its main aspects expressed by the above cited elements. This multiplicity is due basically to the different way to appraise the three fundamentals included in the accessibility concept and to the different weight that we attribute to them in the particular implementation.

So we can define the accessibility as:

a) Physical measure

b) Opportunity potential

c) Inverse function of the competition

d) Conjoint accessibility

e) Dynamic accessibility

f) Utility.

The accessibility as physical distance d_{ij} (from the origin *i* to the destination *j*) is expressed by the relation:

$$A_i = \sum_j d_{ij} \qquad (1)$$

and weighting the indicator on the present activity in *j* by settlement weight W_j of the place *j*, the (1) becomes:

$$A_i = \sum_j W_j * d_{ij} \qquad (2)$$

Obviously the same indicators can include the generalized cost c_{ij} of the travel between *i* and *j* instead of the simple space or time distance, so they will be certainly more representative of the travel charges.

The accessibility, so defined as direct function of the average distance or time or generalized cost, will indicate as lower value as the access facility is greater, in opposition to the most part of the indicators. The (1) indicator is frequently used in the graph theory with other topological measures like the number of the network nodes or links (Cattan, 1992), and also in the geographic researches and network analyses.

The accessibility as opportunity potential, that is as a measure of the access facility to opportunity within the area, is still the base concept more used by the researchers to appraise the indicators measuring it. The notion of accessibility is therefore related to the concepts of proximity, closeness and spatial interaction facility, opportunity potential for the interaction and faculty to contact activities (Weibull, 1980). Essentially the accessibility is considered an attribute of the opportunities set in a defined area aimed to a spatial interaction with them. These opportunities can be places of work, production centres, services of all sorts and every place drawing travels characterized by distance, transport mode, travel time or cost, supply capacity and quality, etc. The global accessibility of all opportunities of the *j* place is assessed by the amount of the activities measures located in the destination nodes *j* weighted on the impedance function referred to the connections *i-j* that is decreasing with the growth of the transport generalized cost and therefore expressed by the relation:

$$A_i = \sum_j D_j * f(c_{ij}) \qquad (2)$$

Where:

A_i = accessibility of the *i* place under consideration (origin of the possible travels);

D_j = measure of the activities (opportunities) located in the *j* destinations

$f(c_{ij})$ = impedance function referred to the *i-j* travel;

c_{ij} = generalized cost of the transport referred to the *i-j* travel.

The different formulation developed for the impedance function produced distinct expressions, like those due to Ingram (1971) and to Wilson (1974), all used a lot in the practical implementations because of the extreme simplicity of the (1) basic formula .

Other scholars, developing researches on this accessibility indicator, examined many works and so they showed a relation between accessibility and employees.

<u>The accessibility as an inverse function of the competition</u> is based on a calibration factor a_i, hence called competition factor (Wilson, 1982), related to a spatial interaction model with only one constraint. The indicator is expressed by the following formula:

$$A_i = \frac{1}{a_i} * \sum_j D_j * \exp(-\beta * c_{ij}) \qquad (4)$$

Where:

a_i = competition factor (to calibrate)

D_j = attractive capacity of *j* (for instance, amount of employees or of local units or gross domestic product - GDP, etc.)

β = calibration factor

c_{ij} = generalized cost of the travel from *i* to j

The (4) formula is formally identical to the (2) one (except for the explicit form of the impedance function) but the first one involves a specific calibration of the competition factor. The accessibility expressed by such indicator can also be explained as a measure of the benefit produced by the place attractive capacity, so as Wilson (1970) and Williams (1977) highlighted.

The notion of <u>conjoint accessibility</u> derives from both the models simulating the users sequential decision-making process in the serial travels and the spatial interaction models by which an accessibility double function derives (Fotheringham, 1983). Particularly, in a two phases decision-making process, related to two destinations *j* and *k*, the conjoint accessibility is:

$$A_i = \sum_j A_j * D_j * \exp(-\beta * c_{ij}) \qquad (5)$$

where $A_j = \sum_k D_k * \exp(-\gamma * c_{jk})$

The (5) formula represents the accessibility of the *i* place, for the travels with destination in the *j* place, expressed by the accessibility A_j referred to the travels from *j* to the destinations *k*.

The dynamic accessibility at the present is not enough expanded in international literature because of theoretical and computational intricacy caused by both the dynamic features of the methodological tools used and the dynamic calibration of the real data. The dynamic – entropic approach followed by Nijkamp e Reggiani (1988) is interesting; they produced a dynamic form for a spatial interaction model and consequently the related dynamic accessibility factors that are equivalent to the ones derived by the static approach.

The dynamic accessibility indicator is expressed as follows:

$$A_i = \frac{1}{a_i^*} \qquad (6)$$

Where $a*_i$ is the dynamic calibration factor that is:

$$a_i^* = \frac{1}{\sum_j b_j^* * D_j * \exp(-\beta * c_{ij})} \qquad \text{with} \qquad b_j^* = b_j * g_j$$

a_i and b_j are the calibration factors of the double constrained spatial interaction model with all variables depending on the time; g_j is a dynamic accessibility factor.

The implementation of the customer-surplus theory included in the microeconomic theory allows to measure the accessibility as utility (Ben-Akiva e Lerman, 1979). Making use further of discrete-choice theory, we assume that the user chooses, among a series of travel options, the one maximizing its utility. Therefore the accessibility attributed by the *k* user to the origin place *i* is defined as the utility associated to the choose option by the individual k, that is the maximum utility value related to the available options, and so:

$$A_i^k = \max(U_j^k)$$

Since U^k_j is different from an individual to another one, we consider the expected value of the maximum utility (expectation E) and then:

$$A_i^k = E\left[max\left(U_j^k\right)\right] \qquad (7)$$

and, should the random residuals be distributed under the Gumbel distribution, we make explicit the (7) formula by this one:

$$A_i^k = \ln \sum_j \exp\left(V_j^k\right) \qquad (8)$$

where V^k_j is the regular rate of the systematic utility U^k_j perceived by the *k* user.

By the (8) formula the accessibility measure is brought to the specification of the V^k_j systematic utility analytical expression and of its calibration.

3. The set indicators

International bibliography shows a prevailing use of accessibility indicators based on the opportunity potential or on physical measures. In the real implementations the choice of the most suitable indicator is influenced by the accessibility aspects that we want to study and then by the analysis purposes and also by the faculty to appraise the parameters of which the indicator is function.

The indicators set in this research fall into two types: those ones based on travel space and time physical measures and the others based on the utility. The choice is justified by the need to measure the performances of the transit service both in terms of route length and commercial speed and in terms of supplied rides amount and travel time realized by each ride.

The indicators measuring space and time distances of the connections are related to the same value allowed by the personal car in the travels between the same origins and destinations. We think in fact that the accessibility related to the car, which is the transport mode in direct competition with the public transit service, is more useful than the absolute accessibility. Particularly, to obtain indicators with values growing in accord to the improvement of the considered transport system performances, we have placed on the numerator the specific performance allowed by the private vehicle and on the denominator that one supplied by the public service. So the indicator varies from the minimum value trending to zero when the public transit routes and times trends to infinity, to the maximum value trending to 1 when travel routes and times supplied by the service are the same of the personal car; logically we excluded the possibility that the public transit can hit higher performances than the private one because they are impossible by road collective vehicles that we considered in this work.

Therefore the set physical accessibility indicators are:

- Relative space accessibility

$$A_{ij}^{SR} = S_{ij}^{car} / S_{ij}^{bus}$$

with:

S_{ij}^{car} = minimum space route by car, between *i* and *j,* allowed by the road network (km)

S_{ij}^{bus} = minimum space route allowed by bus between *i* and *j* (km)

- Relative time accessibility

$$A_{ij}^{TR} = T_{ij}^{car} / T_{ij}^{bus}$$

with:

T_{ij}^{car} = minimum travel time by car between *i* and *j* (minutes)

T_{ij}^{bus} = minimum travel time by bus between *i* and *j* (minutes).

The accessibility indicators based on the utility takes into account the contribution of more rides on the same transport line increasing the connections, not because they reduce the travel time, but because they bring the supply close to the demand needs and so they increase the possibility for the user to have a ride fitting his specific time requirements.

- The supply accessibility A^{O}_{ij} is a measure of the service utility on the considered connection based on the rides amount and on the commercial speed of each one. The indicator is the sum of all supplied rides, each one weighted on the difference between its travel time and the minimum travel time allowed, from *i* to *j*, by the most rapid ride. This weight is really a measure of each ride utility based on its speed. The supply accessibility is represented by this formula:

$$A^{O}_{ij} = \sum_{r} \exp\left[K_p * \left(T^{bus}_{min.ij} - T^{bus}_{r.ij} \right) \Big/ T^{bus}_{min.ij} \right]$$

where the summation notation is extended to all *r* bus rides supplied between *i* and *j*, and also:

$T^{bus}_{min.ij}$ = travel time between *i* and *j* allowed by the most rapid ride

$T^{bus}_{r.ij}$ = travel time between *i* and *j* allowed by the *r* ride

Kp = weight ampliative or reductive factor (usually we can assume it = 1)

$\exp\left[K_p * \left(T^{bus}_{min.ij} - T^{bus}_{r.ij} \right) \Big/ T^{bus}_{min.ij} \right]$ is therefore just the weight of the *r* ride and its value is 1 (the higher value) for the more rapid ride (that one allowing $T^{min}_{.ij}$) and smaller values for all others.

Since an absolute measure of the rides utility based on their speed is helpful only to compare different connections but loses significance if absolute and taking into account that the choice of the public or private vehicle depends on the performance of these options, we defined also a relative supply accessibility relating the supply accessibility produced by the public transit, as above, to the same one allowed by the personal car.

As obvious, the comparison between the utility produced by a limited amount of transit rides on a traffic connection and that one resulting from the personal car use is rather difficult. This last vehicle, in fact, is characterized by an unlimited availability in the time and therefore it is equivalent to an infinite amount of rides. Nonetheless it’s possible reduce this infinite amount of rides allowed by the personal car to a finite amount, even if it’s high, taking into account that the car user perceives this availability inside finite time intervals on decrease or in addition to a fixed time. Essentially the car user notes the freedom, associate to the car availability, of choosing the departure time only if the difference between its required departure time and that one of the of the public transit is a remarkable rate of the travel time. That is, if the public service departure time is not noticeable different from that one desired by the user, he will perceive as substantially concurrent the real and the desired departure time and therefore he will believe the public transit accurately matching his time requirements. Hence the full car availability is comparable to a finite amount of public transit rides (virtual rides amount of the personal car $N_{CV.ij}^{car}$) given by:

$$N_{CV.ij}^{car} = 2 * T_C / \left(T_{ij}^{car} * F_v\right)$$

where:

Tc is a corresponding time that is the span to realize the outward and return travel and spend in the destination site the necessary time for the activities to carry out; it matches the span within, according to the activities to carry out, the outward and return travel must end; it can be assumed, for the analyzed mobility, equivalent to 10 hours;

T_{ij}^{auto} is the travel time by car between *i* and *j*;

Fv is the time rate longer on the car user perceives the departure time difference between the supplied service and the desired one which is possible only by his own car; an acceptable value for this parameter can be 0,30.

After we have calculated the amount of the virtual rides corresponding to the private vehicle availability we can define another accessibility indicator.

- <u>Relative supply accessibility</u> A_{ij}^{OR}:

$$A_{ij}^{OR} = A_{ij}^{O} / N_{CV.ij}^{car}$$

This indicator, made explicit, becomes:

$$A_{ij}^{OR} = \frac{\sum_r exp\left[K_p * \left(T_{min.ij}^{bus} - T_{r.ij}^{bus}\right) / T_{min.ij}^{bus}\right]}{2 * T_C / \left(T_{ij}^{car} * F_v\right)}$$

If we still make use of the notion of accessibility as utility, we can build another indicator based on the transport generalized cost perceived by the user for the public transport and for the private one. This parameter, as known, is not only the monetary cost but also the time, risk and stress cost sustained by the passenger and therefore it is complementary to the utility closely associate to the travel and then inversely proportional to this utility. The generalized cost in its more simple expression includes the only variables charge P_{ij} e and time T_{ij} expended in the travel from i to j; it is indicated as follows:

$$C_{ij} = P_{ij} + \lambda_t * T_{ij}$$

where λ_t is the perceived monetary value of a time unit spent in the travel.

- Relative generalized accessibility A_{ij}^{GR} :

$$A_{ij}^{GR} = C_{ij}^{car} / C_{ij}^{bus}$$

that, made explicit, becomes:

$$A_{ij}^{GR} = \frac{c_{km}^{car} * S_{ij}^{car} + \lambda_t * T_{ij}^{car}}{Tar_{ij}^{bus} + \lambda_t * \left(T_{ij}^{bus} + Ta_{ij}^{bus}\right)}$$

with the following simbols:

c_{km}^{car} = perceived cost of the personal car per kilometre

Tar_{ij}^{bus} = public transit fare on the connection *i-j*

λ_t = monetary value of the time unit

T_{ij}^{car} = travel time by car form *i* to *j*

T_{ij}^{bus} = travel time by bus form *i* to *j*

Ta_{ij}^{bus} = nominal waiting time associate to the public transit use.

This last parameter, more than the time spent at the bus stop that is usually very small for the transport services at fixed time, is for most of the time spent at the destination waiting the starting time of own activity and/or of the return ride at the end of own activity. We can assume this value equal to an half of the average time interval between a ride and the later one and therefore:

$$Ta_{ij}^{bus} = T_C / \left(2 * N_{C.ij}^{bus}\right)$$

with:

T_C = corresponding time as above specified

$N_{C.ij}^{bus}$ = amount of the daily rides of the service between *i* and *j*

Thus the expression of the relative generalized accessibility becomes:

$$A_{ij}^{GR} = \frac{c_{km}^{car} * S_{ij}^{car} + \lambda_t * T_{ij}^{car}}{Tar_{ij}^{bus} + \lambda_t * \left[T_{ij}^{bus} + T_C \big/ \left(2 * N_{C.ij}^{bus}\right) \right]}$$

4. The experiment

4.1 The analyzed system

The area selected for the test is the district of Potenza in the South of Italy. It has different features for economy, orography and infrastructures: it includes internal zones, largely mountainous, that have low infrastructural accessibility, limited economic development and relative depopulation and more developed ones typified by various infrastructures and by manufacture, food and oil extractive industries (Vulture-Melfese-Bradano-Val d'Agri), and also by services sector (metropolitan area of Potenza). As well the more developed zones reveal gaps in the road network: there is no highway apart from the highway link " Potenza – Sicignano" and the small part of the A3 Highway in the Lagonegro zone; the higher level of service roads are the valley line roads (SS.407 Basentana – SS.598 fondovalle Agri – SS.653 fondovalle Sinni – SS.585 fondovalle Noce) and the main road SS. 658 (Potenza-Melfi)

The distribution of the local mobility for study and work within the traffic areas of the district allows to identify 5 traffic sub-area (Potenza, Melfi, Lagonegro, Val d'Agri e Senise). This is a zoning based on the attractive capacity of the greatest towns towards the nearby municipalities for some type of travels. It's manifest that this schematization is not representative of the whole travels within every traffic sub-area and between the sub-areas but it is enough effective for the systematic travels.

The traffic data of the systematic generated / attracted intercity flows for work and study within the traffic area (ISTAT 2001) point out that the whole district mostly moves towards the district capital and the municipality of Melfi; these last ones together attract the 65% of all daily inside travels of the district (Potenza 50% - Melfi 15%). The modal split shows a dominance of the private vehicle with a popularity rating of 62,7%. With reference to the travel purpose, the data shows that the public vehicle is preferred by the students ("constraint" users) in the 70,3% of the study purposed travels, whereas only the 29,8% of the work purposed travel uses the public mean. The growth of the intercity mobility registered in the period

1991 – 2001 affected mainly the private mean use (+33,3% with respect to the 1991) (ISTAT 1991); the increased motorization index changed from 3.6 vehicles on 10 citizens in the 1991 to 4.9 vehicles on 10 citizens in the 2001 (ACI 1991 - 2001) is certainly one of the causes of the enhanced use of the personal car.

The local public transit service in the Potenza district can be grouped on the basis of the prevailing type of bus lines; particularly we can distinguish five categories of service:

- *interregional*, that is connecting the traffic area to Salerno, Fisciano (SA) and Naples;
- *(for) factory workers,* addressed to the industrial zone of S. Nicola di Melfi;
- (for) *farm workers*, towards the farm lands (area of Metaponto, Sele valley, Sibari plain);
- *generic*, that is not specifically aimed to the connections for students;
- *school and mixed*, including the lines mainly with school rides and not targeted lines.

The trend of the supplied services is increasing, in fact in the period 2000 – 2007 we recorded an increase of the haul of the 28% (from 13.380.000 to 17.140.000 bus x km / year). The category analysis underlines that the users show their approval (by an high vehicle loading index) for the interregional connections, for those ones addressed to the industrial zone of Melfi and for the entirely school connections; all these ones are targeted services with a well-established demand as distinct from mixed and farm-workers services.

4.2 The present state

To underline the different accessibility in the traffic sub-areas and its consequences on the public / private modal split we calculated the indicators defined in the previous section, that is:

- relative space accessibility A^{sr}_{ij};
- relative time accessibility A^{tr}_{ij};
- relative supply accessibility A^{or}_{ij};
- relative generalized accessibility A^{gr}_{ij}.

The computation practice for the relative space and time accessibility needed the appraisal of the travel time and distance between the centre of each traffic sub-area (Potenza, Melfi, Moliterno-

Marsicovetere, Lagonegro, Senise) and the centres of all municipalities gravitating around it. For the public transit we examined the connection realized by the present service timetable, to file time and distance of every single origin – destination connection and to calculate its average value. For the private vehicle we found, related to the same connections, the faster route by car adopting a medium travel speed equal to 25 km/h on urban roads, 55 km/h on district roads, 65 km/h on main roads and 120 km/h on the highways lengths.

We calculated the relative supply accessibility as a ratio between the supply accessibility of the public vehicle and that one of the personal car. We obtained the first one by classifying the travel times (drawn out from the departure and arrive timetable) of all rides addressed from all municipalities to the centres of the traffic sub-area and comparing these ones with the travel time of the faster ride; we assessed the equivalent supply accessibility of the personal car on the basis of the car minimum travel times on the origin –destination route (with reference to the formulas in the 3 section).

The relative generalized accessibility, described as the ratio between the travel cost of private and public vehicle, was calculated for the public transit on the basis of the present fare, of the travel time and of the nominal waiting time; while, for the personal car we assumed a cost of 0,30 €/km (inclusive of fuel, insurance, taxes and car depreciation); the monetary value of the time unit λ_t (for the user of the public and the private vehicle) was drawn out as a ratio between a medium wage of 14.400,00 €/year and a amount of worked hours in one year equal to 1560.

Table 1 reports the values of the estimated indicators.

Table 1: accessibility in the traffic sub-areas (at the present)

	A_{ij}^{TR}	A_{ij}^{SR}	A_{ij}^{OR}	A_{ij}^{GR}
sub-area of Potenza	0,51	0,84	0,11	0,50
sub-area of Lagonegro	0,59	0,97	0,07	0,66
sub-area of Melfi	0,63	0,84	0,15	0,67
sub-area of Senise	0,57	0,79	0,05	0,46
sub-area of Val d'Agri	0,63	0,87	0,045	0,69
average in the sub-areas	0,58	0,86	0,09	0,60
centres of sub-area and Potenza	0,64	0,90	0,22	1,30

The traffic sub-areas included in the district traffic area have different accessibilities: the largest criticisms with reference to the district average values of the built indicators are recorded in the sub-areas of

Senise and Potenza even if the causes of this phenomenon are different in the two sub-areas in question.

In the traffic sub-area of Potenza the lower accessibility, mainly the time one, has the most important source in the noticeable slowdown of the buses in the routes inside the district capital because of the slow urban traffic in the peak hours; the negative weight on this accessibility of the travels towards Potenza from the bordering municipalities, realized totally or partially on limited standard roads, is although not irrelevant. The criticism observed in the traffic sub-area of Senise is instead due to an inside network of the public transit service favouring the direct connections among the served centres to the detriment of the celerity, in addition to an unfavourable mix of towns settlement and road network leaving many internal travels towards the centre of the traffic sub-area out of the main road which is the SS.653 Sinnica.

4.3 The proposals and their effects

Taking into account what came to light by the analysis of the present state, we built different action scenarios for the two sub-areas.

For Potenza we studied the possibility to integrate the intercity bus lines entering the capital with the urban public transit, entrusting this last one, and particularly the urban FAL railway, with the delivery inside the city of the penetration travels only for those destinations directly served by the train.

So, the suggested solutions are aimed to reduce the intercity bus routes along the capital road network, taking advantage of the urban length of the FAL railway. Especially we set the road–rail exchange nodes in the train stop of viale Marconi (in the RFI station square), of Macchia Romana and of borgo S. Rocco; then we placed here the intercity bus terminals entering the city and we entrusted the present FAL urban service, if possible developed in terms of capacity and frequency, with the task to deliver the passengers to their destinations served by rail.

Table 2: Haul of the intercity public transit services converging on Potenza interested to the integration with the railway: present and designed state

	Present haul (busxkm/year)	**designed haul** (busxkm/year)	**Difference** (%)
NORTH gateway	120.780	95.862	-20,6%
SOUTH and EAST gateways	178.803	140.755	-21,3%
Total	299.583	236.616	-21,0%

Therefore we had an average saving of 4 minutes for every passenger, in addition to a greater reliability of the service that is not more conditioned by slowdown and delays associate to the district capital road congestion. This result, specially appreciable in the shorter travels from the near towns that are largely the most numerous, is still more important because it turns out in an advantage for the public transport towards the private one and, as a consequence, in the growing of its attractive capacity. From the managerial point of view this action scenario involves a reduction in the intercity buses use assessed about 15 minutes for every ride with a total saving on the haul of about 63.000 bus x km / year; the set actions produce a gain in the relative time accessibility of the sub-area equal to 6% (from 0,51 to 0,54), in the space one of 2% (from 0,84 to 0,86) and in the supply accessibility of 10% (from 0,11 to 0,12).

In the Senise traffic sub-area instead we designed again some lines trying, where it is possible, to detour the connections on the higher standard roads to have an haul saving that is been employed to increase the amount of the rides on some routes. Specifically we adjusted different actions scenarios involving the same haul amount or a minimal increase.

The choice of the bus exchange on the length of the main roads in the sub-area of Senise allowed to reduce the travels on the internal road network; this last one, because of its larger tortuousness, influences negatively the bus speed and therefore the travel time. The sensible increase of the relative supply accessibility in this sub-area (+40%) depending on the rise of the service commercial speed; this rise is caused from the bus lines exchange, thanks to them the buses travel mostly on the main roads with speed comparable to the private vehicles one.

The diagrams of figures 1 and 2 report the values of the accessibility indicators respectively for the sub-areas of Potenza and Senise, at the present state and after the actions designed for the public transit supply within the District.

Fig. 1: Relative accessibility in the sub-area of Potenza at the present and designed state

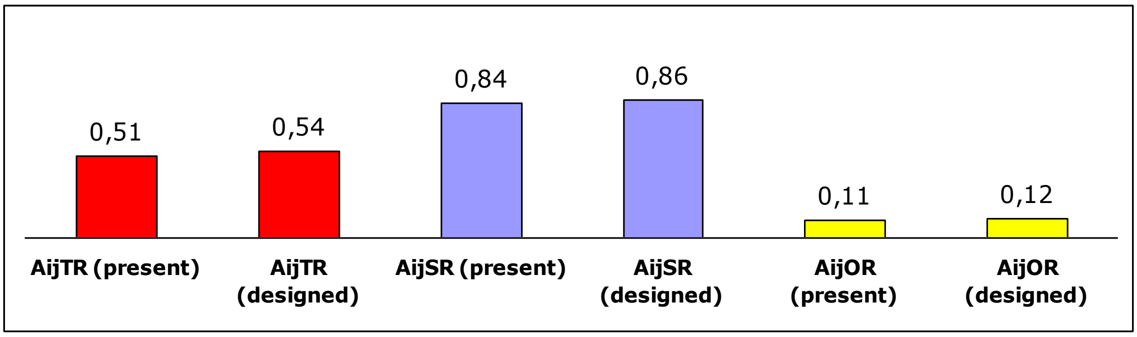
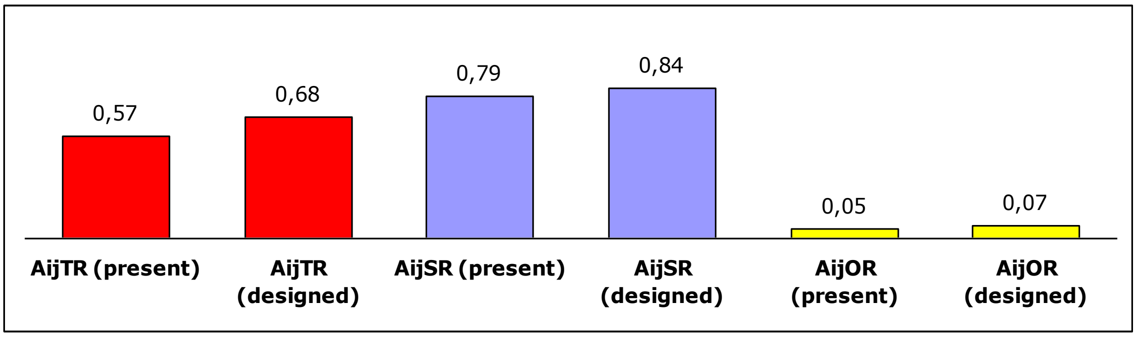


Fig. 2: Relative accessibility in the sub-area of Senise at the present and designed state



The vehicle choice is certainly influenced by the relative accessibility. In order to highlight the link between this last one (independent variable) and the modal split (dependent variable) we looked for a correlation comparing the data base of the public / private modal split in the 2001 (ISTAT 2001), only for the work purposed travels (demand that probably can opt for the car as an alternative to the public transit), and the relative accessibility of the five traffic sub-area in the Potenza district.

Looking for the aforesaid correlations we need to adopt a weight to homogenize territories (traffic sub-areas) with different length of internal connections. That because the larger distance of the travel make, other things being equal, the public vehicle more desirable for the not constraint users which enjoy by it an economic and travel stress saving. Therefore the indicators of the relative space and time accessibility are been multiplied for a weight which is the ratio between the average distance of the internal sub-area connections and the average value of the same distance among the sub-areas.

Table 3: simple and weighted on the distance accessibility indicators (present state)

	A_{ij}^{TR}	A_{ij}^{SR}	A_{ij}^{OR}	A_{ij}^{GR}	d_i	d_i/d_{mi}	A_{ij}^{TR} x (di/dmi)	A_{ij}^{SR} x (di/dmi)	A_{ij}^{OR} x (di/dmi)	A_{ij}^{GR} x(di/dmi)
Sub-area of Potenza	0,51	0,84	0,11	0,50	38	1,10	0,56	0,92	0,12	0,55
Sub-area of Lagonegro	0,59	0,97	0,07	0,66	32	0,92	0,55	0,90	0,06	0,61
Sub-area of Melfi	0,63	0,84	0,15	0,67	43	1,24	0,79	1,04	0,19	0,83
Sub-area of Senise	0,57	0,79	0,05	0,46	29	0,84	0,47	0,66	0,04	0,39
Sub-area of Val d'Agri	0,63	0,87	0,045	0,69	31	0,90	0,56	0,78	0,04	0,62

We obtained the more significant correlation by the relative space accessibility (R^2=0,7); the correlation between the modal split and the relative time accessibility is lower and those ones based on the generalized and on the supply accessibility weighted on the distance are not significant.

This underscores the high responsiveness of the demand to the public transit route lengthening with respect to the minimum route allowed by the way network and then a firm preference for the direct connections. The lack of correlation between the modal split and the accessibility indicators based on the transport generalized cost and on the rides amount indicates the need to build, for this purpose, more complex indicators.

The interpolating functions manifesting the link between the relative space and time accessibility weighted on the distance and the modal split have both an exponential form and are outlined in the figure 3 and 4.

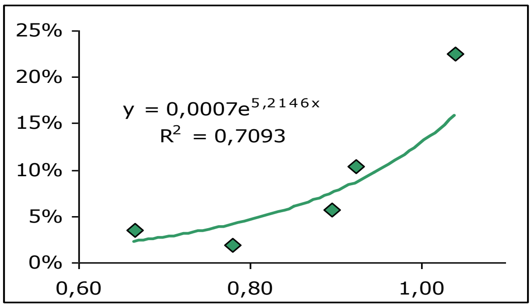


Fig. 3: Correlation between modal split and relative space accessibility weighted on the distance

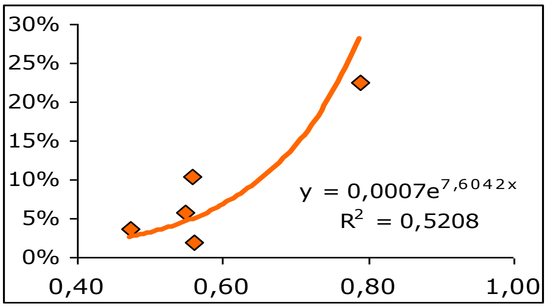


Fig. 4: Correlation between modal split and relative time accessibility weighted on the distance

The tuned actions to improve the service produced an appreciable increase of the accessibility parameters in the sub-area of Potenza and Senise; this scenario could increase the public vehicle use for an amount appraisable by the found correlations. Specifically in the sub-area of Potenza we can expect a gain in the public transit use of about 11% with respect to the present situation; the expected gain in the sub-area of Senise is larger (+30%).

5. Final remarks

The built indicators are able to measure the relative accessibility that is produced by a local public transit network in a district traffic area with respect to the one hit by private transport in the same area. The aspects of accessibility considered by this indicators are space and time distance, services amount and rapidity and travel generalized cost in terms of needed money and time.

Indicators are tools to appraise the effects on the accessibility produced in a given area by a local public transit network, not in absolute value but related to the same characteristic resultant from private vehicle use. Therefore the strength of these tools lies, further in considering various aspect of the transport supply, above all in providing measures of the public transport accessibility which, because related to that one of private transport, are not affected by the supply amount and the standards of the routes. That is a clear vantage for the designer of the public transit services who must generally work accounting the infrastructure network as an invariant, both because of his competence limits, and because the actions on this last one, differently by that ones on the services, are realized in the medium-long period.

Furthermore we looked for a correlation between the built indicators and the modal split, both to test the effectiveness of this tools in measuring the accessibility, and to try to provide an approximate forecast tool of the changed accessibility effects on the transport mean choose. By the found correlation we can appraise the effectiveness of the actions tuned for the services network on the public transit use.

By the performed experiment we have also defined an operational practice, based on the built indicators, divided in the following steps:

1. calculation of the accessibility indicators on the whole examined area and on parts of it taking into account the present supply of public and private transport;
2. identification of the sub-areas with lower accessibility than the average values of the whole area or than reference values;
3. definition of suited actions (designed on the basis of the values reached by the different indicators) to overcome the observed criticisms;
4. new calculation of the accessibility indicators on the basis of the changed supply, to verify the achievement of the targets.

The performed experiment has highlighted a good response of the indicators to targeted improvements on the public transit supply system. Further experiments will allow a more precise calibration of the parameters attending in some indicators and mainly the looking for more significant correlations between the accessibility indicators and the modal split.

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