

# ACCESSIBILITY AND SOCIOECONOMIC ACTIVITIES LOCATION

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## 1 INTRODUCTION

The term "land-use" may identify several variables of the urban economic system, such as the level and the location of the workplaces and of the employed; the housing stock and the level of housing prices; the distribution of the residents and so on. That all these variables may affect (directly or indirectly) the transport systems is intuitive and well-established. In fact, there is a wide literature of empirical studies and modelling analysis of the impacts of land-use on the transportation system. On the other hand, the reverse impact, that is how transport influences land use, is less well known.

In principle it is possible to distinguish among different effects that a change in the transportation system (e.g. a reduction of travel time, or more in general, a differentiated changing of zone accessibility) can induce on land use.

The first effect relates to the redistribution of the working population due to the introduction of new services or by means of the construction of new infrastructure. Given such intervention on the transportation system, people may find more convenient to live in certain areas (i.e. those that have gained in accessibility) with respect to others. They can decide to move at a higher distance from their working places and afford for better housing accommodation (e.g. lower rental prices) and/or for better living environment (e.g. bigger houses).

The second effect relates directly to the firms located in a given area. It derives from the fact that changing accessibility may induce a modification of transportation costs from the production zones to the final and to the intermediate consumers. This may firstly induce a relocation of the firms towards those zones closer to the final markets and to the inter-linked production sectors. Moreover, a reduction of the transportation cost induces, in general, a reduction of the total production cost which may in turn induce the following other indirect economic effects:

- 1) the increase of the labour supply market of the firms located in that zone: given the wage level, the firms may potentially consider to employ more people e.g. to increase the production;
- 2) the increase of the firms productivity, maintaining the same production size but at a lower cost;

- 3) the increase of the labour demand market: the reduction of production total cost allows potentially the firms to offer higher wages and thus more people may find convenient to work there.

In addition, there are also indirect effects on the housing market that may rise from investment in transport, such as the increase of housing and land price in a given area induced by the increase of the accessibility of that area, and so on.

In this paper we focus on two specific economic effects of changing accessibility: the relocation of residents and the relocation of firms within the study area due to the changes in the accessibility on the road network.

One of the earliest study analysing the effects of transport on urban land use is the one by Hansen (1959), in which he demonstrated for Washington, DC, that locations with good accessibility had a higher chance of being developed than remote locations. However, there is also counter-evidence. For instance, Giuliano and Small (1993) observed that in the Los Angeles metropolitan area commuting cost has little impact on residential location choice. Knight and Trygg (1973; 1977) reported wide differences in the strength of impacts between cities, ranging from significant in Boston, Montreal, Toronto and Philadelphia to negligible in Cleveland and Chicago.

Besides the small number of studies on the impacts of transport on land use, most of them suffer from methodological problems. In facts, these are mainly based on simulation results, very few of them are based on empirical analysis and observed data. One reason for this may be the fact that land use changes occur much more slowly than changes of travel behaviour and are subject to many other influences other than transport, such as population growth, economic development changes in lifestyles, household formation, consumption patterns and production technology and are therefore difficult to isolate (Wegener and Furst, 1999). This is confirmed by Miller et al. (1998) who note that in virtually no case the study design provided an adequately controlled 'experiment' to properly isolate the impacts of transport investments from other evolutionary factors at work in the urban region.

From this brief review of the literature, it can be noted that most of the studies presented:

- refer to North-America cities, in facts, there is a lack of such studies in Europe;
- they have been carried out for urban or metropolitan areas, very few have focused on the regional scale;

- most of them are based on simulation results, very few are supported by empirical analysis and have been validated using observed data.

This paper aims at giving a contribution in order to investigate in these areas. In the first part (section 2) the results of a before-and-after analysis of the impacts that changes of accessibility may induce on the distribution of residential and economic activities location is presented. The case study is that of the “Regione Campania”, one of the 20 administrative regions of Italy. This is of particular relevance, firstly because the scale of the analysis does not focus only on a specific urban/metropolitan context but cover an area consisting of more than 550 municipalities, with about 5,6 millions of residents and including both very congested zones (e.g. the metropolitan area of Napoli with densities above the 10.000 inhabitants per squared Km) and sparse areas. Moreover, in the study area, after a big earthquake in year 1980, there was a large investment in the reconstruction of transport infrastructures, particularly of the new regional road network (see Figure 2). Therefore, it is expected that the effects due to the changes in accessibility (which occurred in a small number of years) can be isolated and utilised for the scopes of the analysis.

In the second part of the paper (section 3) a modelling framework to simulate the above interactions (i.e. accessibility on residential and economic activities location) is proposed and the results of the aggregate calibration of the significant parameters of the model are discussed.

## **2 EMPIRICAL ANALYSIS**

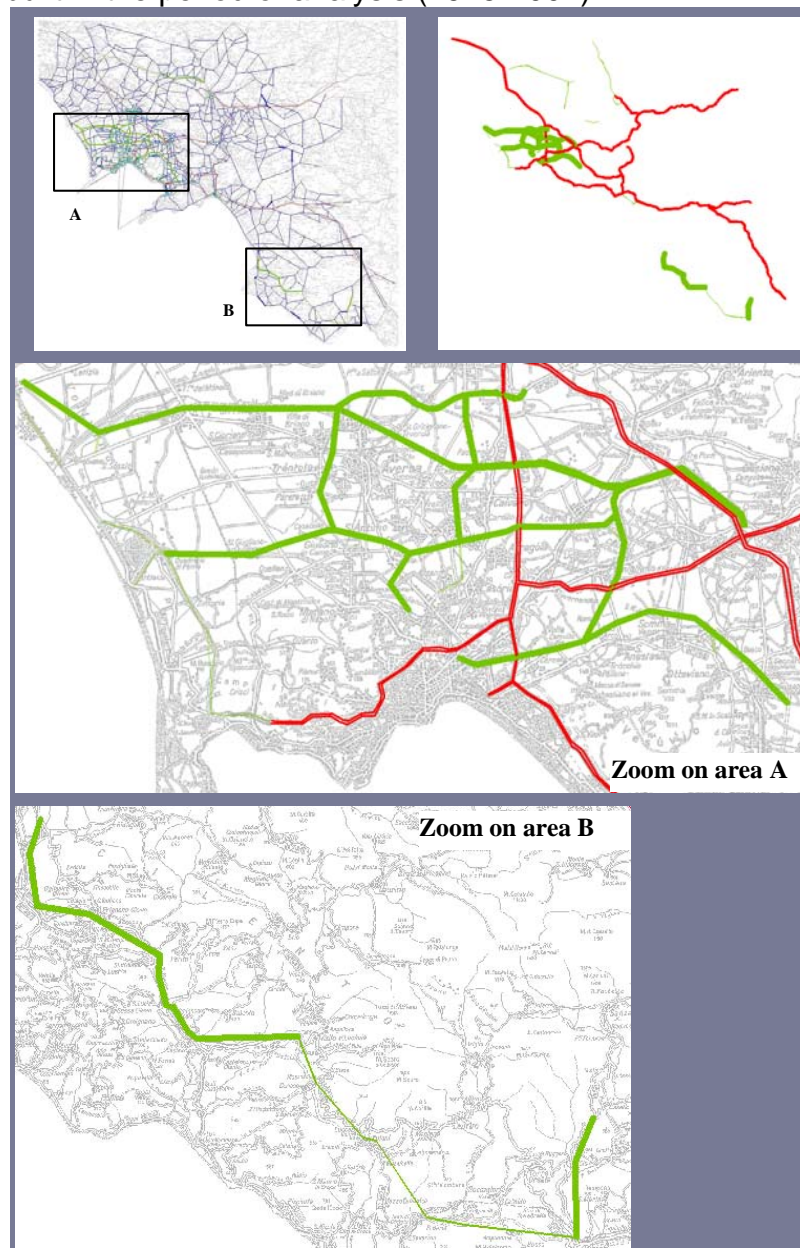
In doing an empirical analysis of the feedback from transport on the land use, the first arising question concerns which are the effects (direct or indirect) we are interested in, among the several ones mentioned in the previous chapter. In this respect, the objective of the analysis here presented is to investigate whether and to what extent it is possible to identify an inter-relation between the variation of accessibility, differentiated over the zones of an extended regional area, and the variation of population and economic activities in such zones.

The second question, then, is how we are going to measure such effects and how we are going to represent them. To answer to this question we should start from the data available for the analysis.

## 2.1 Data availability

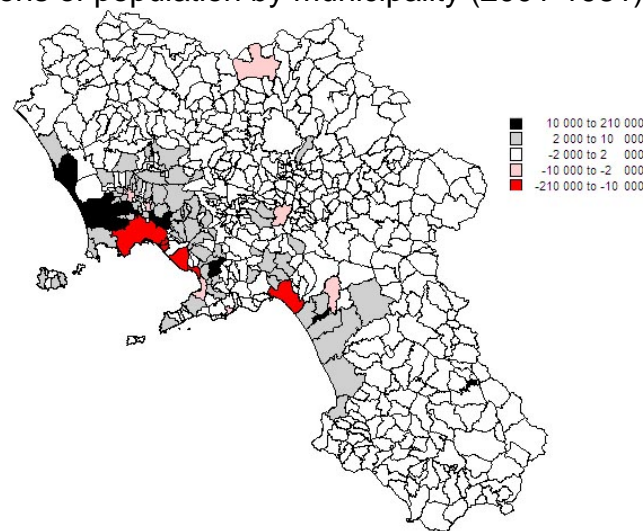
For the considered case study, the data available were the Census data for the years 1981, 1991 and 2001 of the population per zone sorted by age, working activities and other social characteristics, and the employed per zone in different economic sectors (land use data). On the other hand, we had the maps and the functional characteristics of regional roads in the years 1975, 1985, 1990, 1995, 2000 (transportation data).

*Figure 2* The case study of Regione Campania: the new road infrastructures (in green) built in the period of analysis (1975-2001).



Based on these data, a GIS embedding both land use and transport information was first built. Based on the thematic maps representing, on the one hand, the variation of the population and of the employed in economic sectors in the more than 500 municipalities of the Regione Campania, and, on the other hand, the modification of the regional road network, the following considerations can be derived. First, the main changes in the regional road network occurred between 1985 and 1990. This can be explained by the fact that in year 1980 a big earthquake devastated the whole Region, particularly the area around Napoli and Avellino. Consequently a wide reconstruction plan allowed the renovation and partly the reconstruction of most of the regional road network, particularly the one in the North of Napoli (see Figure 2).

*Figure 3* Variations of population by municipality (2001-1981).

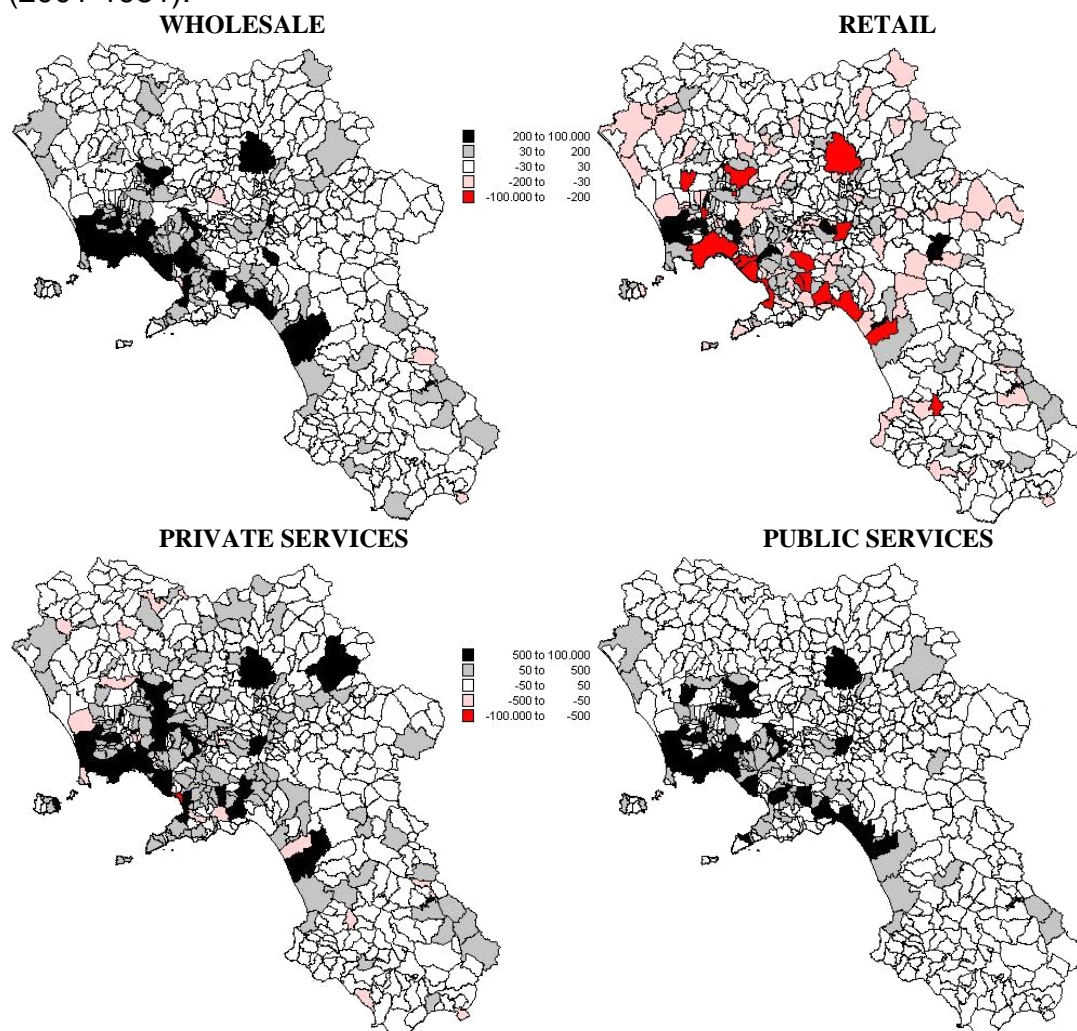


Concerning the variation of population, it can be observed a general decrease in the main cities (e.g. Napoli, Salerno) and in the highly congested urban areas (e.g. Portici, Casoria) and an increase in the municipalities next to such areas, particularly those in which the new road infrastructures have been built (see Figure 3). The first phenomenon of population migration can be clearly explained by the fact that the high level of urban density has led to an increase of housing prices and to a decreasing quality of the living environment, which in turn has induced people to move. What is interesting to note is that such migration is directed more towards the municipalities in the area in the North of Napoli, where the new road infrastructure were built (see Figure 3). This would confirm that an impact of the accessibility on housing location choice actually does exist.

Concerning the variation of economic activities, we have analysed the variation of the employed in four different aggregated economic sectors (see Figures 4):

- the “Public Services” sectors (e.g. Welfare, Education, Primary, Secondary sectors, etc.);
- the “Private Services” sectors (e.g. Banks, Insurance Institutes, professional activities sectors, etc);
- the “Retail” commerce;
- the “Wholesale”commerce;

*Figure 4* Variations by municipality of employed in four aggregated sectors (2001-1981).



It can be observed that conversely to what happened for the population, employed has greatly increase in the main cities of the region (i.e. Napoli, Caserta and Salerno). Moreover, it can be observed that for the retail commerce there exist a trend similar to the one observed for the population.

For such sector the movement towards the area where an increase of accessibility occurred, could be related both to the increased accessibility itself and to the increase in the population that has occurred in such area. Which of such effects is predominant is something we are going to investigate in the next section.

## 2.2 Accessibility measures

From the figures presented in the previous paragraph, an interrelation seems to exist between changing accessibility and variation of population and of other economic sectors. In this paragraph we try to quantify such interrelation by comparing the zone accessibility variations to the variation of the working population and to the variation of the employed in the four considered economic sectors. To this scope an indicator of the zone accessibility needs first to be defined.

In literature different definition of accessibility are proposed (see for a state of the art Reggiani 1998). Here we consider two type of accessibility referred to as “active” and “passive” accessibility (Cascetta, 2001). The active accessibility of a given zone  $o$  is a proxy of the opportunity of reaching the activities located in different zones of the study area for a given purpose (e.g. workplace, shopping, ...) moving from  $o$ . On the other hand, the passive accessibility is a proxy of the opportunity of an activity located in a given zone  $d$  to be reached from the potential consumers moving from all the various zones of the study area for a given purpose. In the present study we have calculated the following two types of accessibility:

- the active accessibility of the residents towards the workplaces of the study area;
- the passive accessibility of the economic activities with respect to the residents of the study area.

Following the above definition the accessibility is made up of two functions, one representing the activities or the opportunity to be reached for a given purpose and the other representing the impendence (e.g. time, cost, distance, etc) needed to reach them. Accordingly the “active” accessibility of the residents of zone  $o$  to the workplaces in the whole study area is given by:

$$A^{act}(o) = \sum_i E(i)^{\alpha_1} \cdot \exp(\alpha_2 \cdot C(o,i))$$

where

- $E(i)$  is the number of workplaces in the zone  $i$ ;
- $C(o,i)$  is the generalised travel cost (i.e. weighed sum of the travel time and travel costs) between zone  $o$  and zone  $i$ ;
- $\alpha_1 \alpha_2$  are calibrated parameters respectively equal to 0.85 and 1.25.

The “passive” accessibility of the economic activities in a given zone  $d$  with respect to residents in all the zones of the study area, is given by:

$$A^{pas}(d) = \sum_i Res(i)^{\gamma_1} \cdot exp(\gamma_2 \cdot C(i,d))$$

where

- $Res(i)$  is the number of people residing in zone  $i$  (i.e. the potential costumers of the economic activities in  $d$ );
- $C(i,d)$  is the generalised travel cost (sum of the travel time and travel costs) on the road network between zone  $i$  and zone  $d$ ;
- $\gamma_1 \gamma_2$  calibrated parameters respectively equal to 0.65 and 1.25.

The above definition of the accessibility measures requires the subdivision of the study area into traffic zones (*zoning*) and the definition of the relevant infrastructures and services.

The Regione Campania has been subdivided into 383 traffic zones “homogeneous” with respect both to their land-use characteristics (e.g. level of population and economic activities) and to their accessibility to transportation networks. A traffic zone represents either one municipality, or a group of municipalities (typically the small one) or part of a municipality (this is the case of the large cities).

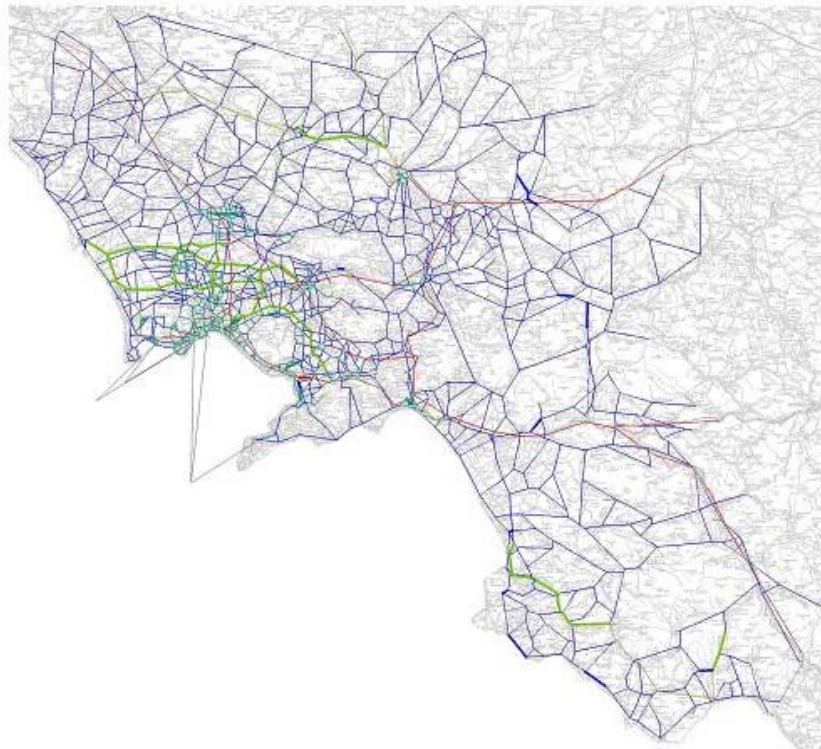
Zoning is related to the subsequent phase of selection of the relevant supply elements. We have assumed that the relevant infrastructures to the scope of calculating the spatial accessibility of the traffic zone of the Region Campania can be identified into the regional road network. In the computation of the accessibility we do not have included the contribution of the regional public transportation system. In facts, in our analysis we were interested in the variation of zone accessibility and, in the period of analysis, relevant changes (e.g. construction of new railways) did not occur in the regional public transportation system of the Regione Campania. The impacts of PT services variation such as increasing frequencies, or changing service timetables, have been considered negligible to the scope of the analysis. Moreover, although some studies have shown that it could exist an impact of railway accessibility



on residents location (see for instance the Glasgow Rail Impact Study by Gentlemen et al., 1983 which have found that some reversal of population decline occurred near rail stations), it is also true that at the regional scale of analysis the mayor contribution to the accessibility of a zone is given by the level of connection with the other zones basically on the road network.

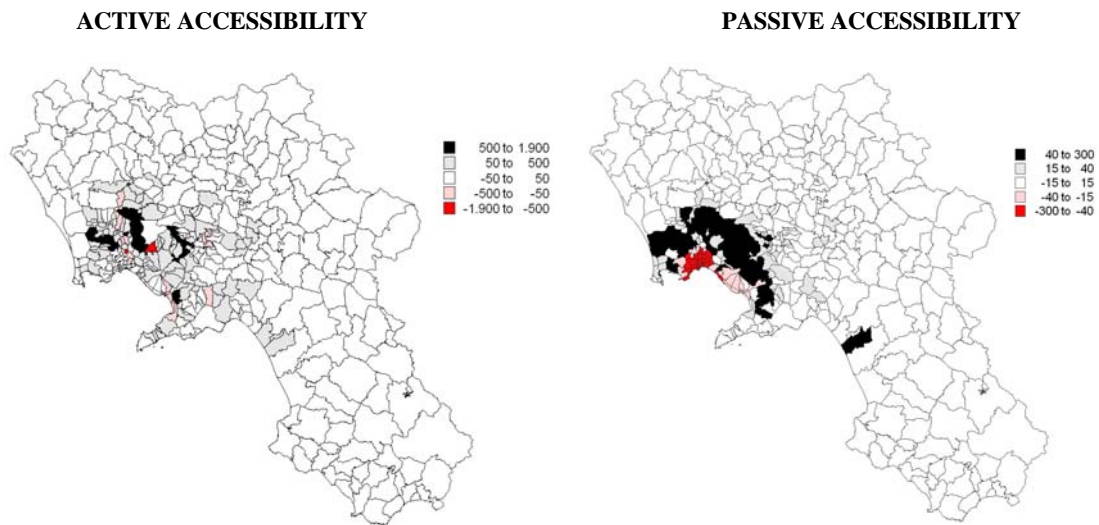
The graph of the regional road network model consists of about 1900 nodes and 6500 links representing the main road connecting the traffic zone previously identified. By means of this graphs the OD travel cost and travel time need for the computation of the generalised travel cost have been estimated in two different scenarios: the scenario “before” previous than the construction/renovation of the new roads (i.e. the ones depicted in green in figures 2) and the scenario 2001, in which it has been assumed that the effects of the construction of such infrastructures be entirely kept out.

*Figure 5* The graph of the regional road network (in green the new roads included in the “after” scenario).



The variation of active and passive accessibility in such scenarios is reported in Figure 6: it can be observed that the main increase is related to the zones in the North of Napoli where in the period of analysis there have been a concentration both of population and economic activities and the construction of new roads.

Figure 6 Variation of active and passive accessibility.

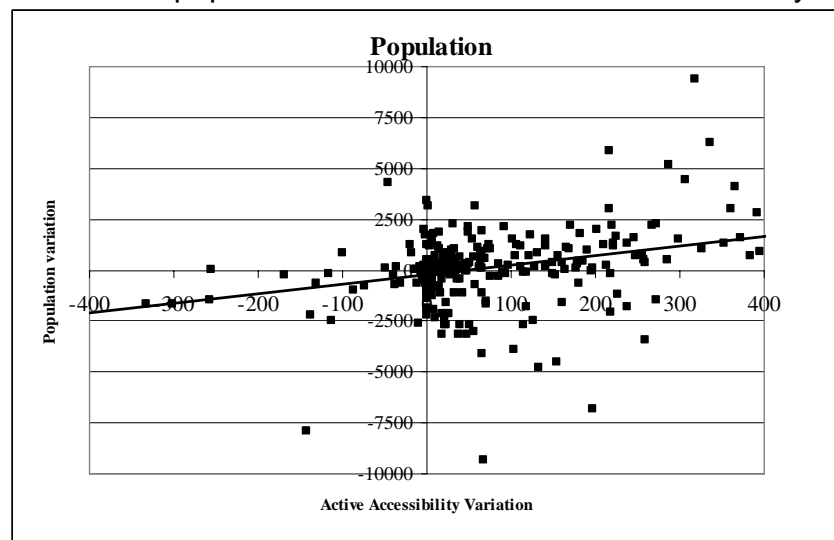


### 2.3 Population location vs. active accessibility

In Figure 7, for each zone of the study area, the population variations (y-axis) are plotted against the variation of active accessibility (x-axis). It can be observed that the zones with higher increase of accessibility are those which have had also the higher increase of population. However, there are some zones for which this trend cannot be observed. Particularly, there are zones with a small increase in accessibility but with a big decrease of population. From a deeper analysis of such group of zones, it emerges that these are the zones belonging to the urban areas of Napoli, Salerno, Caserta and Avellino. The fact that such zones are the most populated of the region, explains, firstly, why the population variations are so high compared to the variation related to the other zones. Moreover, it should be noted that the decrease of population in the period of analysis, equal respectively to 18% (Napoli), 12% (Salerno), 14% (Caserta) and 7% (Avellino), is in line with the general trend of population of the cities that have been observing in the main Italian cities in the last years. This is a well-known demographic phenomenon that is not correlated to the accessibility but to other socio-economic factors such as the decreasing quality of life of the urban areas, the increasing level of housing prices, and so on. It is interesting to note that in moving from the before to the after scenarios, the origin-destination generalized travel cost decreases. Thus, the decrease of accessibility observed in some zone is due to a (negative) variation of working places in the close zones (see the formulae of the active accessibility). From figure 7 it can be seen that such zones are those in which also a negative variation of population can be observed. Therefore the variations of population appear to be related also to the distribution of workplaces within

the study area. From the analysis of figure 7 we can conclude that the variation of population is actually correlated to the variation of accessibility but there are also other factors that may influence the movement from zone to zone: socio-economic factors related to housing market, the level of congestion of the urban system, the distribution of working places, and so on.

*Figure 7* Variation of population vs. variation of active accessibility.



#### **2.4 Economic activities location vs. passive accessibility**

A similar analysis has been carried on for the aggregate economic sectors, above introduced. In Figure 8, for each zone of the study area, the variations of number of Employed in Retail and Wholesale sectors (y-axis) are plotted against the variation of passive accessibility (x-axis). For the retail commerce it can be observed a similar trend as for the population: the higher variation in accessibility, the higher variation in the number of employed. This is less relevant for the wholesale sectors.

On the other hand, for Services activities both “private” and “public” a correlation with the passive accessibility cannot be observed (figure 9a). Particularly, there zone with a high increase of Services activities corresponding to a decrease of accessibility. These zones belong to the urban area of the main cities of the region. Here, as already noted, there is a negative trend in population which caused a decrease of passive accessibility. The fact that such negative trend does not correspond to a similar trend in services activities, shows that the location of services is not correlated to the location of the population, as it happens for the commerce. If we exclude the zones of the main cities from the analysis of services variation, it can be

observed (Figure 9b) a correlation between service and accessibility variations. This is less significant for the Public Services sector.

Figure 8 Variation of Commerce activities per zone vs. variation of passive accessibility.

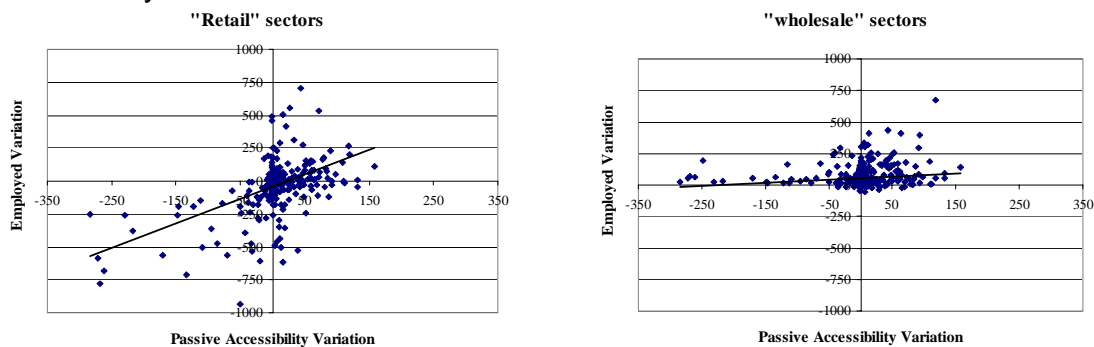
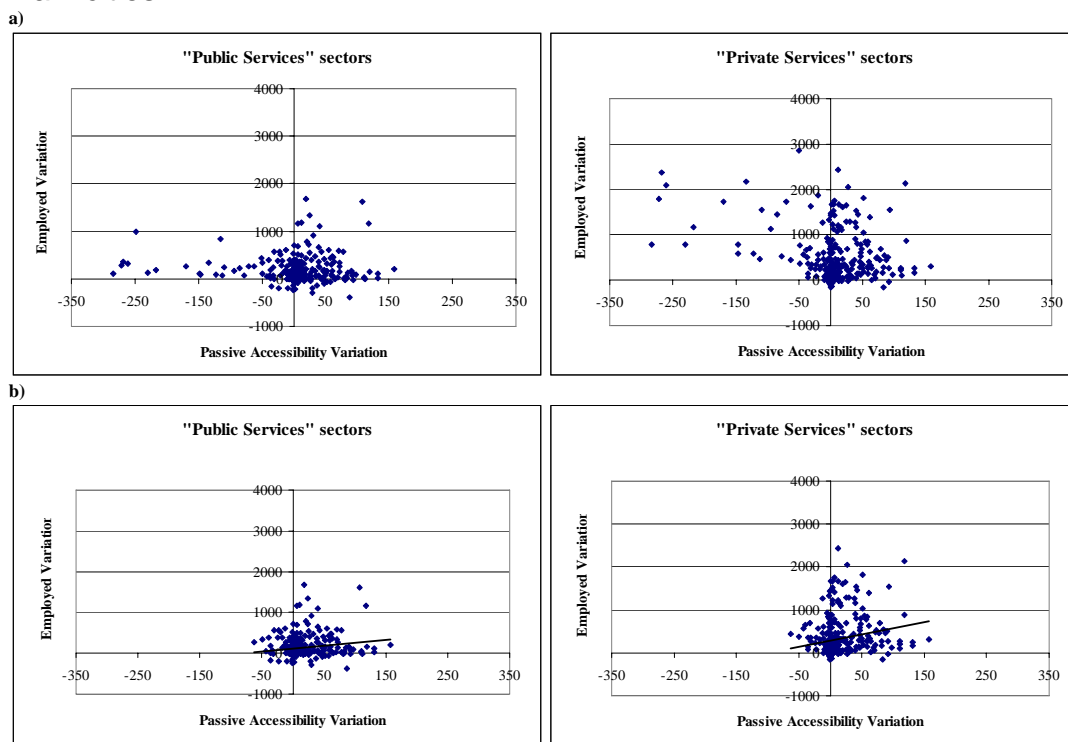


Figure 9 Variation of Services variation per zone vs. variation of passive accessibility: a) with all the zones; b) with the exclusion of the zones of the main cities.



In conclusion, from the analysis carried out, it emerges that:

- 1) Despite some exception related to the urban highly congested zones of the main cities, a correlation between population variation with the accessibility can be observed;
- 2) Commercial activities variations follows both the population variations and, to a certain extent, also the accessibility variations. Retail sectors appear more elastic to the accessibility than the Wholesale sectors.
- 3) Services activities variations do not follow the population movement but are slightly correlated to the accessibility variation. This trend is more evident for Private service sector than Public Services ones.

In the next chapter we present a modelling framework to quantify such interactions.

### **3 THE PROPOSED LAND-USE TRANSPORT INTERACTION (LUTI) MODEL**

In the previous chapter empirical evidences have shown that, although small, there exists an inter-dependency between transportation accessibility and the location of socioeconomic activities within a regional area. In this chapter a modelling framework to simulate such interactions is proposed and the results of some application to the previously presented case study of the Regione Campania, are discussed.

In theory almost all of the components of a social and economic system in a given geographical area interact with different levels of intensity. However, it is practically impossible to take into account every interacting element to solve a transportation engineering problem. The typical system engineering approach is to isolate those elements, which are most relevant to the problem, and to select a certain number of interaction. Our *analysis system* consists of the *transportation system* and the *activity system*, the latter being schematically decomposed into two sub-systems consisting of:

- the people divided into categories living in each zone (*the residential sub-system*);
- the economic activities located in each zone and divided by sectors (*the economic activity sub-system*);

Based on the results of the empirical analysis, the interactions which we are going to simulate are schematically represented in the overall modelling framework depicted in Figure 10:

- the transport model given the resident and the number working places per zone allows to compute the Origin-Destination (OD) generalised travel cost and the (active and passive) accessibility of each zone;
- the residential location model given the working places per zone and the OD generalized travel cost allow to estimate the distribution of residents per zone;
- the activities location model given the distribution of residents per zone and the accessibility estimate the distribution of the activities among the zones of the study area.

How the transport model estimates the zone accessibility and the OD generalized travel cost has already been seen in the previous section. In the following paragraphs the residential and the activities location models will be described and how their interaction are simulated will be explained.

### 3.2 The Residential Location Model

The residential location model gives the number of residents in each zone of the study area as a function of the location advantages and the characteristics of the supply transportation system. Following a behavioural approach, it is assumed that the choice of the residential zone is the result of the decision-making process of the workers residing in the study area. Thus, each worker chooses his/her residence zone according to the characteristics of the zone itself (price per square meters, presence of services, etc.), but also according to the “distance” from his/her workplace.

Different classes of workers can be considered, according for example to the level of income, to the professional condition and so on. For the generic worker class  $i$ , the number of workers in a given zone  $o$ , is given by:

$$w^i(o) = \sum_d P_{res-cond}^i(o/d) \cdot E_{tot}^i(d)$$

where  $P_{res-cond}^i(o/d)$  is the probability that worker  $i$  chooses to live in zone  $o$  conditional to working in zone  $d$  and  $E_{tot}^i(d)$  is the total number of people of class  $i$  employed in the zone  $d$ , given in turn by the sum of the employed of class  $i$  (e.g. low-income employed people) in all the economic sector  $a$ :

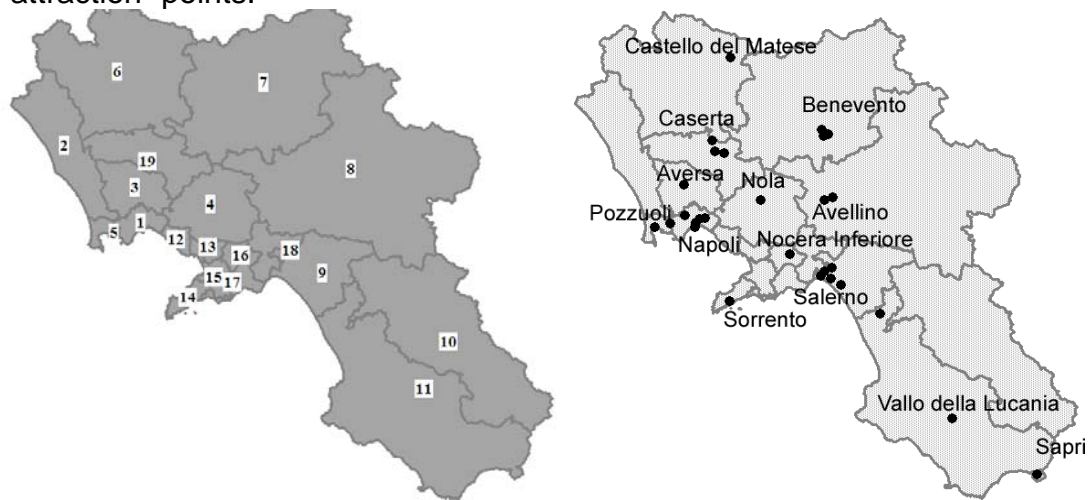
$$E^i(d) = \sum_a E_a^i(d)$$

In order to estimate the conditional probability  $P_{res-cond}^i(o/d)$ , consistently with Random Utility theory we assume that each worker  $i$ , in choosing his residential zone, associates an utility,  $U_{o/d}^i$ , to all the available zones and

chooses the one which maximizes the utility.  $U_{o/d}^i$  is assumed to be a random variable consisting of two terms: the systematic utility  $V_{o/d}^i$  and the random residual  $\varepsilon_o$ . If random residuals  $\varepsilon_o$  are independently and identically Gumble (0,1)-distributed, the conditional probability  $P_{res-cond}^i(o/d)$  is given by the well-known Logit formulation:

$$P_{res-cond}^i(o/d) = \frac{\exp(V_{o/d}^i)}{\sum_{o'} \exp(V_{o'/d}^i)}$$

Figure 11 The 19 territorial-basins of the Regione Campania and their “attraction” points.



The systematic utility of locating a residence in zone  $o$ , given the workplace in zone  $d$ ,  $V_{o/d}^i$ , is given by:

$$V_{o/d}^i = \beta_c^i \cdot C(o, d) + \beta_R^i \cdot x(o) + \beta_P^i \cdot P(o) + \beta_S^i \cdot S(o) + \sum_{k=1}^{19} \beta_k^i \cdot B(o, k)$$

where:

- $C(o, d)$  is the generalised travel cost between OD pair  $o$  and  $d$ , already introduced in section 2;
- $x(o) = \left( \frac{Res(o)}{R(o)} \right)^2$  being  $Res(o)$  and  $R(o)$  the number of residents and the number of residential rooms in zone  $o$ , is a proxy of the level of occupancy of the available housing stock in zone  $o$ ;
- $S(o)$  is the housing stock i.e. the number of houses (expressed in thousands) in zone  $o$ ;
- $P(o)$  is the average price per square meter of the houses in zone  $o$  (expressed in Thousands of Euro per square meters);

- $B(o,k)$  are dummy variables equal to one if the zone  $o$  belong to basin  $k$ , 0 otherwise; note that for the Regione Campania 19 territorial “basins” have been identified according to socioeconomic, historical and geo-political reasons (Figure 11).

Following previous studies (Cascetta et al., 2000) workers of the study area have been disaggregated into two socio-economic classes: the “High” and the “Medium-Low” income workers. The estimation of the parameters  $\beta$  of the model has been carried out through the Generalised Least Squares method using the Census data of the year 2001. The results obtained are reported in Table 1.

It can be noted that the signs of the estimated coefficients is consistent with the behavioural assumptions at the basis of the model. For instance, the coefficient of the housing stock is positive while the coefficient relative to the housing prices is negative, meaning that the higher the number of houses in a zone the higher the probability of residing in that zone, as well as the higher the prices the lower the probability.

The coefficients relative to the generalised travel cost from the (residing) origin zone to the (working) destination zone are also negative. The fact that the coefficient for “medium-low” class is higher means that the distance from the workplace zone is a factor affecting residential location choice for medium-low income workers more than for high income ones. This is mainly due to the more flexible working-time of the former, which imply work trips not necessarily in the peak period, when the transportation system is usually congested. It is also related to the fact that high income workers typically travel more (e.g. for business purpose) and are not committed to go to the working place every day.

It is important to note that there are other significant differences among the perception of the attribute introduced in the model among the two classes of workers. The coefficient of the proxy of level of occupancy of the houses,  $x(o)$ , is higher for high income workers than for low income ones, while the price of the houses is not significant for high income categories. Such differences point out that there is actually a different residential location choice behaviour which justifies the classification introduced.

Finally, concerning the estimates of the coefficients of the basins, it is not possible to give a behavioural interpretation. However they allow to improving highly the goodness of fit of the model as it will be seen in the paragraph 3.3. Once the workers per zone are estimated, it is possible to proportionally compute, the number of residents in a given zone by:



$$Res(o) = \sum_i k(o) \cdot w^i(o)$$

where  $k(o)$  is the ration between working population and total population residing in zone  $o$ .

Table 1 : parameters of the Economic activity and residential location model.

<b>Economic Activity location models</b>			<b>Residential location models</b>		
$\beta$	<i>Retail Commerce</i>	<i>Private Services</i>	$\beta$	<i>High income</i>	<i>Medium-low income</i>
$A^{Das}$	0,105	0,137	C	-0,6	-0,8
Res	0,75	0,1	x	-3.1	-1.9
$E_{base}$	0,04	0,30	Price	-	-0,1
Att	0,6	0,9	Stock	0,08	0,10
leisure	0,1	0,2			
Border	0,3	0,4			
Comm	0,6	-			
1	0,4	0,5	1	-0,3	-0,9
2	-0,15	-0,2	2	0,2	0,6
3	0	-0,6	3	-0,5	-0,2
4	-0,05	-0,3	4	-0,1	0,2
5	-0,25	-0,05	5	0,3	-0,2
6	-0,4	-0,25	6	-0,4	0,7
7	-0,25	-0,1	7	-0,2	0,8
8	-0,25	-0,1	8	-0,2	0,4
9	0,15	0	9	-	0,3
10	0,05	-0,2	10	0,2	0,9
11	-0,15	-0,3	11	0,2	0,8
12	0	-0,2	12	-0,2	-0,4
13	-0,1	0,1	13	-0,2	0,3
14	0	0,1	14	0,5	0,4
15	0,1	0	15	-0,15	0,3
16	0,1	-0,2	16	-0,3	0,2
17	0,1	0	17	0,7	0,4
18	0,1	0,1	18	-0,2	0,35
19	-0,1	0,1	19	-0,2	-0,1
N. obs.	383	383	N. obs.	383	383
$R^2$	0.36	0.27	$R^2$	0.41	0.35

### 3.2 The Economic Activity Location Model

The economic activity location model allows to determine the distribution of the number of employed in the economic sectors  $a$  in each zone  $d$  of the study area,  $E_a(d)$ .

This is given by:

$$E_a(d) = P_a(d) \cdot E_a$$

where:

- $P_a(d)$  is the probability of locating an activity of sector  $a$  (e.g. retail) in a given zone  $d$ ;
- $E_a$  the total number of employed in the economic sector  $a$  in the study area.

Based on the results of the empirical analysis described in the previous section, we focus on two types of demand-oriented activities location choice, i.e. Retail and Private Services. To simulate these location choices a behavioural approach consistent with Random Utility theory is followed. Private investors (i.e. firms, craftsmen, companies, etc.) in choosing the zone  $d$  where to locate their activity, associates an utility,  $U_a(d)$ , to all the available zones and chooses the one which maximises the perceived utility. This is assumed to be a random variable consisting of two terms: the systematic utility  $V_a(d)$  and the random residual  $\varepsilon_d$ . If the random residuals  $\varepsilon_d$  are independently and identically Gumble (0,1)-distributed, the probability  $P_a(d)$  of locating activity  $a$  in zone  $d$ , is given by the well-known Logit formulation:

$$P_a(d) = \frac{\exp[V_a(d)]}{\sum_{d'} \exp[V_a(d')]}$$

The systematic utility  $V_a(d)$  of locating an activity  $a$  in the zone  $d$  is given by:

$$V_a(d) = \beta_{a,acc} \cdot A^{pas}(d) + \beta_{a,Res} \cdot \text{Log}[Res(d)] + \beta_{a,E} \cdot \text{Log}[E_{base}(d)] + \beta_{a,Att} \cdot \text{Att}(d) \\ + \beta_{a,Leisure} \cdot \text{Leisure}(d) + \beta_{a,Border} \cdot \text{Border}(d) + \beta_{a,comm} \cdot \text{Comm}(d) + \sum_{k=1}^{19} \beta_{a,k} \cdot B(o,k)$$

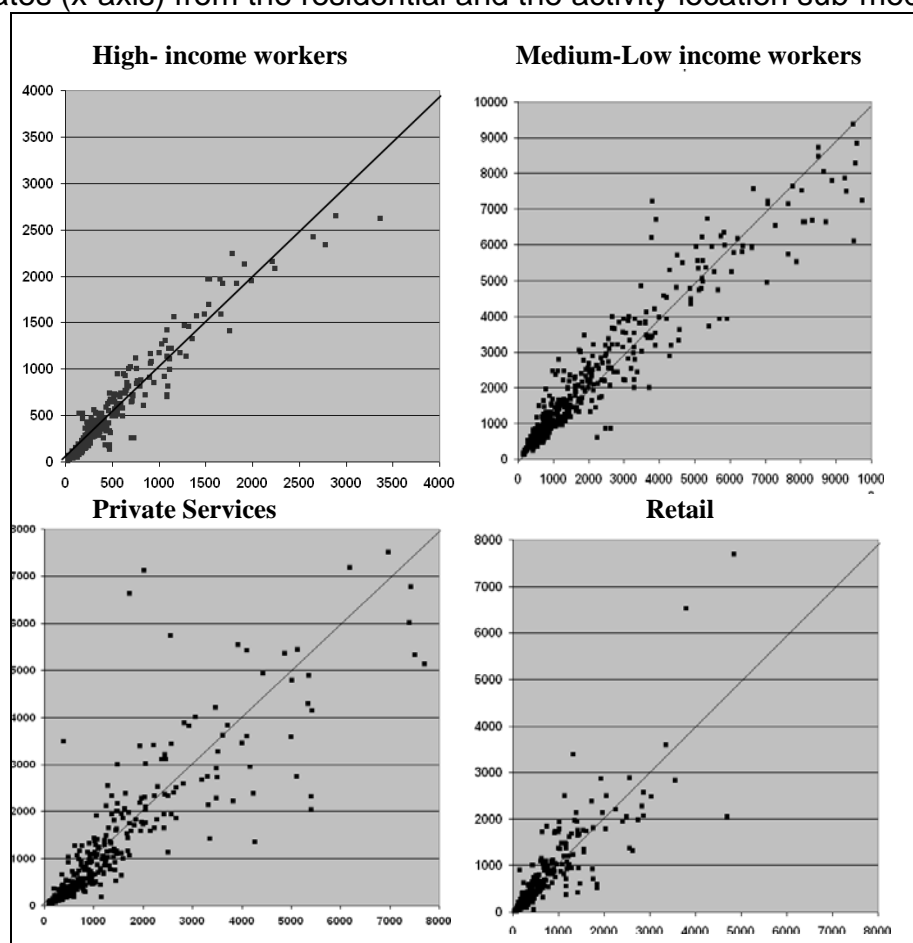
where:

- $A^{pas}(d)$  and  $Res(d)$  are the previously introduced, passive accessibility and residents in the zone  $d$ ;
- $E_{base}(d)$  are the number of employed in the base sectors (consisting of Public services, industry etc.) in the zone  $d$ ;

- $Att(d)$  is a dummy variable equal to 1 if the zone  $d$  is an “attraction point” within the basin to which it belongs (see figure 11), 0 otherwise;
- $Leisure(d)$  is a dummy variable equal to 1 if  $d$  is a zone with sea attraction, with places of Arts or any other tourist attraction, 0 otherwise;
- $Border(d)$  is a dummy variable equal to 1 if  $d$  is a zone on the border of the region, 0 otherwise;
- $Comm(d)$  is a dummy variable equal to 1 if the zone  $d$  includes commercial centres and/or big shopping mall, 0 otherwise.

Two different activity location models have been calibrated: one for the Private services and the other one for the Retail commerce. The calibration has been carried out based on Census data of the year 2001. The calibration results are reported in Table 1.

*Figure 12* Census data of the workers and employed in each zone (y-axis) vs. estimates (x-axis) from the residential and the activity location sub-models.



It can be noted that all the parameters estimated have expected signs. The parameters of the passive accessibility are positive meaning that the more accessible a zone is to residents the more it is convenient to locate an activity there. This is confirmed by the positive value of the parameter of  $Res(d)$ . Similar consideration can be made for the attribute  $E_{base}$ : the higher the number of other base activities in the zone, the more the zone is a convenient location for a given activities. The impact of the attributes  $Res$  and  $E_{base}$  is different for the economic sectors considered: the former has a higher impact on the location of the retail activities, while the second has a higher impact on the location of the Private services. It is interesting to note that this is what emerged also from the empirical analysis described in the previous section. Finally, it is worth noting the value of the parameter of the attribute  $Att(d)$  and  $Border(d)$  which have both a positive value for Service and Retail activities location, and the positive value of the attribute  $Comm(d)$  which, as expected, is significant only for retail activities.

Once the employed per sector and per zone are estimated, it is possible to compute the number of employed per sector belonging to each workers class  $i$  by:

$$E_a^i(d) = e_a^i \cdot E_a(d)$$

where  $e_a^i$  is the percentage of working population in a given sector  $a$  belonging to the working class  $i$ , e.g. the percentage of “high” income workers, employed in Private Services sector. These percentages are here calculated on the basis of the Census data for the whole Region, but in principle they can be estimated separately for each zone.

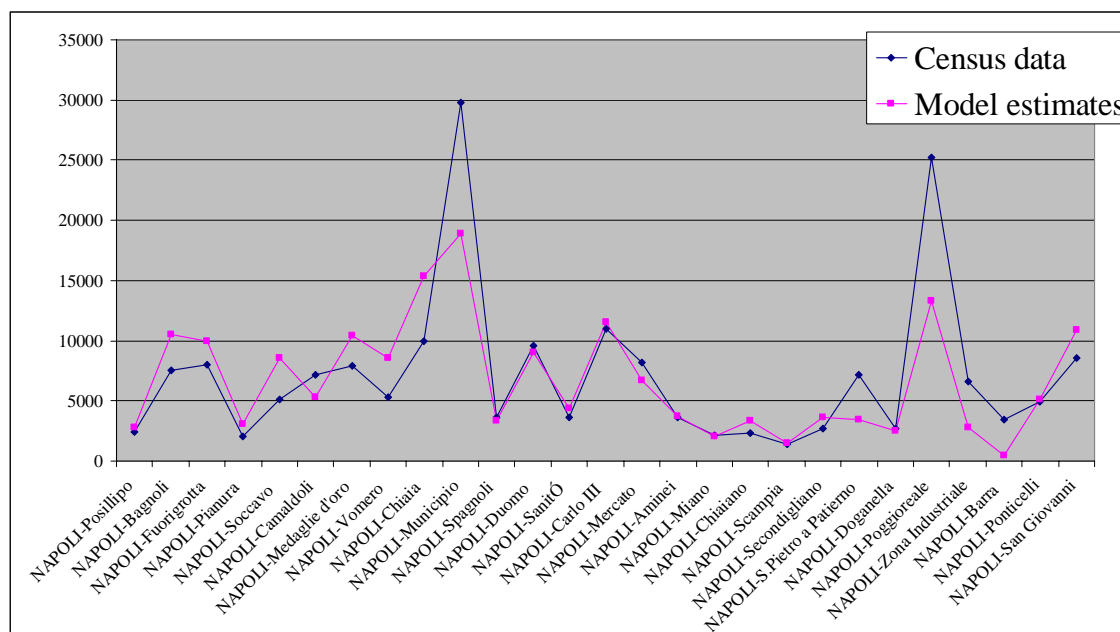
### 3.3 Model validation

In order to validate the proposed approach to the simulation of land-use and transport interactions, the model above presented have been applied to the case study of the Regione Campania.

The estimates provided by the model have been compared to the Census data for each zone. In figure 12 the model estimates (x-axis) are plotted against the census data (y-axis) for the two classes of workers considered (i.e. high income and medium-low income) and for the employed in the Private Services and Retail sectors. It can be noted a good fitting of the model provided that the estimation error for more than the 75% of the zone is in between -20% + 20%.

If we aggregated the estimates at the level of basin, it can be seen that the estimation error is in absolute value less than 15% for high income workers, less than 25% of medium-low income ones, less than 10 % for Retail sectors and less than 20% for Services. For the basin in which a higher average error is observed, e.g. the basin no. 1 (i.e. the urban area of Napoli) a more detailed analysis has been conducted for each zone. It has emerged that the error is concentrated in some zone characterized by an very high concentration of activities due to presence of a Central Business District such us the zones “Napoli-Poggioreale” or “Napoli-Municipio” (Figure 13). These zones present so high a concentration of activities with respect to the average of the other zones of the study area, which can be kept only by means of duly calibrated specific alternative constant.

Figure 13 Census data for the services in the zones of the urban area of Naples vs. estimates from the residential and the activity location sub-models.



#### 4 CONCLUSIONS

This paper aims at giving a contribution in order to investigate the impacts that the differentiated changing accessibility of the zones of an extended regional area have on the location of the residents and for the economic activities. The study has been carried on by means of both an empirical analysis and an integrated modelling approach.

The empirical evaluation was based on a before-and-after analysis of the variation of road accessibility, and the variation in the number of residents and economic activities for each zone of the study area. The results have shown that a certain interrelation can be observed for the Residents, the “Retail” activities and the “Private Service” activities. In facts, it can be observed that the zones with higher increase of accessibility are those which have had also the higher increase of population. However, there some cases where this conjecture does not hold and some other factors need to be taken into account. Particularly, for the Residential location a factor affecting location choices is the level of urban density and the level of the housing prices. On the other hand, for the economic activity location variation, it can be observed that these are marginally related to the changing accessibility and are more affected by other factors such as the variation of population, and the presence of base activities.

The above empirical results have been confirmed by the modelling analysis carried out by means of a system of spatial interaction models aiming at simulating land-use and transport interaction. The overall framework consists of integrated behavioral sub-models in which land-use pattern derive from the location choices of different decision-makers (i.e. households, workers, firms, companies,...). The sub-models have been calibrated based on the Census data using the generalized least squares methods. The estimates of the model parameters have confirmed the high impact of level of congestion of the housing market (i.e. the ratio of the number of residents in the zone and the number of rooms available for living) on the choice of the residential zone, both for “Medium-low income” and for “high income” worker classes, as well as that of the housing price and the housing stock. On the other hand, it has been estimated the impact that the number of residents in a given zone has on the location choice of the retail activities in that zone, as well as the role played by the presence of other activities in the location choice of the services. Finally, the modeling analysis has allowed to identifying a number of other key factors in the location of residents and activities, and the relative weight with respect to the accessibility.

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