A Land Use and Transport Interaction Model for the Greater Florence Metropolitan Area

Massimiliano Petri[1(✉)], Antonio Pratelli[1], Guglielmo Barè[2], and Leonardo Piccini[3]

[1] Department of Civil and Industrial Engineering, University of Pisa, Pisa, Italy
{m.petri,a.pratelli}@ing.unipi.it
[2] Citilabs, Lodz, Poland
gbare@citilabs.com
[3] IRPET-Regional Institute for Economic Planning of Tuscany, Florence, Italy
leonardo.piccini@irpet.it

Abstract. The paper presents the first results of the LUTI model built to analyse territorial impact of future project in the area around Florence, starting from the province of Pistoia, and arriving to Florence throw Prato province. The works is made of two main steps: the first one is the collection, homogenization and comparison of actual most important planned measures at different scale, from the single involved municipalities to the Tuscany Regional Plan.

The second main step is the construction of a LUTI model to evaluate different evolution scenario joining complementary infrastructure and territorial evolution measures. The obtained results show the importance of the LUTI model to support territorial planning at a multidisciplinary level.

Keywords: Land use · Transport model · Big data · LUTI model · Florence metropolitan area

1 Introduction

Recent studies on the status of mobility at urban level, both at Italian national level [1] and at European level [2] show that actually there are not so satisfactory level of sustainability in our mobility relative to the objective of the general Environmental policies and objectives [3–5].

One of the causes of this phenomenon is the almost total absence of interdisciplinary in the daily practice of territorial and urban planning. Planning sectoriality leads to solutions that are not able to optimize the city and territory system, but it only provides partial solutions that answer the single problem (energy, transport, commerce, etc.) but do not read the city as a whole, a *"unicum"* body.

A clear and explanatory example of this phenomenon was the occasion of an analysis for the City of Cascina (Tuscany, Italy). It is an example of rare multidisciplinary approach regarding the impact of the measures of its Urban Planning

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Regulation on mobility, joining two sectors, which often and erroneously are very different[1].

The obtained results show that the urban planning already carried out is not compatible with the existing road infrastructures and with the flows generated by the new activities. In fact, these generate an increase in total traffic (daily there are about 125,000 trips in the urban area) between 20 and 44% (with some areas arriving in increments of over 500%) with consequent problems of congestion and the inadequate spaces parking number (actually, the parking supply is about 1,000 places).

This paper starts from the above necessary premise and describes a strategic and interdisciplinary planning case, carried out thanks to the sensitivity of the IRPET, Regional Institute for Economic Planning of Tuscany, highlighting all the innovative and interdisciplinary analysis.

In the first part of the paper, there is a general introduction about LUTI models, in the second part both the specific software program, and its embedded LUTI Model have introduced. The crucial and innovative research aspects have described in brief, while in the third part of the paper the study area jointly with the update project forecasts have presented. Finally, some results are discussed (the study is yet in progress for scenarios definition and simulation phase) of the first simulation scenarios implemented, emphasizing the multidisciplinary decision support provided by these applied models.

2 The Land Use and Transport Interaction Models

The models integrating urban development/land-use and the transport field are mainly divided between top-down models and bottom-up ones. Nevertheless, in the current literature, there are numerous classifications based on the purpose of the models, on their structure, on the analytical approach (own top-down versus bottom-up), on the general methodology, on the mathematical approach (optimization against simulation), on the analysis sectors, on the analyzed time horizons, on the data requested and other [6–9].

Taking four of the main criteria mentioned above and better detailed below, it is possible to make the following first attempt classification:

Criterion 1: Does the system allow interaction within the various elements that compose it (users, services, housing, etc. ..)?
Criterion 2: Do models capture emerging properties (bottom-up vs top-down)?
Criterion 3: Does the model consider time explicitly (static vs. dynamic)?
Criterion 4: Are spatial information explicitly considered?

Starting, in order of presentation, from these four criteria, can be sketched the following classification tree (see Fig. 1).

[1] For instance, also the new Tuscany Regional Urban Planning law on territorial governance, L. R.41/2018, does not never mention the word ‘mobility’.

Reading the same from bottom to top it has found that the only models that do not consider the relationships between the internal elements of the system are the localization optimization models. These, starting from a series of possible localizations, following purely mathematical maximization principles under different kind of constraints (they are the models deriving from the theories of Operational Research), identify the best solution. These last have often used at the commercial level to locate the warehouse with respect to a network of sales points or to locate a sales point with respect to an existing network, trying to maximize the new customers reached and minimize the cannibalism effect.

All the other models can be considered as interaction models, where the LUTI models specifically consider the interaction between population, land-use/distribution of activities/gravitation of the individual areas and existing transport services.

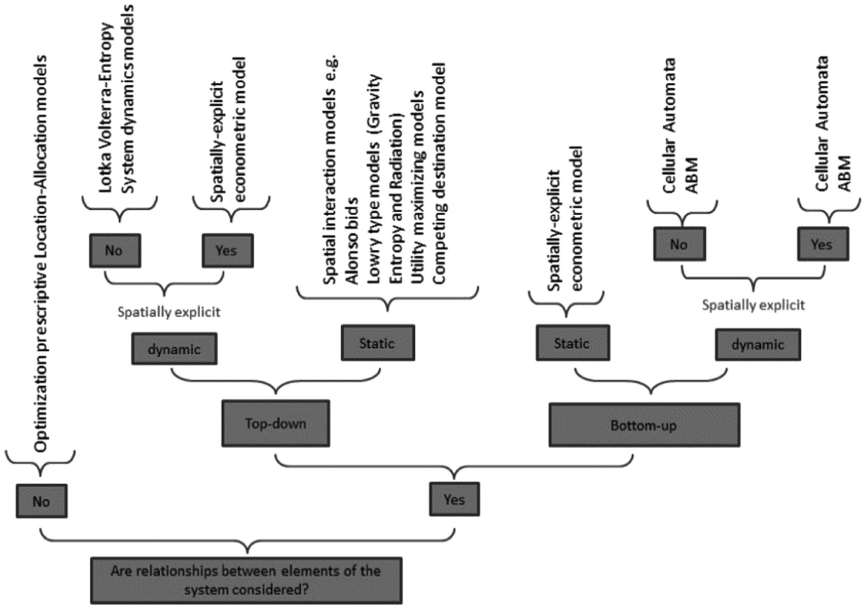

Fig. 1. Different classifications of LUTI models

Another differentiation is the type of model, or if the same captures emerging behaviors, in which case the analyst is faced to bottom-up models or does not have this ability and then it has talked about top-down models.

The most famous static top-down models are spatial interaction models deriving from Lowry's theory that predict travel flows between different zones, assuming the achievement of an equilibrium but without directly explaining the concept of time and considering variables such as population density, travel costs and job offers as invariants.

The top-down dynamic models work on successive simulations where a step represents the previous temporal situation that supplies the input data to the next step.

In this case the equilibrium can or cannot be reached (see the example in the following figure of the dynamic top-down model elaborated by Lombardo and Petri [10, 11] on the basis of the dynamic formulation of Wilson's spatial interaction model [12]) where the system dynamics is given by the following non-linear differential equation:

$$\frac{dS_j}{dt} = \varepsilon \left[\sum_i \left(R_i \cdot A_i \cdot S_j^{\alpha} \cdot e^{-\beta d_{ij}} \cdot fc_j \right) - B_j \cdot S_j \right] \tag{1}$$

$$A_i = \left(\sum_j S_j^{\alpha} \cdot e^{-\beta d_{ij}} \right)^{-1}$$

where:

Sj is the number of employees in the services; the considered typology includes services with a users basin which exceed the local size (municipalities), for example high schools, ipermarkets, sanitary services, etc.;

Ri is the number of users living in zone i;

dij is the time distance between cell i and j (calculated with the Floyd algorithm);

α is a measure of users scale-economies;

β is a measure of users predisposition to travel;

Bj is the total cost of management and installation of services;

Ai is a normalization factor;

fcj is a scale factor.

These models can implicitly insert the spatial aspect, and then we talk about models such as the Lotka-Volterra, or models of the prey-predator type, or models that are called double constraint gravitational models (case of calculation of the simple flows) or with a single constraint in origin (for typical applications of the geo-marketing field) or in destination (for typical urban planning applications). In the case of explicit representation of the geographical component, we speak of spatial econometric models based on dynamic systems estimating their parameters on elements such as distance from the CBU, accessibility to areas and more.

On the other hand, there are bottom-up type models, i.e. models whose dynamics derive from the interaction between the individual elements of the system (also called microsimulation models). These models are of the cellular automata type or MAS-based agent-based models. The only static models are those with cellular automata or MAS where the individual cells/elements interact on the basis of pre-established rules that do not change during the simulation and that lead to predict the changes in distribution of land use.

These models have had different developments over time with bottom-up microsimulations representing the latest recent developments. We started in the mid-70s (Lowry's theory dates back to 1964 with the Model of Metropolis) with top-down models of the gravitational family, then we switched to the aggregate econometric type models that were the precursors of the models of microsimulation that apply theories of random utility at the individual level.

Focusing now on the LUTI models, these can be both top-down and bottom-up but they are usually dynamic, as they must explicitly insert internal dynamics and processes of change of different speeds [13]:

- Very slow changes: changes in the network and land use;
- Slow changes: variation in the distribution of assets and residences;
- Fast changes: changes in employees and the population;
- Very fast changes: changes to freight and passenger journeys

In the territorial area all these activities and changes interact, each with its own times, as shown in Table 1. The distribution of land uses (residential, industrial, commercial areas) determines the locations of human activities such as residence, work, shopping, study or recreational activities. The geographical distribution of activities requires travel to cover the distances necessary to move. The distribution of the transport infrastructure provides the accessibility levels and this distribution of accessibility in the space contributes to being a datum for future locations of activities and changes in land use. Then a cycle has activated and its center is precisely the use of the land.

Many of these (excluding the CUFM model) use the theory of Discrete Choice Models and involve behaviors of territorial actors such as investors, families, companies or travelers. The following table shows the main features of some of these models.

Table 1. Urban subsystems represented in land-use transport models and their temporal dimension (source: [14])

Models	Speed of change							
	Very slow		Slow		Fast		Immediate	
	Networks	Land use	Work-places	Housing	Employ-ment	Popula-tion	Goods transport	Travel
BOYCE	+				+	+		+
CUFM	(+)	+	+	+	+	+		(+)
DELTA	(+)	+	+	+	+	+		(+)
ILUTE	+	+	+	+	+	+	+	+
IMREL	+	+	+	+	+	+		+
IRPUD	+	+	+	+	+	+		+
ITLUP	+	+			+	+		+
KIM	+				+	+	+	+
LILT	+	+	+	+	+	+		+
MEPLAN	+	+	+	+	+	+	+	+
METROSIM	+	+	+	+	+	+		+
MUSSA	(+)			+	+	+		(+)
PECAS	+	+	+	+	+	+	+	+
POLIS	(+)	+			+	+		(+)
RURBAN	(+)	+			+	+		(+)
STASA	+	+	+	+	+	+	+	+
TLUMIP	+	+	+	+	+	+	+	+
TRANUS	+	+	+	+	+	+	+	+
TRESIS	+	+	+	+	+	+		+
URBANSIM	(+)	+	+	+	+	+		(+)

(+) provided by linked transport model

3 The Choice of the LUTI Model

The problem is the choice of the LUTI model compatible with the data and time available for the study.

The IRPET Institute needed results within a few months and had no functioning and updated transport model. This has led to the need to find a model integrating the transport part with the land use model and that does not require a long calibration time (so, for example, it can't be used the Austrian MARS model). On the other hand, IRPET wanted to use a model capable of providing simulations of dynamics not only for the employees or factories localization, but also for the evolution of the land use value (e.g., the dynamics of property values).

Therefore, the final choice has been the Cube Land Framework of Citilabs, a commercial software already used in many areas in the world (Milan, Montgomery-Alabama, Bakersfield-California, Metropolitan Council of the Twin Cities and others).

Cube Land models can be estimated by using disaggregated as well as aggregated data also if the forecasting process is represented by using an aggregate approach because it deal with zones, demand clusters and supply groups.

As input data, it requires:

- Control totals of households and jobs by type;
- Transportation accessibility measures by zone (to be defined by the modeler and calculated in the transport model of Cube);
- Any other relevant data and/or policies by zone (restrictions that certain land use types cannot be attributed to certain zones, subsidies and taxes)

As output data it gives:

- Households and jobs by type in each zone;
- Land uses by category in each zone;
- Locations (socio-economic information): number of Households/Firms (by cluster) in each zone and each real estate type
- Updated endogenous measures (e.g. average income)
- Supply (land uses by category): number of occupied real estates (by type) in each zone
- Economic measures: relative rental values for each real estate type (of land uses) by zone

Cube Land is a land-use forecasting model based on the Bid-Rent Theory [15, 16]. Bid Rent Theory says that the closer a property is to the center of the district, the more desirable it is. The further out a piece of land is, the smaller its value. The amount that the competing land users are willing to pay for these properties is called the bid rent. Following this theory Cube Land allocates aggregation of households and firms to real estate in each zone.

The Land Use algorithms have based on the MUSSA Land Use model developed by the Laboratory of Transport and Land Use Modelling (LABTUS) of the Faculty of Physical and Mathematical Sciences, University of Chile. The original model is been developed in 2000 for studies of land-use and transportation policy and in year 2006 it

has been integrated into Cube™ suite. We do not want here to describe MUSSA model [17–20] in detail but only to introduce its main features.

MUSSA models land use changes by simulation of the real-estate market solving the classical location problem that is to say simulating the expected location of agents (residents and firms) in the urban area. Agents' behaviour is probabilistic while there are internal interactions that makes the equilibrium research a complex and nonlinear problem. In fact, the model assumes a final land use equilibrium state with a Microeconomic approach the system need to reach equilibrium between suppliers (developers) and consumers (households and firms). The calculation complexity is due to each agent location choice that depends on all other agents' choices with an internal endogenous dynamic. The system, also allows the explicit representation of the set of physical constraints (e.g. land availability) and planning regulations that supply must comply with (taxes, fares and others).

MUSSA has developed initially to build land use scenarios as inputs for the transportation model of the Santiago del Chile area. In this case study it has been used to forecast residential and non-residential location and, then, to estimate the transport demand required by the strategic transport equilibrium model in Santiago (previously, land use scenarios were estimated by using historical trends, linear growth rates, information of recent real estate projects, spatial capacity constraints, etc.). Thereafter, this model has also been used to detect relocation processes originated by transport projects (as we will see in the next paragraph, this is one of the project presents of our study area).

4 The Study Area and the Urbanistic Forecasts

The study area includes the whole Florence city urban area and the metropolitan area linking Florence to the city of Prato and Pistoia, the so-called "Piana Fiorentina". The main feature of this Area, which covers a surface of approximately 681 km^2, consists of the presence of a high tourist attractive city, i.e. Florence.

Moreover, there are several industrial locations, such as Pistoia tree nursery sector and industrial area of Prato, as well as a number of medium-sized urban centers (Signa, Lastra a Signa, Scandicci and other centers) gravitating towards Florence Area (see Fig. 2). In addition, the road network contains the E35 motorway linking Florence and surroundings to Northern Italy, mainly with Milan and Bologna, and to the South with Rome; while the A11 motorway, which connects Florence with the coastal area of Versilia, i.e. with cities of Viareggio and Forte dei Marmi. Finally, the regional road S. G.C. Fi-Pi-Li, links Florence Area with West cities of Pisa and Livorno [21].

4.1 The Collection of Project Forecasts

The first step, preliminary to each modeling activity, was the collection of data relating to the projects planned in the aforementioned area, searching from the regional Mobility plan up to the urbanistic forecasts of the single municipality.

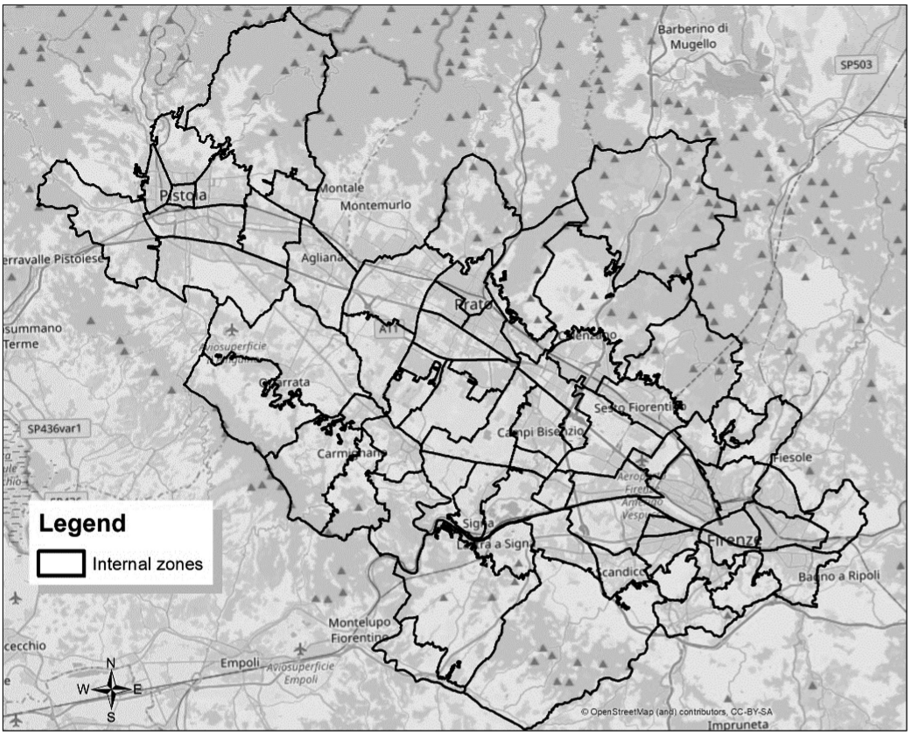

Fig. 2. The study area

The main road infrastructure projects are the four tramway lines completion, three new roads to avoid crossing flows in urban centers and four new roads including the one near Peretola Airport (dues to main airport runway direction change).

The greatest data collection work was the gathering and homogenization of the urbanistic forecasts (surfaces foreseen for each land use type) in the thirteen Municipalities involved. Results involved about 2.6 km^2 of which 49% of new residential settlements, 29% of new commercial areas and 22% of future productive/industrial areas. The new residential areas widely distributed, with the exception of the municipalities in the province of Pistoia while commercial areas are concentrated near Calenzano and Campi Bisenzio and the industrial/productive settlements are mainly in the area of Osmannoro in the North-West of Florence and in the South-West of Prato (see Fig. 3).

4.2 The Multimodal Transport Model

The multimodal transport model is based on a daily temporal step for an average winter school day. The area was divided into internal zones (71 zones, see Fig. 2), local outdoor areas, corresponding to the neighboring municipalities within the Florence province and areas outside the province itself. The private network transport supply was inherited from the existing graph of the Tuscany Region model, introducing some

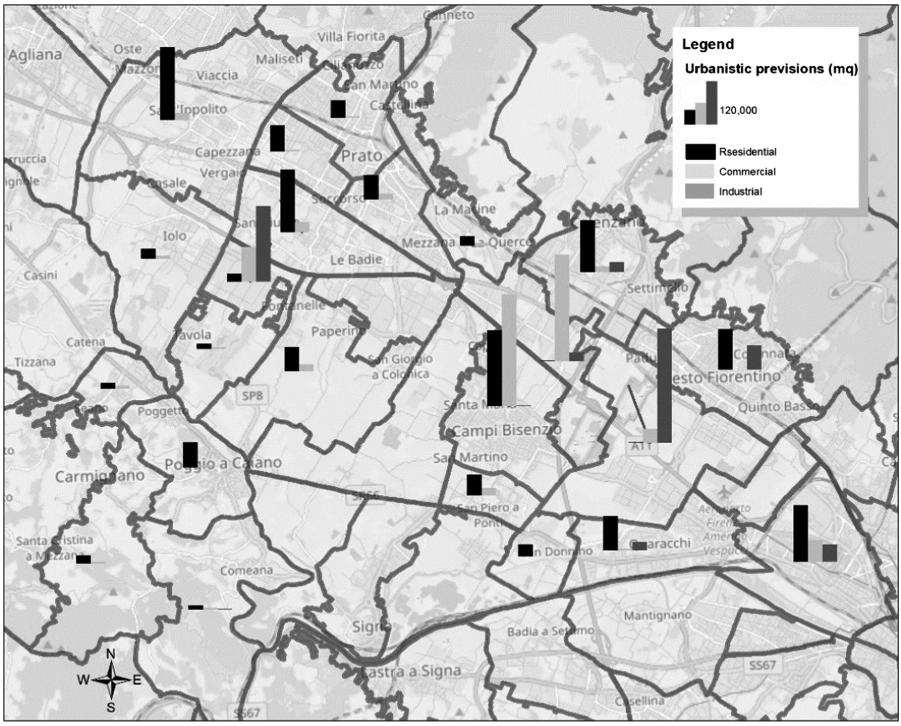

Fig. 3. Urbanistic forecasts for each land use type

further details in correspondence with future project areas. Furthermore, for the road cost functions calibration, the data of car insurance Black Box were asked at the CNR (Italian National Research Center), data consisting of GPS tracking points that is real big data, data on which extensive research has already been done [22–24] and which, after verifying the statistical significance of the data, allow us to calculate the average vehicles speed on the single street links.

Daily schedule public transport program where collected, both of rail service and for bus one and over 400 lines with frequency scheme and their mileage rates were loaded in the model.

Now the generation and distribution model step has built within Cube Voyager™, and both the generation and distribution steps have calibrated. The greatest difficulty has encountered in the generation step, because there were areas with similar characteristics at the level of employees and population but with different ability to generate/attract movements. The final calibration of the generation phase reported an RSquare index of 0.59 with a trend per zone as shown in Fig. 4. After, the distribution phase has calibrated, reaching in this case an RSquare value of 0.89 and verifying the same for distance bands equal to five kilometers (see Fig. 5). At the level of the modal split model, the model used in the city of Florence was inherited. The assignment phase finally has produced the cost matrices that are one of the inputs of the land use model and represent the interaction between the latter and the transport theory.

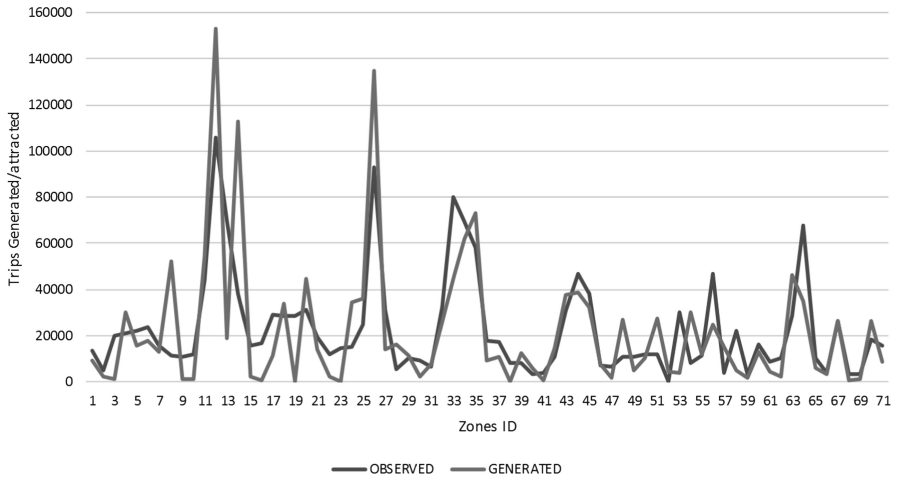

Fig. 4. Graph of the generation phase calibration results

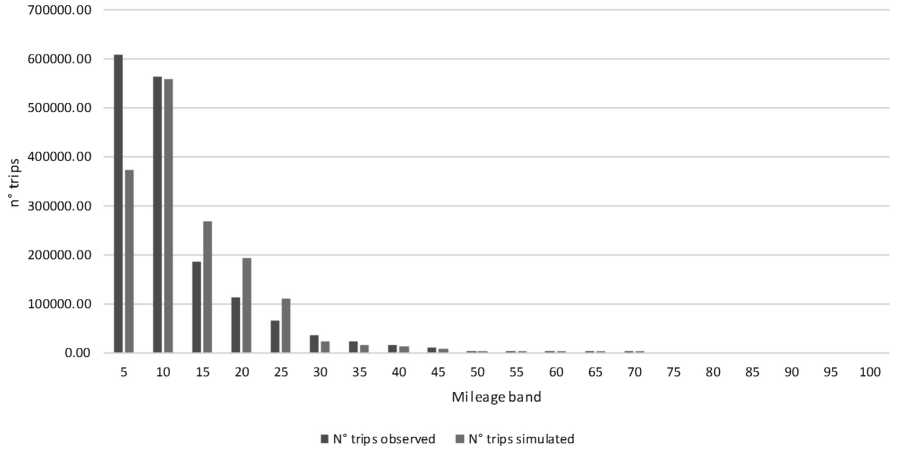

Fig. 5. Graph of the distribution phase calibration results

4.3 The Land Use Model

The Land Use model implement two main markets, namely the housing market and that of economic activities. For each market, a series of agents have introduced competing for the occupation of the territory and localization choice.

In relation to the residential market, the agents identified, quantified at household level for each zone, are:

- Household with head without work - Agent 1 (divided between students and unemployed);
- Household with head without work - agent 2 (retired);

- Low-income households;
- Middle-income households;
- High-income households.

In relation to the business sector, the following agents have introduced:

- Activities of the large-scale retail trade;
- Minor commercial activities (<20,000 km^2 surface);
- Tertiary sector activities;
- Productive/Industrial activities

The data collected, about accessibility (time to reach all other zones with private or public modes or time to be reached in a passive viewpoint), land values, employees, population, school system and others, allowed us to calibrate the Land Use model Bid Rent Functions based on two Discrete Choice Models (Login Multinomial model), one relating to the residential market and the other relating to economic activities one. Biogeme™ software [25] has used to calibrate the above models. The following are the utility functions generated by the aforementioned model for the two markets:

– Residential Market (Likelihood ratio test: 225.025, Adjusted rho-square: 0.179)
  Utility (Students/Unemployed) = −0.00765 * Private active Accessibility Index + 5.87 * N° Household (Stud/Unempl.)
  Utility (Retired) = −0.000914 * Private active Accessibility Index + 5.87 * N° Household (Retired)
  Utility (Low Income Hous.) = −0.0104 * Private active Accessibility Index + 7.13 * N° Household (Low Income Hous.)
  Utility (Medium Income Hous.) = −0.00592 * Private active Accessibility Index + 6.67 * N° Household (Medium Income Hous.)
  Utility (High Income Hous.) = −0.0223 * Private active Accessibility Index + 12.6 * N° Household (High Income Hous.)
– Activities Market (Likelihood ratio test: 237.581, Adjusted rho-square: 0.271)
  Utility (Minor Commercial Act.) = −1.48 * av1 −0.0113 * Private active Accessibility Index + 8.65 * Minor Commercial Act. Percentage
  Utility (Large-scale Retail Trade Act.) = −2.55 * av2 −0.00626 * Private active Accessibility Index + 18 * Large-scale Retail Trade Act. Percentage
  Utility (Tertiary Sector Act.) = 2.44 * av3 −0.0172 * Private active Accessibility Index −3.84 * Tertiary Sector Act. Percentage
  Utility (Productive Act.) = 1.60 * av4 −0.0103 * Private active Accessibility Index −2.18 * Productive Act. Percentage

The previous equations show some important features: High Income Households, in the Residential Market, are the agents most sensitive to proximity to other agents of the same type. Moreover, these last give greater weight to accessibility while accessibility is important for all residential agents excluding retired people. With attention focused on the Activities Market, it is clear that Large-scale Retail Trade activities are the most sensitive to proximity to similar agents, but they give low importance to accessibility index; commercial activities, in general, search to localize near other commercial ones while for Tertiary and Productive Sectors there is a negative weight to the presence of other similar activities.

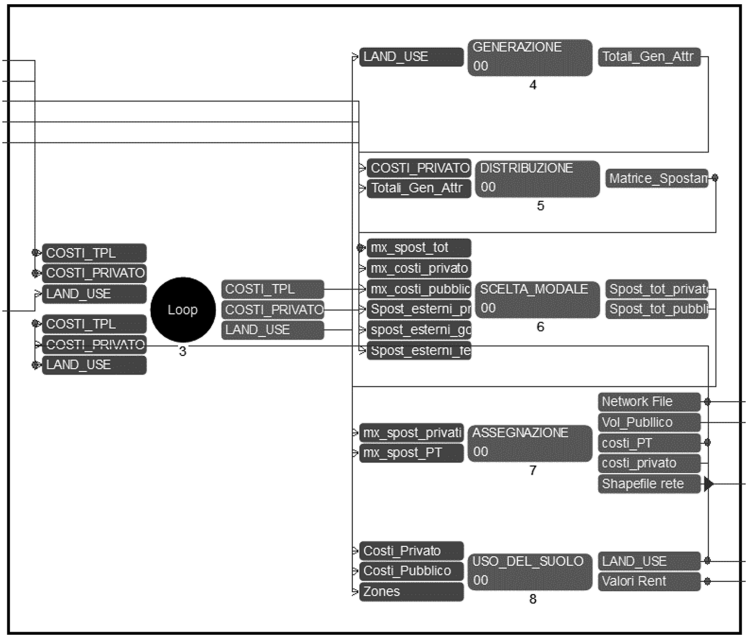

Fig. 6. The Land-Use model loop

These equations have introduced in the model inside the Land-Use equilibrium loop (see Fig. 6).

5 Results and Future Researches

The first simulated scenario regards the complete functionality of the tramway lines, including some extensions not yet present but planned. The introduction of an easy access system to the Florence CBU highlighted two very interesting phenomena, one relating to the population residences distribution and the other to the activity market.

In relation to the first one, given the increase of real estate values of the center, a phenomenon of migration towards external areas was highlighted; areas at lower costs, made closer by the tramway, became of interest for low-income households against an increase of population in the center for high-income households (see Fig. 7). Probably, this interest for the center underline their attempt to invest in its space and in the value that this area comes to have, buying homes to rent to foreigners and tourists. In practice, it can be hypothesized the origin of the classical Gentrification dynamic, given the tourist rents high profitability. This would lead to the loss of identity of the central inhabited areas, certainly a phenomenon to be avoided by housing policies aimed at encouraging population to remain in the city center. Another phenomenon emerged, relating to the activity sector, is due to the increase in the land value in the peripheral areas made more accessible by the tramway. The model shows a replacement phenomenon between tertiary and industrial activities: in fact the former tend to move to

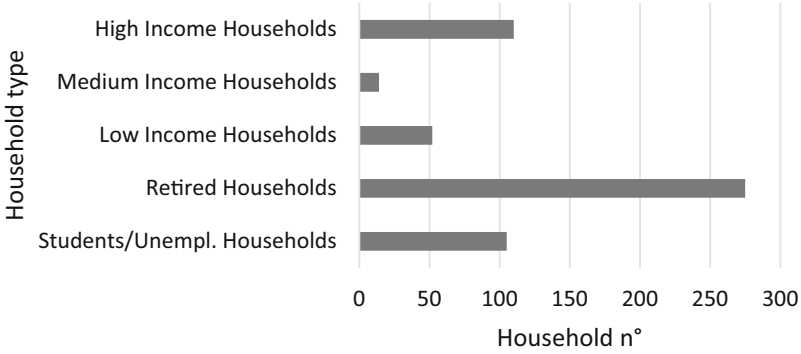

Fig. 7. Number of households divided for type changing their residential location

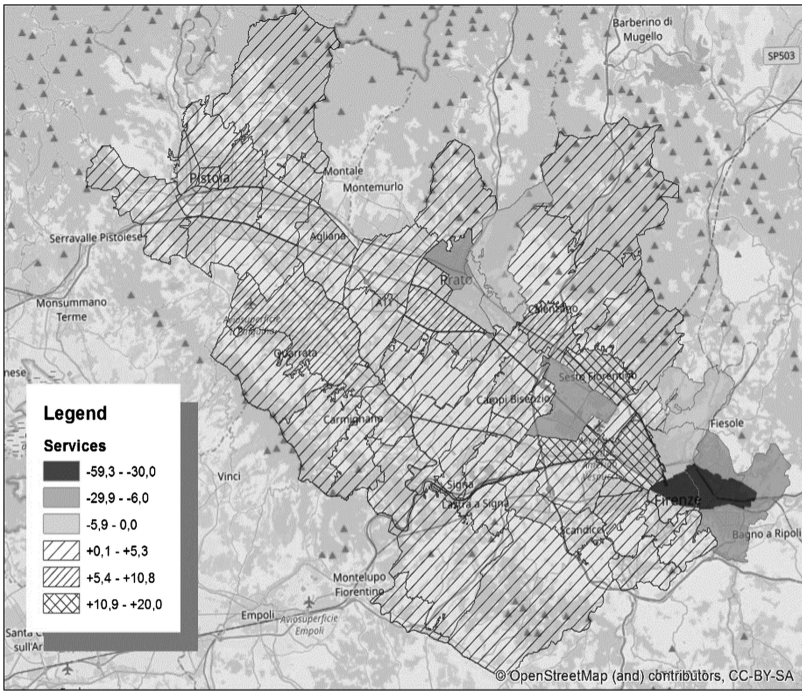

Fig. 8. The replacement of Tertiary/Services activities (negative for leaving activities)

the new areas made accessible by the tramway where the population will increase while the industrial activities tend to move to areas where land value does not change, areas not affected by the tramway presence (see Figs. 8 and 9).

As a result, the model in this first scenario shows very interesting and useful land-use dynamics able to change the residences and activities distribution in the study area and to influence the territory gravitational power with a deep impact on the flows

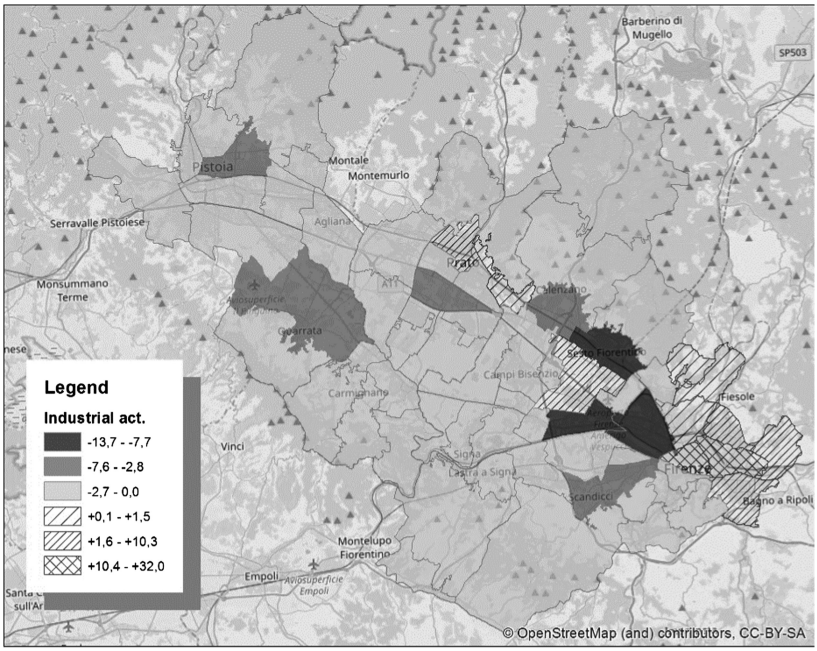

Fig. 9. The replacement of Productive Sectors activities (negative for leaving activities)

distribution with respect to a static territorial scenario, typical of purely transportation models. The analysis of further scenarios, for example, the one related to the City Urbanistic Plan forecasts (see Fig. 6) will add other decision support information for Tuscany Region and IRPET Institute.

References

1. ISFORT-Superior Institute of Teaching and Researching on Transport, 2018: 15° Report on Italian mobility
2. Chinellato, M., Staelens, P., Wennberg, H., Sundberg, R., Bohler, S., Brand, L., Adams, R., Dragutescu, A.: Sumps-Up-Users' needs analysis on SUMP take up. European programme for accelerating the take-up of sustainable urban mobility plans, deliverable **1**, 2 (2017)
3. European Commission 2007: Sustainable Urban Transport Plans - Preparatory Document in relation to the follow-up of the Thematic Strategy on the Urban Environment, Annex, 25 September 2007, Source. http://ec.europa.eu/environment/urban/pdf/transport/2007_sutp_annex.pdf
4. European Commission 2009: Action Plan on Urban Mobility COM, 490/5 (2009). Source. http://ec.europa.eu/transport/themes/urban/urban_mobility/action_plan_en.htm
5. European Commission 2011: WHITE PAPER. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. COM (2011). 144 final. Source: http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm

6. Oliva Garcia, C.R., Feijòo, C., Aggarwal, S.: D2.3 Review of Urban Models: Use in Urban Policy, European project Insight (2014)
7. Ransford, A.A., Silva, E.: Land use-transport interaction modeling: a review of the literature and future research directions. J. Transp. Land Use (2014)
8. Iacono, M., Levinson D., El-Genheidi A.: Models of transportation and land use change: a guide to the territory (2010)
9. Rosenbaum, A.S., Koenig, B.E.: Evaluation of Modeling Tools for Assessing lan use policies and strategies, Office of Mobile Sources U.S. Environmental Protection Agency (1997)
10. Lombardo, S., Petri, M.: The simulation of spatial change: what relation between knowledge and modeling? A proposal and its application. In: Albeverio, S., Andrey, D., Giordano, P., Vancheri, A. (eds.) The Dynamics of Complex Urban Systems. An Interdisciplinary Approach. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-7908-1937-3_16
11. Lapucci, A., Lombardo, S., Petri, M., Rotonda, M.: A participative multi agent system for urban sustainable mobility. In: Murgante, B., Borruso, G., Lapucci, A. (eds.) Geocomputation and Urban Planning a cura di Borruso. Murgante e Lapucci. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-540-89930-3_15. ISBN 978-3-540-89929-7
12. Wilson, A.G., Bennett, R.J.: Mathematical Methods in Human Geography and Planning. John Wiley and Sons, Chichester (1985)
13. Waddell, P.: Building an integrated model: some guidance. In: Presented at, TRB workshop 162 on integrated land use-transport models, Washington, D.C. (2005)
14. Wegener, M.: Overview OD land-use transport models. In: Hensher, D.A., Button, K. (eds.) Transport Geography and Spatial Systems, Handbook 5 of the Handbook in Transport, pp. 127–146. Pergamon/Elsevier Science, Kidlington (2004)
15. Alonso, W.: Location and Land Use, Towards a General Theory of Land Use. Harward University Press, Cambridge (1964). ISBM 9780674730854
16. Ross, S., Morgan, J., Heelas, R.: Essential AS Geography, Nelson Thornes Ltd (2000). ISBN-10: 0748751750
17. Martínez, F., Donoso, P.: MUSSA: a behavioural land use equilibrium model with location externalities, planning regulations and pricing policies, University of Chile (2006)
18. Martínez, F., Aguila, F., Hurtubia, R.: The constrained multinomial logit: A semi-compensatory choice model. University of Chile, Santiago, Chile (2009)
19. Martínez, F.J.: MUSSA: A Land Use Model for Santiago City. Transportation Research Record 1552: Transportation Planning and Land Use at State, Regional and Local Levels, pp. 126–134 (1996)
20. Martínez, F.J.: The bid-choice land use model: an integrated economic framework. Environ. Plann. A. **24**, 871–885 (1992)
21. Pratelli, A., Petri, M., Ierpi, M., Di Matteo, M.: Integration of Bluetooth, vechicle count data and transport model results by means of Datamining Techniques. The application to the regional highway S.G.C.Fi-Pi-Li linking Florence to Leghorn and Pisa. In: 2017 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), 12–15 June 2018. Palermo (2018)
22. Petri, M., Frosolini, M, Pratelli, A., Lupi, M.: ITS to change behaviour: a focus about bike mobility monitoring and incentive—The SaveMyBike system. In: IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC) (2016). https://doi.org/10.1109/eeeic.2016.7555463. ISBN: 978-1-5090-2321-9
23. Petri, M., Fusco, G., Pratelli, A.: A new data-driven approach to forecast freight transport demand. In: Murgante, B., et al. (eds.) ICCSA 2014. LNCS, vol. 8582, pp. 401–416. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-09147-1_29

24. Petri, M., Pratelli, A., Fusco, G.: Data mining and big freight transport database analysis and forecasting capabilities. Trans. Marit. Sci. **5**(2), 99–110 (2016)
25. Bierlaire, M.: BIOGEME: a free package for the estimation of discrete choice models. In: Proceedings of the 3rd Swiss Transportation Research Conference. Ascona, Switzerland (2003)