Irregularities in the output of transport planning models’ forecasts for capital infrastructure planning decisions

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Abstract

In this paper, evidence from the literature on the inaccuracy of forecasts from transport planning models is presented and its impact on capital infrastructure planning decision-making is demonstrated. Empirical evidence suggests that forecasts used for major planning decisions internationally have been found to be rather inaccurate (when comparing forecast flows with actually realized flows after time passed). Evidence of these irregularities in the case of a major expressway infrastructure project in Southern Greece is presented, providing a typical example of a country with an inadequate freeway network. Data from the immediate impact zone of the Attiki Odos tollway in the metropolitan area of Athens are used to demonstrate that the project resulted in a considerable change in the land use patterns and density, resulting in the generation of additional traffic flows. Having demonstrated the need for re-thinking how long-term traffic is forecast, suitable recommendations for promising directions are made. Dealing with uncertainty is one key aspect that can be easily incorporated to existing forecasting tools. Furthermore, the need for more detailed and area-specific models, e.g. through the integration of activity-based modeling, specific mobility patterns and demands etc. are also outlined.

1. Introduction

Transportation planning and forecasting models are used as the basis for capital infrastructure decisions. Quite often, however, the results of these models show considerable irregularities, when compared with the actual traffic observed when the forecast horizon has passed. This does not imply that the models or the modelers underperformed, but rather that there are some inherent difficulties that may not be always taken into account. The objective of this paper is to provide some insight into these difficulties, through a review of related literature, and then attempt to quantify the impact of one such factor (the land-use – transport interaction) through an application in the Attiki Odos motorway in the Athens, Greece, area.
According to Rodier (2004), it is widely acknowledged that forecasts produced by travel and emission models are typically inaccurate; it is not uncommon to find large differences between predicted and actual outcomes. Some transportation professionals believe that current state-of-the-art methods can forecast emissions with an accuracy of plus or minus 15 percent to 30 percent (Chatterjee et al, 1997). Rodier (2004) also concludes that recent evidence for the induced travel hypothesis has increased concerns over the limited ability of most regional travel demand models to represent how an increase in roadway supply reduces the time cost of travel and, to the extent that demand is elastic, increases the quantity of travel demanded.

Parthasarathi and Levinson (2009) note that while research efforts have focused on improving the technical aspects of a typical four-step transportation planning model, few studies have evaluated the model accuracy by comparing forecasts to actual traffic counts. The analysis indicated that traffic forecasts on 61.5% of the links were underestimated compared to the actual traffic counts and the forecasts were more accurate for higher volume roadways. Parthasarathi and Levinson (2009) also evaluate the accuracy of demand forecasts using a sample of recently completed projects in Minnesota (with a horizon forecast year of 2010 or earlier) and identify the factors influencing the inaccuracy in forecasts. The analysis indicates a general trend of underestimation in roadway traffic forecasts with factors such as highway type and functional classification playing an influencing role. Roadways with higher volumes and higher functional classifications such as freeways are subject to more severe underestimation compared to lower volume roadways/functional classifications.

An explanation for the underestimation seen in forecasts, specifically road forecasts, can be attributed to the non-incorporation of induced traffic into the model forecasting procedure (Noland, 2001). The theory of induced demand states that increases in highway capacity induces additional growth in traffic resulting in increased levels of vehicle traffic. From an economic perspective, the travel demand increases as the cost of travel decreases due to capacity improvements resulting in an elasticity of demand associated with travel (Noland and Lem, 2000).

Flyvberg et al. (2006) present results from a large-scale study of traffic forecasts in transportation infrastructure projects, using a sample covering 210 projects in 14 nations worth US$58 billion. The study shows that forecasters generally do a poor job of estimating the demand for transportation infrastructure projects. For 72% of rail projects, forecasts are overestimated by more than two-thirds. For 50% of road projects, the difference between actual and forecasted traffic is more than ±20%; for 25% of road projects, the difference is larger than ±40%.
2. Factors affecting inaccuracy of transportation forecasting

Sammer (2006) observes that while the currently available modelling approaches are considerably more flexible and powerful than those of the 1990s, there is considerable evidence that the gap between state-of-the-art theory and practice, i.e. the actual modelling of transport, is widening. One of the implications of this observation is that trust in the validity of modelling results is decreasing significantly. Concluding, Sammer (2006) summarizes the problems in transportation forecasting as: (i) the models, and especially the produced forecasts, suffer from the “black-box effect”, as they cannot be followed through and understood, (ii) many of the models are no longer state-of-the-art, (iii) there is little or no evidence for the validity of the input data used or how the model was calibrated, and (iv) the results are presented as point estimates, rather than interval estimates based on a probability function, with confidence limits specified.

Transport models are (often complex) approximations of very complex systems. Therefore, a number of errors can occur which may have an impact on the accuracy of the forecast results (Sammer, 2006):

- Measurement errors;
- Random errors;
- Forecast errors due to the input data used;
- Computational and application errors;
- Model specification errors;
- Transferability errors (when attempting to apply a model calibrated in one region to another);
- Aggregation and disaggregation errors.

These errors may either result in additive (or even multiplicative) effects, or cancel out (thus hiding potentially important model shortcomings).

Litman (2005) examines how various land use factors such as density, regional accessibility, mix and roadway connectivity affect travel behaviour, including per capita vehicle travel, mode split and non-motorized travel. Litman concludes that land use factors can have significant impacts on travel patterns, but that current transportation models are not accurate at predicting their effects.

Wegener and Fuerst (1999) indicate that the impacts of transport policies on transport patterns are clearer and stronger compared to the interplay of land use and transport. While travel cost and travel time have a negative impact on both trip length and trip frequency, accessibility has a positive impact on trip length and frequency. Mode choice is dependent upon the relative attractiveness of a mode compared to all other modes. The fastest and cheapest mode is likely to have the highest modal share. In general, the theoretical considerations support the conclusion that the impact of ‘pull’ measures, i.e. land use measures, is much weaker than the impact of ‘push’ measures, i.e. increases in travel time, travel cost etc.
3. An empirical analysis of the changes in land-use and traffic patterns due to the Attiki Odos Motorway

In this section, an empirical analysis of the impact of land-use into traffic patterns due to the Attiki Odos motorway in the Athens area is presented.

3.1. Methodology for on-site surveys for data-collection

One of the big challenges associated with modeling and other estimation efforts lies in the original data input. In this case, we have relied in a wide variety of sources for data collection. In the core of this effort, however, is a set of **coordinated on-site surveys**, aimed at providing first-hand, reliable evidence for the ground-truth situation. These on-site surveys are based on specially designed survey forms and were executed by experienced and skilled engineers on the field.

The objective of this effort is to ultimately obtain reliable estimates for the number of trips that are being generated from second-level induced traffic, i.e. additional trips generated by extended land use changes due to improved accessibility. In this case, the scope of the study is primarily commuter traffic from a strip of land around a major road infrastructure project. These changes are arguably primarily due to **land use changes and subsequent socioeconomic changes**, resulting directly from the infrastructure improvement. More buildings with more apartments result in more households that may make trips. Furthermore, changes in the cost of land might lead to the attraction of more affluent households that presumably have a higher car ownership and make more trips. It is expected that –assuming a reasonable selection of the strip of land under study- the vast majority of the trips will be absorbed by the infrastructure project under study.

The main steps of the methodology are presented next. The first step was the **selection of a suitable project** to be used for the analysis. The criteria for selection included:

- Time since the project was constructed (a more recent project would be more advantageous, as the impact would be closer to the present time)
- Size of the project, ideally a large-scale project.

It quickly became apparent that the **Attiki Odos motorway** is an ideal candidate for this analysis, as it is a large-scale project that was completed only a few years ago.

Once the project has been identified, the next step is to **define the analysis area**. Considering the international literature and engineering judgment on this topic, a strip of land extending 1.5km to each of the sides of the project was selected (i.e. a 3km wide strip). Clearly, the impact of such a project in shaping commuting behavior of neighboring areas extends well outside of this area, but this was selected as a conservative range.

The next step is to **segment the study area** into analysis zones with fairly uniform characteristics. The two main criteria for this segmentation are:
- Building code regulations in the various municipalities.
- Building density and "saturation", i.e. whether the area has reached a state where undeveloped land is scarce and the only way to grow is vertically, or whether there is still room to grow horizontally.

Based on the intersection of the above two classifications, a number of fairly homogeneous analysis zones is developed, for which the analysis will take place.

The last requirement for the performance of the on-site surveys is the **design and validation of the forms**. Suitable forms have been developed, based on the international literature and the experience of the project team. These forms were used by skilled and experienced engineers who recorded the required data in a series of field visits in the covered areas. The surveying engineers collected data such as the number of buildings per block, the number of floors per building and the number of apartments (and hence households) per floor. Prior to the actual on-site surveys, a round of pilot evaluation took place, where the forms were used for surveying a couple areas. Based on the feedback, minor improvements were made to the forms, resulting to the final forms that were used for the on-site surveys. One such improvement was the addition of an area in the form for the inclusion of a digital photo of the surveyed area.

Following the completion of the on-site surveys, the data were **analyzed, validated, and verified**. The process included tabulation of the data in appropriately designed tables, and analysis using reality checks.

The next step, once all the data has been collected, is to use the collected data from the surveys and the aerial photographs (e.g. number of buildings per analysis zone) to observe abrupt land-use changes and estimate changes in the number of households.

Clearly, this kind of work involves several assumptions. The general direction that was followed was towards making **conservative assumptions that would lead to an underestimation of the impacts** of the new infrastructure. This would add an extra layer of confidence in the findings, as the result of the surveys would clearly underestimate the impacts. For example, in the computation of the change in the number of households around Attiki Odos between the years 2000 and 2008 (present), two assumptions (leading to clear underestimation) were made:

- For a large part of the influence zone (more than half), in which the changes were not dramatic, the number of households was held constant. This includes both well built-up areas, such as parts of Marousi, Vrilisia, and Halandri, and less developed areas (such as parts of Elefsina, Aspropirgos and Spata).
- For the parts of the influence zone for which the change in the number of buildings between 2000 and 2008 was computed, the number of households per building was assumed to be constant (for the computation of the change in the number of households).
3.2. Influence of Attiki Odos on residential development

The survey focused only on a subset of the influence zone, for which the impact was more evident. The results are then aggregated with the counts from the remainder of the influence zone, with the assumption that these other zones were largely saturated and the increase in households during this period has been zero. Clearly, this is a very conservative approach.

Figure 1 outlines the survey results for the surveyed zones around the Attiki Odos motorway. A closer examination at these change rates reveals (or rather supports empirically) some interesting patterns. For example, *areas that were already well-built-up prior to the operation of the Attiki Odos* motorway, such as Marousi, Halandri and Agia Paraskevi, show more moderate growth rates (still *around or even exceeding 20% annually for a period of 8 consecutive years*), while areas that were less developed and had more room for growth (e.g. Elefsina, Aspropirgos and Ano Liosia) *show annual growth rates exceeding 50%*.

![Figure 1. Survey results for zone influenced by Attiki Odos. Number of households per survey zone (top); annual change in household number per surveyed zone (bottom).](image-url)
Using household data (showing the exact number of households and population per building block) from the National Statistical Service of Greece (ESYE) for 2000, the number of households in the influence zone in 2000 was 83,802, with 30,222 of them in the areas that showed further growth and 53,850 in the areas that were excluded from the survey (and therefore conservatively assumed that the number of households remained constant). The number of households in the surveyed zones, as computed for the 2008 situation (using the number of buildings from 2006), was found to be equal to 87,458, bringing the total number of households for the entire influence zone (of 1.5km) for 2008 (using data for 2006 for the areas that were not explicitly surveyed) to 141,038 households. Therefore, a total increase of 68% in households was recorded over a period of 8 years, which translates to an annual increase in households equal to 8.5% for the entire influence zone.

4. Findings

In this paper, a synthesis on the literature on the irregularities in the output of transport planning models' forecasts for capital infrastructure planning decisions is presented, along with some empirical evidence supporting it and shedding some light into it. Several directions can be outlined for dealing with these limitations, including:

- Activity based modeling: which can be used to improved forecasting models incrementally by integrating more land use factors, such as mix, connectivity and design, and by incorporating feedback loops between steps to recognize reciprocal impacts (Litman, 2005).
- Dealing with uncertainty: several researchers (e.g. Zhao and Kockelman, 2002, and Beser Hugosson, 2004, 2005) study the problem of how a given transport model cannot only produce a central estimate of traffic volume or revenues, but also uncertainty margins around these.
- Bridging the gap between state-of-the-art and state-of-the-practice: Sammer (2006) identifies several reasons for this, including the demand for low-cost solutions, increasingly complex (and therefore increasingly obscure) transport modeling software, and the lack of available quality standards and procedures.

References


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3This leads to a conservative underestimation of the households for the present situation, since it ignores the extra development that took place in the last few years (2006-2008) in these areas.


