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Evaluation of synergies from transportation policy packages using a social welfare maximization approach: A case study for Madrid, Spain

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ABSTRACT

This paper discusses the evaluation of synergies that derive from the implementation of policy packages designed to promote the use of public transportation and limit traffic congestion in urban areas. In this study, we propose the application of a land-use and transportation integrated (LUTI) model to study the outcomes from the implementation of two policy packages. We apply the long-term strategic LUTI model MARS-Madrid to analyze an empirical case study in Madrid, Spain. The analyzed policies include a road pricing scheme (congestion charge) in the city center and an increase in the level of service of public transportation (bus frequency changes) in the whole region. Different scenarios, involving the implementation of respectively each one of these policies separately or both policies simultaneously, are simulated and compared to a base scenario (business as usual, or "do-nothing"). We evaluate the effects of these policies on several transportation indicators and on social welfare, and discuss the optimization of these policies in isolation or combined as a policy package. The study provides insights into the suitability of the proposed LUTI modeling approach to evaluate the impact of transportation policies in urban and metropolitan areas, and the evaluation of synergies from transportation policies, a topic that is not enough studied in the literature.

1. Introduction

Urban regions face serious problems associated with land consumption and rapid land-use and transportation development. As a consequence, planners and decision-makers have an increasing need to improve their knowledge and access decision support tools for the evaluation of policy strategies that can contribute to reduce traffic congestion, increase quality of life, or ensure future economic prosperity (Pfaffenbichler et al., 2008).

The integration of transportation policies in broader plans and policy packages in urban and regional planning allows a more efficient and successful way to address transportation problems in complex urban areas (Hull, 2008). This is particularly important for the definition of packages of policies that are designed to increase the efficiency of transportation, and to increase environmental sustainability and quality of life in urban areas. The challenge today is in the attempt to create more sustainable urban transportation systems: single isolated policies have often proven to provide only limited results (Hull, 2008; Geerlings and Stead, 2003; van Wee, 2002; May et al., 2001). An isolated policy is usually not able to increase the sustainability of an urban transportation system per se. Not only it might have limited effects in its implementation; an isolated policy, might also have negative side effects on other sectors.

The correct estimation of the benefits (and costs) associated with these policy packages directly depends on the ability to properly assess the impacts of the simultaneous implementation of multiple policies in planning (integration). Unfortunately, the evaluation of synergies associated with policy integration is a rather complex task, which is seldom studied in details in the evaluation of the outcomes from transportation policies.

The simultaneous implementation of several strategies can produce various results, depending on the way the policies interact. The European Project SPECTRUM-D4 (Mayeres et al., 2003) identifies four different types of interactions that can exist: complementarity, additivity, synergy and perfect substitution. A detailed description of each one of these types of interaction is provided by May et al. (2006). May et al. (2012) distinguish

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between different types of integration; for instance, one of those is the strategic integration of transport policy instruments with land-use planning. However, as they note, integration is frequently advocated as a principle in urban transport policy, but rarely defined.

In our study, we make a first step in this direction, analyzing the integration of two transport policies and looking for evidence of synergies. We adopt the concept of synergy to refer to a (predominantly) positive effect that can derive from the simultaneous adoption of two policies. According to this definition, a synergy is associated to the increase in the benefits (and/or, respectively, a decrease in costs) associated with the simultaneous adoption of two or more policies, whose total effects are larger than the sums of the effects that would be obtained if each policy was implemented separately. This concept is strictly connected to the concept of complementarity of the implemented policies: therefore, the definition of (positive) synergies is one of the main targets that planners and decision-makers should try to achieve in the definition of the policies to adopt in planning (Santos et al., 2010).

The most important issues that need to be addressed when investigating the synergies from transportation policies are: (1) the identification of the optimal combination(s) of policies to implement, given that the results of each policy may vary depending on the way other policies are implemented; and (2) the selections of the policies and interventions that are necessary and sufficient to achieve the required targets of efficiency, equity and maximum performance in planning. As May et al. (2006) point out, several restrictions and/or limitations (e.g. budget and local regulations) might exist: these limitations need to be considered in the process of policy evaluation and in the investigation of synergies, as they might limit the possible policy options and/or the applicability of the proposed packages of policies.

This study focuses on one of the issues mentioned above: the identification of the optimal combination of policies to achieve a set of objectives in planning. We adopt two main assumptions in this study: the first one is the adoption of a land-use and transportation interaction context for the evaluation of policy results. In fact, the development of strategies to increase sustainability in transportation requires a holistic approach to the analysis of these relationships, so that transportation, land-use planning and environmental analyses could be more effectively coordinated for the achievement of the proposed goals (ECMT, 2001). Regarding the second assumption, we here limit the scope of this study to the analysis of the interactions between two transportation policies. Previous research has suggested that synergistic effects may increase dramatically when additional policies are added (Wood, 2007), as the number of possible synergistic interactions increases notably (assuming that most of these interactions generate positive synergies).[1] In this study, given the large number of policies (and the differences among them), the analysis is restricted to just two instruments that generate a policy package. In particular, in the empirical study presented in the following sections, congestion pricing is chosen following the Pigouvian tradition of charging for the external costs produced by an agent's decision.[2] This policy instrument charges car users for trips to the city center. The second policy instrument deals with an improvement in the public transportation (PT) service frequencies. In this portion of the research study, we do not discuss the integration of these policy packages with additional land-use policies, which will be the topic of future research extensions. Similarly, additional further extensions of this project will explicitly model the effects of more complex policy packages including more than two transportation or land-use policies.

In this study, the evaluation of the policy packages is carried out through a social welfare maximization approach. We use the land-use transportation interaction model Metropolitan Activity Relocation Simulator, MARS (Pfaffenbichler, 2003) adapted and calibrated for Madrid Region (Guzmán, 2011) to simulate the interactions between transportation and land-use development, and adopt an optimization procedure that maximizes the social welfare objective function in the policy design. We build on the previous experience from the literature to discuss the possible synergies from the combination of these transportation policies in an urban region. A priori, if congestion pricing is implemented, travelers' surplus is expected to decrease as the full price that car drivers pay is larger than the time cost they pay without congestion pricing. Thus, congestion pricing generates an increase in the total social welfare because tax collection becomes higher than traveler surplus reduction. This makes the reinvestment of congestion charge revenues an important opportunity to provide subsidies for public transportation and improve scheduled PT services. This represents one of the most commonly recognized successful combinations of transportation policies in urban areas. Our work focuses on the definition of the optimal levels of the proposed policies that are required to achieve sustainability targets (i.e. maximum social welfare, in the empirical case study presented in this paper). We first develop scenarios in which the implementation of each policy is optimized "in isolation". Then, we simulate the scenarios in which more than one policy is developed at the same time. We compare the results from the implementation of these simple scenarios with those containing the implementation of the combination of the policies. Then, we compare the level of social welfare resulting from each scenario, under the assumption of optimal policies optimized "per se", or combined in a policy package to reach an optimal strategy.

The remainder of this paper is organized as follows: after this brief introduction, the next section discusses the background and methodology of this study. It briefly describes the land-use and transportation interaction (LUTI) model MARS-Madrid and the cost-benefit analysis methodology used in the analysis of scenarios. The following section describes the case study for the metropolitan area of Madrid (Spain) and provides details on the policy scenarios to optimize. Then, we present the results from the optimization process; evidences of synergies in policy scenarios are highlighted. The final section offers some concluding remarks and discusses the relevant findings from this study in terms of policy recommendations that can be derived from the analysis of synergies.

2. The evaluation and optimization of strategies in transportation planning

Comprehensive policy packages that generate positive synergies and amplify the outcomes of each policy are important pillars in the road toward increased urban transportation efficiency and environmental sustainability. The major research difficulty with the analysis of these synergies, however, lies in the correct evaluation of the multiple outcomes from these complex policy packages. The identification of synergies among policies (if/where they exist) is in fact not a trivial task, for which researchers are called to cooperate with transportation planners and policy makers in order to develop robust evaluation methodologies and identify the solutions that can optimize these strategies

[1] The presence of additional policies might further increase the level of synergies or reduce it, depending on the dominant effect of the more complex interactions among these policies. The evaluation of these complex policy packages is indeed not an easy task to develop, as the total effect of a policy package may significantly differ from the sum of the single policy effects. Each combination of policies should be specifically studied for a correct assessment of the specific interactions.

[2] Road pricing policies which aim to reduce the use of private vehicles and to promote modal shift to public transportation or non-motorized modes of transportation, have been already introduced, or proposed, in several EU cities.