Economic Evaluation of Transport Projects

The impact of transport infrastructure projects on spatial and distributional equity

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Abstract

Any public transport infrastructure project causes an heterogeneous impact on different socioeconomic groups and geographic areas. This paper describes the consequences of a project of this kind on distributional and spatial equity and it explores a wide spectrum of methods to deal with them. More precisely, the following models are discussed: hedonic price approach, cost-benefit analysis based methods, spatial need indices, multicriteria methods and industrial location models. The choice of method for equity assessment depends on the nature of each case study and the available information.
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1. INTRODUCTION

The assessment of private investment projects takes into account all current and future costs and benefits derived from the implementation of a project. Normally, if the expected rate of return is high enough, the project may be conducted. For this purpose, the methodology of cost-benefit analysis is a useful tool (see De Rus, 2008), especially in the case of private companies where the funds for the investment usually come from the companies and is aimed at making profits for themselves. The evaluation of public investment projects is quite different. On the one hand, the goals may differ with those of private companies, and on the other hand, the cash flow can also be very different because the source of funding (agents who pay taxes) and the final beneficiaries may differ or be benefited in a different proportion. Indeed, most public investment projects consciously or unconsciously cause redistributive impacts that affect the whole population.

*Distributional equity* refers to the project’s impact on net disposable income and agent’s real estate. Moreover, in the case of transport investment projects, it is necessary to determine transport nodes and corridors which cause heterogeneous spatial effects in the territory. This latter case is referred as impacts on *spatial equity*.

The use of nonrenewable resources by the current generation can positively or negatively affect the potential use of future generations. This effect depends on the life of the investment, the use of nonrenewable resources and the existence of harmful and irreversible impacts on the environment. One way to consider *intergenerational equity* into account is using a discount rate. However, there is no agreement on how to adjust it (Portney and Weyant, 1999). After Lind’s influence in the early eighties, and according to Arrow et al. (1996), two schools have emerged: Descriptive and prescriptive school. The descriptive school suggests the choice of the discount rate according to a set of ethical principles which defend the interests of future generations; alternatively the prescriptive school bases their choice of discount rate on the rate of return of other equivalent assets. Another case of impact on spatial equity arises from the differences that may exist in the physical access to the transport infrastructure.

This paper explores alternative methods for assessing the impacts on distributional and spatial equity. The approach focuses in the case of public transport projects and some methods are developed in order to be integrated within the methodology of cost-benefit analysis.
2. IMPACTS ON SPATIAL AND DISTRIBUTIONAL EQUITY

Any investment project in transport infrastructure causes different benefits among agents, such difference may be more or less marked, but it is almost impossible to make it disappear. Every socioeconomic group might have different preferences for different means of transport. These particular users and potential beneficiaries of the investment can easily be identified with a simple demand study. In this sense, an investment project that favors a particular mean of transport implies, at the same time, to favor a certain socioeconomic group. For this reason transport project assessment may consider multiple criteria when making a final decision in relation to the type of investment, transportation mode and location.

Although it is relatively easy to identify the most efficient alternative, this one may not be the most desirable alternative in terms of welfare and public interest. A public transport investment project may contribute in terms of equity and efficiency simultaneously. However, it is common to face a tradeoff between them. Hence it is up to the decision-maker the choice between equity and efficiency. Such choice is not straightforward and lack of methods that deal with this is commonplace in the literature. Given the subjective nature of this decision, any aiding tools for the decision making process and the project choice cannot provide optimal or final solutions. The purpose is to provide the decision-maker with certain quantitative methods and indicators to offer him or her further information for the decision without judging which projects are better than others.

2.1. Distributional Equity

There is much debate on the role of public investment in transport infrastructure in relation to distributional equity. To illustrate this problem we propose several possible scenarios based on two variables: the heterogeneity between winners and losers and the direction of income redistribution.

In relation to the heterogeneity among socioeconomic groups of winners and losers, there are two possible scenarios: a first scenario where everybody wins, albeit in different proportions, and a second scenario where some groups win and others lose. In the first case, if the project implementation benefits all the socioeconomic groups without harming anyone, then the project might be done. In economic terms, this situation is known as Pareto improvement. For the second scenario, it is believed, that if the project offers benefits to a socioeconomic group large enough to offset any losses suffered by other groups, then the project could be undertaken. Still there could be a Pareto improvement if the beneficiary groups compensate those harmed by an income transfer that leave the latter
Impacts on spatial and distributional equity of transport infrastructure projects

at least at the same level of welfare they had before the project implementation. In economic terms, this income transfer is known as *Kaldor-Hicks compensation*. However, if this transfer doesn’t take place, it can’t be considered as a Pareto improvement (see Somanathan, 2006).

Therefore, the success of the project in terms of equity largely depends on the system’s ability to redistribute income after the project implementation. The main controversy arises with this issue. It is possible that one of the objectives of the project is precisely to contribute to this redistribution of wealth. The redistribution can be regressive or progressive, depending on whether the beneficiaries belong to high income segments of the society or vice versa. For this purpose, it is possible to build a function that weighs the benefits and costs obtained in the cost-benefit analysis by each socioeconomic group or income group.

The traditional cost-benefit analysis does not weigh the different groups and thus, unwittingly or not, it considers the same weight for all. However, for many years there is a belief that the social value that an additional euro provides to an individual with high income must be lower than that obtained by individuals with lower income (see Harberger, 1984). According to this criterion, individuals with low income should be taken into account in the cost-benefit analysis with a higher weight than those with high income. Nevertheless, this practice has been questioned from a theoretical perspective (Harberger, 1984) and from an empirical point of view, for example, from the World Bank, who no longer uses any kind of weights in the cost-benefit analysis (Devarajan, Squire and Suthiwart-Narueput, 1995). The main theoretical critique was argued by Harberger (1978), who explains that using weights in the analysis comes along with the risk of accepting inefficient projects. Hence, some projects may be chosen not because of the utility of the project itself, but to satisfy the criterion of inequality among different income groups. The latter case would be undesirable since the project would achieve a redistribution of income that may also be achieved using other fiscal mechanisms at a lower cost.

In practice, as Devarajan, Squire and Suthiwart-Narueput (1995) discussed, the use of distributional weights is subjective, and the technicians responsible for its evaluation may not be comfortable when deciding a weight function. Another drawback is the huge time effort dedicated to identify the benefits of each group. These two reasons, together with the aforementioned inefficiency, overshadow the use of distributional weights.

2.2. Spatial Equity

The choice regarding the location and route of transport infrastructure determines which geographical areas will benefit from the investment and which ones will not, at least in the
near future. Again, the criteria of efficiency and equity may not be compatible; however, in this case, the consequences in terms of social welfare are not as intuitive as in the case of distributional equity. In this sense, a national investment strategy that pursues the increase of efficiency and or equity is not obvious (Puga, 2002).

One way to understand this dilemma is by using models of economic geography. The implications of investment in transport infrastructure, translated into a reduction in transport costs, depend on the labor market mobility, wage regulation, market structure, the degree of specialization in production and development differences between regions, so as the type of infrastructure to implement. The result of this policy may affect the location of businesses and workers and thus the growth or decline of certain geographic areas. Such population movements may lead to greater concentration, or a greater spread of the population in space. It has been shown that increased concentration leads to increased productivity, but also that spatial diversity of the population encourages innovation and specialization in production by geographic area (Duranton and Puga 2001).

The labor market mobility is a key to understand the consequences of transport costs reduction. If market mobility is perfect, Krugman (1991) anticipates that when transport costs fall below a certain threshold, it is expected that the industry will concentrate in a single region. However, if labor mobility is imperfect, as it is the case of Spain, industrial concentration causes an excess of unmet labor demand, causing an increase in wages. Consequently, the industry prefers to locate in areas where the labor costs are cheaper (Krugman and Venables, 1995).

Although a new or improved transport link between two regions with marked differences in development may prove to be beneficial to both of them, it is also possible that the latter region may need to experience an adaptation process to a more competitive environment. High transport costs are a natural barrier to trade which can protect the local industry. The ability and necessity of this region to adapt to a new environment keeping the competitiveness of the industrial sector or finding new alternatives for the sector will be the key to expect the investment in transport infrastructure to be beneficial for this region or not.

The type of transport infrastructure implemented affect differently the service and production sectors. Highway construction has a greater impact on the location of manufacturing companies, whereas high-speed lines lead to a greater concentration of business services and head offices in the largest cities (Duranton and Puga, 2001). Vives (2001) confirms the hypothesis that in Spain there has been a trend to spatial concentration of economic power further than it has been in the economic activity and that a high-speed
line between a capital and an industrial city favors the relocation of several head offices to move to the capital.

On the other hand, Davies (1976) finds a negative relationship between population density and distance from transport infrastructure, and in the case of an urban subway, an elasticity between 0.10 and 0.20. Increased population density has usually positive consequences on productivity, but it also may have negative effects if we consider other criteria or any other welfare measure different than GDP.

3. EQUITY ASSESSMENT METHODS IN TRANSPORT INFRASTRUCTURE PROJECTS

The wide range of transport projects and the varying available information make it impossible to develop a unique method of universal application. This section explores different methods to quantify equity variations between the situation without project and the situation with-project. The results of equity indicators will differ depending on the starting point for comparison. In order to illustrate this concept, we define equity in relative terms between two areas A and B, such that for instance the ratio of accessibility of Area A in relation to Area B is 1 to 10 (overall/joint equity indicator). Let’s say a new transport project improves the accessibility in Area B according to a 5 to 1 ratio (partial equity indicator) in relation to Area A. However, according to the starting point, the project leads to a new ratio of 9 to 1 in the accessibility in Area A in relation to Area B. Hence, the partial equity indicator takes into account equity variations between groups or areas, comparing the situation without project with the situation with-project, regardless of their staring points. The joint equity indicator takes into account the initial situation and how it is altered with the implementation of the project. The implementation of these indicators requires a set of implicit or explicit preferences of the decision-maker. In this sense, if the purpose is to accept projects that do not alter the current equilibrium in terms of equity, the use of partial equity indicators is sufficient. However, if the project pursues the reduction of the current equity differences, then the employment of joint equity indicators is necessary. This chapter is devoted to the development of different assessment methods of partial and joint equity criteria.

4. PARTIAL EVALUATION METHODS OF EQUITY

The aim of these methods is to assess by how much agents and geographic areas benefit with the implementation of a project without considering the initial equity equilibrium, but focusing on the new differences that the project may cause.
4.1. Hedonic Price Approach

Let us assume that within a geographic area, two new residential areas are developed. They are located at the same distance from the main business center, but they have a main difference: Area A enjoys a better transportation infrastructure than Area B. Thus, it is expected that given the same prices, Area A will be more demanded than Area B. If both areas have a restricted growth, the market will solve such disequilibrium by offering a higher price for houses in Area A. The divergence in prices between the two areas will grow up to a point where the preferences of all agents remain indifferent when choosing between areas. In this case, the difference in prices between the two areas will reflect the market value of a better transport infrastructure. This concept is the basis of hedonic prices approach.

Thus, one way to identify which agents and how much benefit they obtain with a public transport infrastructure project is through the revaluation of assets such as housing, offices, commercial premises or land. Damm et al. (1980) recognize that, in theory, at least a great part of the benefits of these infrastructures are capitalized in the housing market. The hedonic price approach may be able to capture the market value for the new infrastructure through revealed preferences. However, this method is not free of drawbacks. On the one hand, the observed price matches the one of the agent with the greatest willingness to pay for the asset. This implies that the rest of the demand function is unknown (Alonso, 1964), and the results from such models are not based on the interaction between traditional supply and demand but on a reduced form of both (Damm et al., 1980). On the other hand, the adjustment process towards equilibrium occurs at an uncertain time. This process starts when the project is announced or it can be anticipated, and it ends once the market perceives the true impact more clearly. Such uncertainty regarding the length of the adjustment process is one of the reasons why any attempt to compare real-estate market prices before and after the implementation of the project has to be invalidated. One advantage of the hedonic price approach is that it does not require inter-temporal comparison because it is based on a cross-section dataset collected at a particular moment of time. The cross section dataset has to be collected in a period of stability and as close to the equilibrium as possible, otherwise the relationship between asset value and access time to the infrastructure might not be reliable and the results could be biased.

In this context, an aspect that relates distributional and spatial equity is the concept of *aggregated benefit* in contrast to the *relative benefit* received by the residents of the most affected areas by the project. The result of both benefits depends largely on the degree of mobility of the society studied. For a further understanding of this concept, we assume two extremes, a perfect-mobility case, where families and firms have no objection to relocate, and another case, where none of the agents are allowed to change their residence. It is
expected that any society will lie at different intermediate points between any of these two extremes. Let’s now assume that in these two areas the appreciation was such that Area A is revalued by 20% and Area B by 10%. In terms of aggregated benefit, on average, each agent of this region benefited by 15%, and in terms of relative benefit, agents with properties in Area A obtained twice as much as Area B. Under perfect-mobility scenario, agents can cash the assets and move to another area obtaining actual benefits for it.

In this case, the impact on equity is local, to the extent that some areas get a greater benefit than others, but also regional, due to the fact that members of the town obtain benefits in relation to other regions. However, assuming no mobility, the result is very different. Locally, one area benefits more than others, but there is no regional impact. This effect means that the aggregated benefit of 15% is fictitious and is turned into inflation. In fact, the latter effect was already identified by Spengler (1930) in New York in the 30’s when a new railway line was built. According to Spengler, new railway lines benefited real estate owners in the area, at the same time that they hurt other owners from different areas. He also pointed out that the increase in asset prices depended directly on the level of development. In developed areas, a new rail line had a much smaller impact than it does in the less developed areas.

In line with the perfect mobility, an unequal distribution of benefits between landholders and tenants could be possible. An investment in transport infrastructure that benefit a particular area, causes, as mentioned before, an increase in demand in the sale and rent markets. This latter effect can cause that tenants who have a higher willingness to pay want to move to that area and, consequently, push up the rent prices upward, displacing some of the current tenants. As a result, in this context, it is possible that the main beneficiaries are the real estate/land owners, so that not all residents of the area benefit because of the investment. This conclusion reinforces the use of the hedonic price approach as an indicator of the impacts on equity.

The aim of the hedonic price approach, within the context of this paper is to identify a parameter that relates an improvement in transport infrastructure with an increase in the price of the real estate assets. Therefore, it is necessary to consider a wide range of variables that simultaneously determine the final price of an asset in a weighted and statistically significant way. The most common way to achieve this is building an econometric model.

One of the most important factors in the housing market is the size of the asset. Thus, a first criterion to standardize prices \( P \) is dividing it by its size \( T \): \( \frac{P}{T} = \alpha_1 \). A second variable of interest is the accessibility and distance to the transport infrastructure. This variable has
to be adjusted to the reality of each case study. To keep generality, we denote by \( A \) and adjust the value of the real estate asset to reflect this new information, so that: \( \frac{P}{\alpha^2} = \alpha_2. \)

The ratio \( \alpha_2 \) does not weigh size and accessibility, however, weights for each of them can be considered, so that: \( \frac{P}{T^\alpha A^{\alpha_2}} = \alpha_2. \) If we solve the price, we obtain that: \( P = \alpha_3 T^\beta_2 A^{\beta_2}. \)

Taking logarithms on both sides of the equation, and renaming \( \ln (\alpha_3) \) as \( \alpha \), we get that: \( \ln(P) = \alpha + \beta_1 \ln(T) + \beta_2 \ln(A). \) Based on the available information, the following three alternatives can be taken.

### 4.1.1. Model 1: Least Squares

This model incorporates a set of additional variables \( X \) that include more information that explain why asset prices differ and therefore, can identify more precisely the role of transport infrastructure.

\[
\ln(P) = \alpha + \beta_1 \ln(T_i) + \beta_2 \ln(A_i) + \beta_k \ln(X_i) + u_i
\]

The way this function is built allows obtaining the value of the price elasticity of transport infrastructures directly. More precisely, \( \beta_2 \) reflects the sensitivity of the asset price to marginal improvements in the accessibility to the transport infrastructure. This parameter allows us predicting increases in the real estate asset prices due to the implementation of improvements or new transport infrastructure, and thus, impacts on equity by geographical areas.

### 4.1.2. Model 2: Least Squares with Spatial error correction

One drawback of model 1 is that the asset price depends largely on the area where the asset is located. Incorporating dummy variables that identify each asset with a given area is one way to solve this problem. However, the delimitation of areas is problematic because of the fact that some borderline cases have a diffuse participation among them. One solution is to omit such location variable and accept the existence of an error. This error captures information of the area, so that if for instance it is positive, it would mean that, on average (and according the asset characteristics) it is overvalued based on its location. The price of an area is often conditioned by the price of the surrounding areas and less affected by other more remote. In order to capture this effect, the error is spatially modeled and so that it takes the value of the error of the surrounding areas weighted by the distance. For this purpose, a matrix representing the distance between zones is constructed and each matrix element is denoted by \( w_{ij} \), which is used as a weight and multiplied by the value of the
error in each of these zones \( u_j \). This weighted sum should reflect the value of the area as a function of the value of the surrounding areas. This variable is associated with a parameter \( \rho \) within the previous OLS model and a new component of the error \( e_i \) is incorporated.

\[
u_j = \rho \sum_{j=1}^{n} w_{ij} u_j + e_i
\]

The significance of \( \rho \) is used as a test of spatial dependence:

\[
H_0 : \rho = 0 \\
H_1 : \rho \neq 0
\]

**4.1.3. Model 3: Least Squares with Spatial Dependant variables**

One drawback of model 2 is the absence of actual information related to the way in which the error component is modeled. Another alternative model that extends the idea of this one is to incorporate additional spatial error components to the exogenous variables (see Arbia, 2006). Hence, using the same spatial concept, the impact on the price of the implementation of transport infrastructure in the surrounding areas may be captured by this model.

\[
\ln \left( P_i \right) = \alpha + \beta_1 \ln \left( T_i \right) + \beta_2 \ln \left( A_i \right) + \rho \sum_{j=1}^{n} w_{ij} \ln \left( P_j \right) \\
+ \alpha_1 \sum_{j=1}^{n} w_{ij} \ln \left( T_j \right) + \alpha_2 \sum_{j=1}^{n} w_{ij} \ln \left( A_j \right) + e_i
\]

This paper does not intend to cover all possible specificities of each particular case, but to offer an introduction to the way in which these models can be used, instead. In fact, it is possible that none of the previous models will fit perfectly in the studied case. Any combination of models 1, 2 and 3 are also possible models, and the implementation of some ideas does not necessary exclude the others.

**4.2. Cost-Benefit analysis based methods**

**4.2.1. Surplus approach**

The information used in the surplus approach (Campos y de Rus, 2009), if it is available, can be helpful to assess the impacts of the project on equity. In this model, the point of view taken is the change in social welfare. Similarly, this method has some differences on equity motivated by the implementation of project.
The surplus approach concludes that the change on social welfare is composed by the following components:

\[
\Delta BS = \sum_{t=1}^{T} \delta \left[ \frac{1}{2} \left( g_t^0 - g_t^1 \right) \left( q_t^0 + q_t^1 \right) + \left( p_t^1 q_t^1 - p_t^0 q_t^0 \right) - \left( C_t^1 - C_t^0 \right) \right] \\
+ \left( \psi_t^1 q_t^1 - \psi_t^0 q_t^0 \right) + \left( \phi_t^1 q_t^1 - \phi_t^0 q_t^0 \right) + \sum_{i,j} D_{ij} \left( q_{ij}^0 + q_{ij}^1 \right)
\]

At the same time, it can be decomposed (see Campos and Rus, 2009) in:

\[
\Delta BS = \Delta EC + \Delta EP + \Delta EG + \Delta ER
\]

This classification allows us to obtain an initial distribution of the social welfare according to different groups of interest. In order to illustrate this point, a fictitious distribution is considered in Figure 1. This distribution highlights that the consumer surplus group has been the most benefited, accounting for 54\% of the improvement, followed by other surpluses, as the producers, who receive 24\% of the improvement.

From these distributions, ratios that capture the relative benefit of some groups compared to others can be obtained. For example, \( k_{EC,EP} = \frac{\Delta EC}{\Delta EP} = 2.43 \) represents how much is benefited the consumer surplus in relation to the producer surplus. Hence, \( k_{EC,EP} \) can be used as an indicator of inequality between the profits gained by the different groups. This indicator can be used as complementary information to the one offered by CBA (cost-benefit analysis).

There are two ways to incorporate them into the analysis. One possibility is to consider them as an extra criterion to the one offered by CBA. Thus, the decision-maker will
consider among alternatives, the one that satisfy their preferences in terms of equity and efficiency simultaneously. A second possibility is to use them as values comparable with reference values fixed ex-ante and that represent restrictions to maximum inequality accepted. In this sense, these indicators serve as decision rules or barriers that projects must pass in order to be approved in relation to equity. Once filtered those projects which overcame this constraint, we can move on choosing the one that offers better characteristics in terms of other criteria, such as the cost-benefit analysis criterion.

When information is available, the increase of social welfare oriented to consumer can be decomposed by socioeconomic groups. One source of information for this purpose can come from previous studies of the use of infrastructure by each socioeconomic group, either at the study area or areas where it is expected a similar distribution. In order to illustrate this idea, continuing with the previous example, and if modal preferences of each socioeconomic group related to the infrastructure are known, it is possible to obtain the information shown in Figure 2.

Similarly, since this information, it can be elaborated ratios that represent the relationship by which socioeconomic group i is benefited with the project in relation to other socioeconomic group j: \( k_{i,j} = \frac{EC_{i}}{EC_{j}} \), \( \forall i, j \in G \). In the case of 4 socioeconomic groups, the effect on equity can be summarized in a matrix \( \Omega \) such that:

\[
\begin{pmatrix}
1 & k_{12} & k_{13} & k_{14} \\
1 & k_{23} & k_{24} \\
1 & k_{34} \\
1 &
\end{pmatrix}
\]

This matrix form can promote the creation or verification of some decision rules, restrictions or barriers related to equity that helps to the decision taker to assess the project’s impact on equity.

Some examples of these decision rules are:

- A valid ranged valid for the indicator, e.g.: \( EC_{EP} \in [1,4] \).
- Relations of equivalence, for instance, by imposing a progressive condition, such that: \( 1 < k_{12} < k_{13} < k_{14} < 1 \).
4.2.2. Resources approach

From the resources approach described in Campos and de Rus (2009) it is obtained that welfare improvement is represented by:

$$
\Delta BS = \sum_{t=1}^{T} \left[ v_t^0 r_t^0 q_t^0 - v_t^1 r_t^1 q_t^1 + \frac{1}{2} \left( g_t^0 + g_t^1 \right) (q_t^1 - q_t^0) + \left( c_t^0 - c_t^1 \right) + \left( e_t^0 q_t^0 - e_t^1 q_t^1 \right) + \sum_{i \neq j} D_t \left( q_{it}^1 + q_{ij}^0 \right) \right]
$$

Differences between people are based on two effects

- Differences in mode of transport, frequency of use and value of time:
  $$
v_t^0 r_t^0 q_t^0 - v_t^1 r_t^1 q_t^1, \quad v_{tg} = v_{th}, \quad q_{tg} \neq q_{th}
$$

- Differences in willingness to pay (generalized price):
  $$
  \left( g_t^0 + g_t^1 \right) (q_t^1 - q_t^0), \quad g_{tg} \neq g_{th}
  $$

This is one of the more traditional methods for assessing the impact on equity. The main disadvantage of this method is the time cost and logistic costs to carry it out. The method requires wide information about the current demand as well as a prediction of future demand. To do this estimation, it is needed a sample of individuals which relate their
preferences on the transport mode, frequency of use and other socioeconomic variables. From this information we can estimate the determinants of transport demand that allows the prediction of the time value and willingness to pay per individual \textit{a posteriori}. Models of transport mode choice, either multinomial, nested multinomial, multinomial probit or mixed logit have been resulted useful in these estimations (see Hensher, Rose and Greene, 2005, for recent applications of transport demand).

5. EQUITY JOINT ASSESSMENT METHODS

The purpose of this kind of assessment is to analyze the impact over equity taking the \textit{without project} situation as reference and observing the variations when the project is undertaken. Hence, the decision-maker’s objective function is not simple, because it includes explicitly the tradeoff between efficiency and equity.

5.1. Multicriteria Methods

The main purpose of the Cost-Benefits Analysis is to provide a single monetary value (or its probability distribution) that may help the decision-taker in the choice or the acceptance of a particular project. There are, however, certain aspects basically related to environmental impacts and equity that can hardly be transferred to a monetary value. In the case of being significant, multicriteria methods might be a good approach. These methods try to evaluate multiple criteria simultaneously with three types of procedures: based on utility functions, mathematical programming and outranking methods. Applications of this methodology have been carried out to assess road networks (see eg. Torrieri, Nijkamp and Vreeke, 2002) or airports’ expansion (see eg. Vreeke, Nijkamp and Ter Welle, 2001). Although they can be very helpful, these methods are also limited. It is, for instance, complicated to establish a valid weighting criteria system other than subjective from the standpoint of the analyst, which may call into question the results.

5.2. Spacial Need Index

Murray and Davis (2001) developed this method in the field of transport infrastructure from a previous model developed by Talen (1998). The method is based on an indicator of potential need of transport investment $\Phi_i$ for each of geographical area of interest $i$:

$$\Phi_i = U(R_{1i}, R_{12}, ...)$$
At the same time, indicators are defined for each criteria\(^1\) \(j\) as follows:

\[
R_{ij} = \begin{cases} 
1 & \text{little need} \\
\vdots & \vdots \\
p & \text{much need} 
\end{cases}
\]

Accessibility indicators are also calculated. The proportion of residents with access to the public transport in a certain \(i\) area is specifically calculated:

\[
\tau_i = \sum_{j} \lambda_{ij} f(\bar{d}_i, S),
\]

where:

\[
f(\bar{d}_i, S) = \begin{cases} 
1 & \text{if } \bar{d}_i \leq S \\
0 & \text{otherwise}
\end{cases}
\]

and \(\lambda_{ij}\) stands for the proportion of population \(i\) located in the \(l\) geographical zone. According to this information, an accessibility index similar to the later is developed:

\[
\Psi_{ij} = \begin{cases} 
1 & \text{very good access} \\
\vdots & \vdots \\
p & \text{very bad access}
\end{cases}
\]

The following step is to set thresholds for these indicators to discern the relative need of each area. In cases where both indicators are below an acceptable minimum threshold, it is understood that these are areas of high priority. Finally, using geographic information system, they can be distinguished the neediest areas, which might not coincide with those with lower availability of transport infrastructure as this assessment takes into account the level of population and accessibility simultaneously.

### 5.3. Industrial Location Models

This kind of models aims to determine the role that the accessibility to the transport infrastructure plays in the industry location decision. Thanks to this information, it can be simulated the willingness to pay for improvements on the accessibility, providing information that may be broken down by geographical area. The main contributors of this model are Lall, Schroeder and Schmidt (2009). The econometric model they work with is a Multinominal Logit model, where the expected benefit of being settled down in a region \(j\) is

\(^1\) An illustration from Murray and Davis (2001) showed the following chosen criteria: number of young people, people over 65 years old, people with physical disabilities, people with low incomes and families without cars.
the dependent variable, whereas the independent variables are: localization economies (concentration index of the industry), urbanization economies (Herfindahl index), quality and availability of the interregional infrastructure in relation to major business centers (GIS map with road transport times), local infrastructure (electric power), human capital stock in the region and natural condition of the region.

According to the model, the variation of the expected benefit of locating in region \( j \) given an improvement of the transport infrastructure \( x_{jm} \) can be calculated by using the estimated parameter of the model \( \beta_m \), so that:

\[
\frac{\partial \ln P_j}{\partial \ln x_{jm}} = \beta_m x_{jm} (1 - P_j)
\]

This is a model with many similarities to the hedonic price model. The main difference is that industrial location models can cover a wider geographic spectrum than the hedonic price approach, but in turn it is limited to assessing the impact on companies only, leaving aside what may affect families.

6. CONCLUSIONS

This paper has been devoted to the study of equity indicators. Each of the methods described can be applied according to the nature of the project and the available information. The hedonic price approach requires information of the real estate prices at a moment when the market is stable. The aim is to estimate how much the market price can vary under improvements in the accessibility and availability of transport infrastructure. Such price variations correspond to a quantitative approach to the actual impact on equity. In particular, this method is able to estimate the impact on spatial equity very accurately and also the distributional equity, but with less precision. The method loses strength when the case study has already a well developed transport infrastructure. It is particularly useful for projects where the infrastructure didn’t exist before, for example, new train stations/platforms or underground.

On the other hand, the two methods dependent on the cost-benefit analysis has the advantage of not requiring of any additional information and thus they are cheaper to implement. However, it is not always possible to carry out a cost-benefit analysis by the two methods, hence, limiting any further use of their results for the construction of equity indicators. The surplus approach is ideal for the analysis of distributional equity, whereas the resources approach may be useful for the study of spatial equity. The use of the
resources approach makes more sense in situations where individuals have multiple transportation options and the travel frequency is high.

Additional methods can cover some of the drawbacks of the methods commented earlier. For instance, the rates of spatial needed provide a geographical map to the decision maker that allows him or her to prioritize geographically, thus taking into account spatial equity criteria. Finally, another method capable of assessing the spatial impact of transport investments is the industrial location model, which simulates the expected profit of a company if the transport project is implemented.
REFERENCES


Impacts on spatial and distributional equity of transport infrastructure projects
