# ENVIRONMENTAL ASSESSMENTS INSTRUMENTS FOR URBAN TRANSPORTATION PLANNING. FROM A REACTIVE TO A PROACTIVE APPROACH.

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## Abstract

There is a growing interest regarding the development of environmental assessment instruments for application in urban transportation planning. Nevertheless, a great number of studies show that present instruments have a very low effectiveness when confronted with the complexity of the environmental consequences of urban transportation in its interaction with land use factors. Furthermore, the majority of environmental instruments are rather oriented towards monitoring plans than towards supporting decision-making.

To address these problems, this paper presents a strategy for proactive environmental instruments design ('PEID strategy') as a method for developing environmental assessment instruments for supporting decision-making in urban transportation planning. Accordingly to this strategy, environmental instruments must fulfil four key criteria: be performance-based, reference values-based, integration-oriented and decision-oriented. To illustrate and assess the worth of this strategy, an environmental assessment instrument has been developed following these criteria and applied to evaluate alternative plans for a transit corridor in the city of Granada, Spain. The paper describes this application and reflects on the advantages and disadvantages of the strategy as well as on issues for futures research.

Keywords: Environmental assessment, decision-making support, urban transportation planning,

## 1. Environmental assessment for urban transportation planning

The growing interest regarding the incorporation of sustainability goals into planning has a relevant milestone in 1972. In this year was celebrated by United Nations the seminal conference on 'The Human Environment' in Stockholm, Sweden. Ever since, sustainability has been incorporated into many levels of society such as education, planning, economy, etc.

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In the case of planning, the transition to sustainability requests that its performance must be assessed (Ness et al, 2007). This has originated important challenges to the scientific community in providing efficient tools. As a response to these challenges, sustainability assessment has become a rapidly developing area associated with the family of impact assessment tools (Pope et al., 2004) (e.g. Environmental Impact Assessment and Strategic Environmental Assessment). In Devuyst´s words (2001, p. 9) a sustainability assessment tool is 'a tool that can help decision-makers decide what actions they should take and should not take in an attempt to make society more sustainable'. In recent years, a lot of countries have conferred to sustainability assessment, and specifically to Environmental Impact Assessment (EIA), an important and decisive role into their planning systems.

EIA is a widely used ex-ante tool to support decision-making in transport planning. It is aimed to make an overview of the environmental impacts of projects. The central goal is to reduce the potential negative effects using corrective or compensatory measures (Ness et al, 2007). It has a long tradition starting in the 1960s and a lot of countries made EIA compulsory into their planning systems. For this reason, the role of EIA has become increasingly important. In the case of EU, Council Directive 85/337/EEC was the first European Community directive to provide details on the nature and scope of environmental assessment, its use and participation rights in the process. The origins of the 1985 Directive lay in the EEC's 1973 First Environmental Action Programme, which identified the need to implement procedures to evaluate the environmental effects of certain activities at the earliest possible stage. Ever since, EIA was periodically introduced in the legislation of Member States (EC, 2009). Due to such legal requirements, nowadays there are strict guidelines for the EIA process in the EU and other countries (e.g. USA or Canada) (Cornaro et al., 2010).

Like many others cases, a reduction of negative environmental impacts in urban transportation (air pollution, energy consumption, etc.) is thought to be decisive in promoting more sustainable planning outcomes (Banister, 2005; Litman, 2009). Nevertheless, evidence show that this objective is hardly achieved in daily planning practice (Hull, 2008; Joumard and Gudmunsson, 2010). As a consequence and among other factors, the effectiveness of the EIA for evaluating urban transportation plans/interventions is contested, as strongly argued by several academics (Arce and Gullón, 2000; Browne and Ryan, 2011). Accordingly, assessment innovations seem to be needed. Many of them focus on supplementing and improving the predominant environmental assessment instrument, EIA.

This paper hypothesizes that the problem of EIA in the case of urban transportation planning could be related to its increasingly reactive use in the planning processes by practitioners. This means reacting to environmental impacts that happen rather than avoiding them to happen. This is a consequence of, on the one hand, that many times the EIA process only includes environmental specialists, and on the other hand, that the used methods are not always the most suitable to identify ways of preventin potential impacts (Soria, 2011).

To face this, the paper identifies the need to overcome a certain number of substantive communication barriers between EIA makers and transport planners. Firstly, these barriers are linked to the types of results hoped for. EIA measures static environmental impacts, however, urban transportation is a dynamic system, with varying environmental performance in varying temporal and spatial contexts, as described by different scholars (Peyrbrune, 2000; Dobranskyte et al., 2007). Secondly, transport planners scarcely receive inputs from EIA in order to support their decisions (Soria, 2011). Therefore, tools that foster learning between different specialists are needed.

This paper presents a strategy for proactive environmental instruments design ('PEID strategy'). According to this strategy, environmental instruments must fulfil four key criteria: (i) be performance-based; (ii) reference value-based; (iii) integration-oriented and; (iv) decision-oriented. To illustrate and assess the worth of this strategy, an environmental assessment instrument (ETV-model) has been developed following these criteria and applied to evaluate alternative plans for a transit corridor in the city of Granada, Spain.

The case of Spain is illustrative of the problems previously described (Gomez-Orea, 2007). The RD 1131/1986 Law incorporated EIA into its planning system. The main consequence of that was that different Spanish governments (local, regional, etc.) have used EIA to prioritize their proposed plans and projects. However, despite the application of EIA since 80s, it is being difficult to achieve sustainable goals in the case of urban transportation (Serrano, 2009; Valenzuela et al., 2011). Authors such as Garmendia (2005) and Gomez-Orea (2007) explain that the design of more proactive environmental assessment instruments could contribute to solve that.

In the following, we will start by defining the 'PEID strategy' (section 2). Then, the Environmental Threshold Values Model ('ETV-model') will be presented (section 3). This model has been designed following the 'PEID strategy' and it has been applied on metropolitan transit corridor in Granada, Spain. The suitability of this study-case is due to institutions nowadays debating implementing a Light Rail System in the corridor. Finally, we shortly discuss on the worth and advantages of this strategy, as well as on issues for future research (section 4).

## 2. The 'PEID strategy'

The central goal of the 'PEID strategy' is to lead the design of proactive environmental assessment instruments. The strategy is done in two phases. The first phase is the analytical and comparative phase and the second is the decision phase (see figure 1).

The first phase (analytical and comparative) focuses on designing tools that can compare different alternatives and diagnose the advantages and disadvantages of them. The objective is to evaluate urban transportation according to its dynamic characteristics rather than valuate only its final effects. To achieve that, the 'PEID strategy' proposes to develop environmental assessment instrument fulfilling three key criteria: be performance-based, reference values-based and integration-oriented.

To be performance-based (first criterion) means changing the goals of the evaluation. While EIA measures how each alternative transforms its environment, the performance-based evaluation analyses what alternative has a better environmental functioning. The advantages are not only that the performance based evaluation could represent better the dynamic characteristics of urban transportation (Dobranskyte et al., 2007) (Ricci et al., 2010), but also, it permits the incorporation of other practitioners (non-environmentalist) into the evaluation since earlier stages. This aspect is a consequence of the fact that performance-based evaluations can calculate easier than other methods an aggregated or synthetic value (Gerike et al., 2010).

Complementary to performance-based evaluations, understanding sustainability as a normative orientation can be a useful way to make the outcomes of evaluation more understandable for the spectrum of decision-makers. This could be determining performance trends through the incorporation of reference values into the evaluation (second criterion of the 'PEID strategy'), (Nijkamp and Ouwersloot, 2004). The major problem faced in practice is that the reference values are many times fuzzy, and decision-makers may have different views on their adoption. Consensus solutions to the above could focus on designing methods based on experts´ opinion.

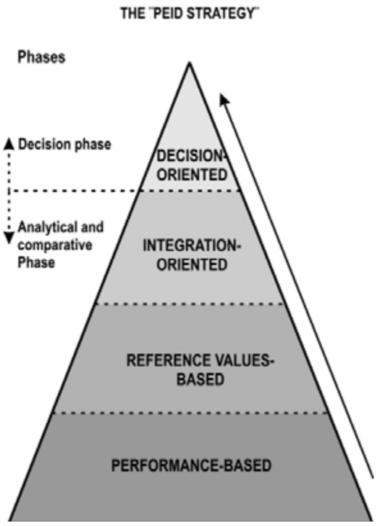


Figure 1. Key criteria of the 'PEID strategy'

The third criterion of the analytical and comparative phase is that the evaluation should be transport land use integration-oriented. In an urban transportation context, this is especially relevant in the case of the interrelationships between urban structure and transport. As studied by several authors (Priemus et al., 2001; Cervero  and Kockelman, 1997; Naess, 2006; Cao et al., 2009), the empirical evidence demonstrates that there are significant influences between spatial planning and transport. Nevertheless, traditional environmental assessment approaches focus solely on transport as environment-polluting agent, obviating these interrelationships. The main advantage of an integration-oriented evaluation is to understand the environmental performance of each alternative under determined urban contexts. This would permit to generate a discussion framework between EIA-makers, urban planners and transport planners since the early phases of the planning process.

With respect to the first phase of the 'PEID strategy', each of the three described key criteria tries to adapt the environmental assessment to the specific characteristics of urban transportation. This can be especially appreciated through the idea of promoting a performance-based evaluation, as well as through the incorporation of an integrated vision between urban structure and transport. On the other hand, this phase pursues to make the environmental assessment results more understandable to non-environmentalist. The proposal of reference values and the adoption of a performance synthetic value are related to this objective. Finally, the interaction and discussion between decision-makers is one of highlighted aspects of this phase. The promotion of integrated visions between urban structure and transport into the evaluation could stimulate this.

Once the first phase of the 'PEID strategy' has been completed, the second phase focuses on implementing decision-oriented tools. The main goal is that decision-makers can know how their decisions can affect the environmental performance of urban transportation. The problem is that traditional instruments as EIA aim to identify the alternative with the lowest negative impact. Nevertheless, it is difficult to find examples where environmental assessment instruments can support to take decisions to design/modify alternatives, and thus improve by decreasing negative impacts. The growing use of sensitivity analysis in social sciences could be a good solution to develop support tools for this (Geneletti and van Duren, 2008).

## 3. Case-study: the ETV-model and an application in Granada, Spain

To illustrate and assess the worth of the 'PEID strategy', an environmental instrument has been developed following the four criteria established by this strategy. The instrument was labelled Model of Environmental Threshold Values (ETV-model) and applied to evaluate alternatives for a transit corridor in the city of Granada, Spain.

Since the 1970s, the metropolitan area of Granada (MAG) began to have significant urban transformations that have lasted until the present. The origin of these transformations is an intense growth in real estate development, the creations of new infrastructures, the growth of the private vehicle market, etc. (Aguilera, 2008). Parallel to this process, a huge increment of environmental problems has been experienced in the region, especially problems originated by urban transportation (e.g. congestion, air pollution, health problems…). To face these problems, local institutions are, among other policies, promoting the implementation of a Light Rail Tran (LRT) System into the most important transit corridor in MAG. The EIA is the tools used to evaluate different alternatives and practical solutions. Concretely, ETV-model will be applied on two possible alternatives: (i) Alternative S.0, based on non-implementation of LRT into the corridor; (ii) Alternative S.1, based on implementation of LRT. Figure 2 shows the location of the proposed Light Rail Train System in MAG.

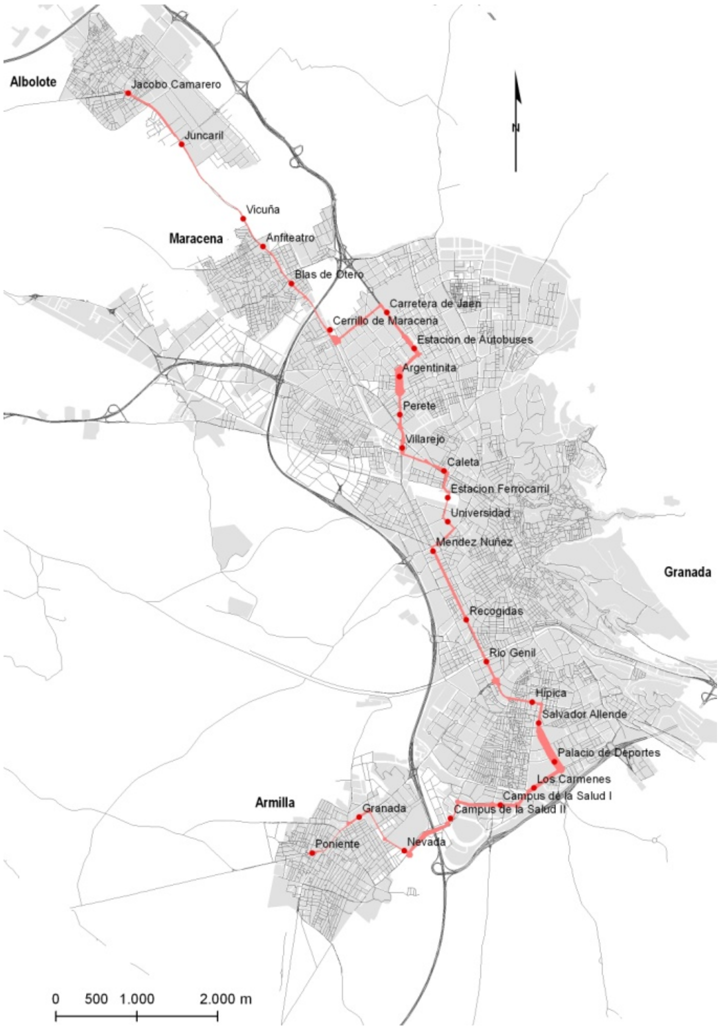


Figure 2. Light Rail Train System in the Metropolitan Area of Granada.

The most representative substantive problems in the use of EIA discussed in section 1 seem to be also present into the study-case (related to types of results hoped for and the fact that transport planners are scarcely involved into EIA processes) (Soria, 2011). Hence, it could be asserted that there is a great suitability of this case-study to prove the 'PEID strategy' through the elaboration and application of the ETV-model.

Before explaining the details of ETV-model development, table 1 shows its main characteristics.

Table 1. Main characteristics of the 'ETV-model' following the criteria of the 'PEID strategy'

| The 'PEID strategy' | | ETV-model |
|---|---|---|
| Analytical and comparative phase | Performance-based | -Input to system (energy and resource consumption).<br><br>-Output to system (waste emission and noise).<br><br>-Integrated use of corridor (barrier effect and public space) |
| | Reference values | -Quality Critical Threshold (QCT). It represents an optimum value of indicators where the environmental impacts of urban transportation would be irrelevant.<br><br>-Impact Critical Threshold (ICT). It represents an impact value of indicators where the environmental impacts of urban transportation would be very serious. |
| | Integrated orientation | -It proposes the concept of 'mobility environment' as spatial unit of integration between urban structure and mobility patterns.<br><br>-The environmental evaluation of alternatives is focused on these mobility environments. |
| Decision phase | Support-based | -Using sensitivity analysis, the model proposes four decision support indicators for decision-makers. |

As can be seen in figure 1, the ETV-model has been developed following the four key criteria proposed by the 'PEID strategy'. The methods proposed through this strategy will be detailed for each criterion below.

Performance-based:

The adoption of performance evaluations must include indicators that reflect various levels of analysis, although it is important to take their relationships into account to avoid double-counting (Litman, 2009).

Therefore, the central goal is to propose an indicators system that permits to evaluate and compare the two alternatives in the case-study. Given the characteristics of the corridor, the indicators system will cover the main negative externalities of urban transportation (figure 3): (i) An inefficient use of energy and resources; (ii) Emission of wastes and noise; (iii) Integrated use (both for staying and passing-through) of corridor.

Six indicators are proposed (see figure X): (i) Energetic efficiency (Mj/Passenger-Km); (ii) Spatial efficiency (m2 corridor/Passenger-km); (iii) PM10 Concentration (μgr/m3); (iv) Noise emission (dbA); (v) Barrier effect (BE/m); (vi) Public space liveability (m2 non-motorized/m3 motorized).

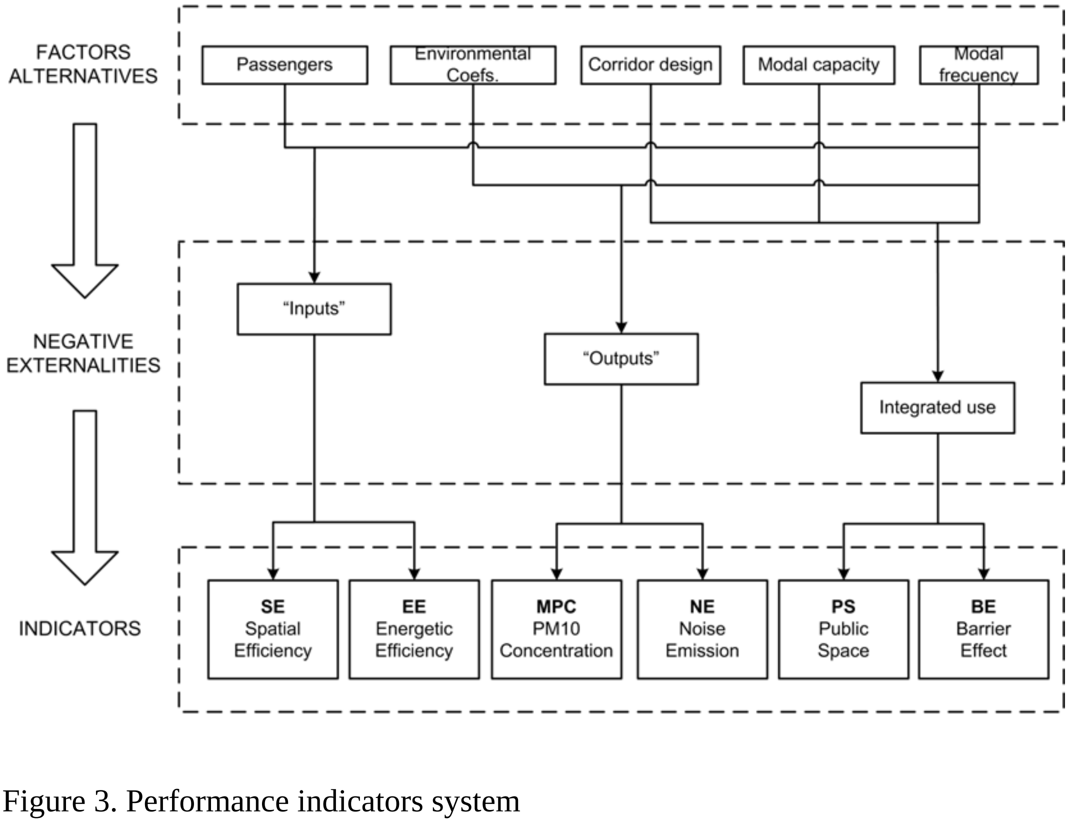


Figure 3. Performance indicators system

Following step-by-step the 'PEID strategy', an aggregated value will be obtained in order to make more understandable the results for non-environmentalists. To address this, simple additive weighting methods are used. These methods have been operationalized using a GIS system. The decision-makers directly assigned weights to each indicator by means of an expert panel. Formally, each alternative (Us) is evaluated by the following formula:

$$U_s = \sum_j w_j x_{ij}$$

Where $x_{ij}$ is the score of each indicator, and $w_j$ is a normalized weight, so that $\sum_j w_j = 1$.

Reference values-based:

Another important aspect of the 'PEID methodology' is to establish a decision framework taking sustainability as a normative orientation. The strategy considerers that the identification and definition of reference values could be useful to achieve this objective.

Inspired by e the 'Flag Model' (Nijkamp and Ouwersloot, 2004), the 'ETV-model' determines two threshold values for each indicator: (i) Quality critical threshold (QCT); (ii) Impact critical threshold (ICT). On the one hand, the QCT would indicate an optimum value per indicator where the environmental impact of urban transportation would be negligible. This means that this concept refers to a threshold value identifying the limits of an acceptable damage to the environment. On the other hand, the ICT would be an impact value indicator where the environmental impacts or urban transportation would be serious. This means that this concept refers to a threshold value that cannot be exceeded without causing unacceptable damage to the environment.

The adoption of two thresholds (QCT and ICT) determines three possible environmental performance ranges for urban transportation (see figure 4): (i) Optimum performance, when the indicator doesn´t exceed the QCT: (ii) Acceptable performance, when the indicator is between QCT and ICT; (iii) Negative performance, when the indicator exceeds the ICT.

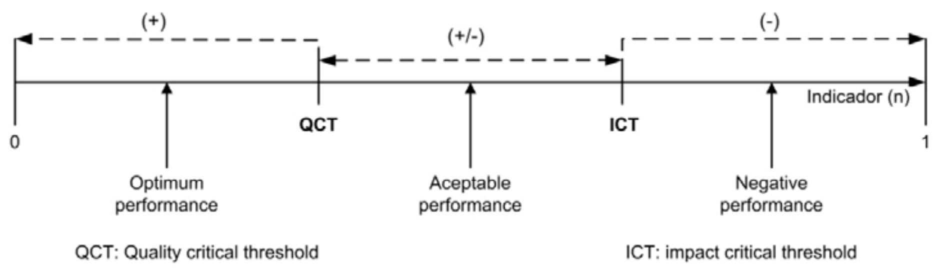


Figure 4. Reference values and performance ranges.

The existence of legislation has been the chosen criteria to determine the reference values for each indicator. Performance indicators such as energetic efficiency, PM10 concentration and Noise emission are regulated by European and national legislations. In the cases of the other three indicators (spatial efficiency, barrier effect and public space), specific thresholds have been estimated for the case-study following handbooks, guidelines, etc.

Integrated-orientation:

Due to the inextricable interrelationships between urban structure and transport, understanding the environmental performance of urban transportation under these parameters seems to be a determinant aspect. The main advantage would be to generate a common framework for discussion between decision-makers since the early planning phases.

To achieve that, the 'ETV-model' proposes to identify 'mobility environments' (inspired by Bertolini and Dijst, 2003) as operational spatial units for the assessment. The objective is that the environmental performance of each alternative can be interpreted under the contexts of these 'mobility environments'.

The ETV-model proposes a method to identify 'mobility environments'. The method includes the definition of representative indicators and mobility vectors of urban structure and transport for the study-case. The combination of indicators and vectors will be used for identifying and defining 'mobility environments'.

After applying the model, five 'mobility environments' have been defined for the corridor: (i) Proximity and local dimension; (ii) Proximity and transit distribution; (iii) Motorized transit; (iv) Metropolitan centrality; (v) Intermodal station. Figure 4 shows the location of each 'mobility environment'.

In the first mobility environment identified (proximity and local dimension), the majority of daily necessities (working, shopping, etc.) can be covered without motorized modes. This is a consequence of that the proximity component is very relevant. On the other hand, in the second 'mobility environment' identified (proximity and transit distribution) is not only very important the proximity component, but it has an important role for the motorized modes too. The rest of 'mobility environments' nominated are more associated with a motorized use of the corridor. Table 2 shows the proposed criteria to diagnosticize the environmental performance of the alternatives in each 'mobility environment'.

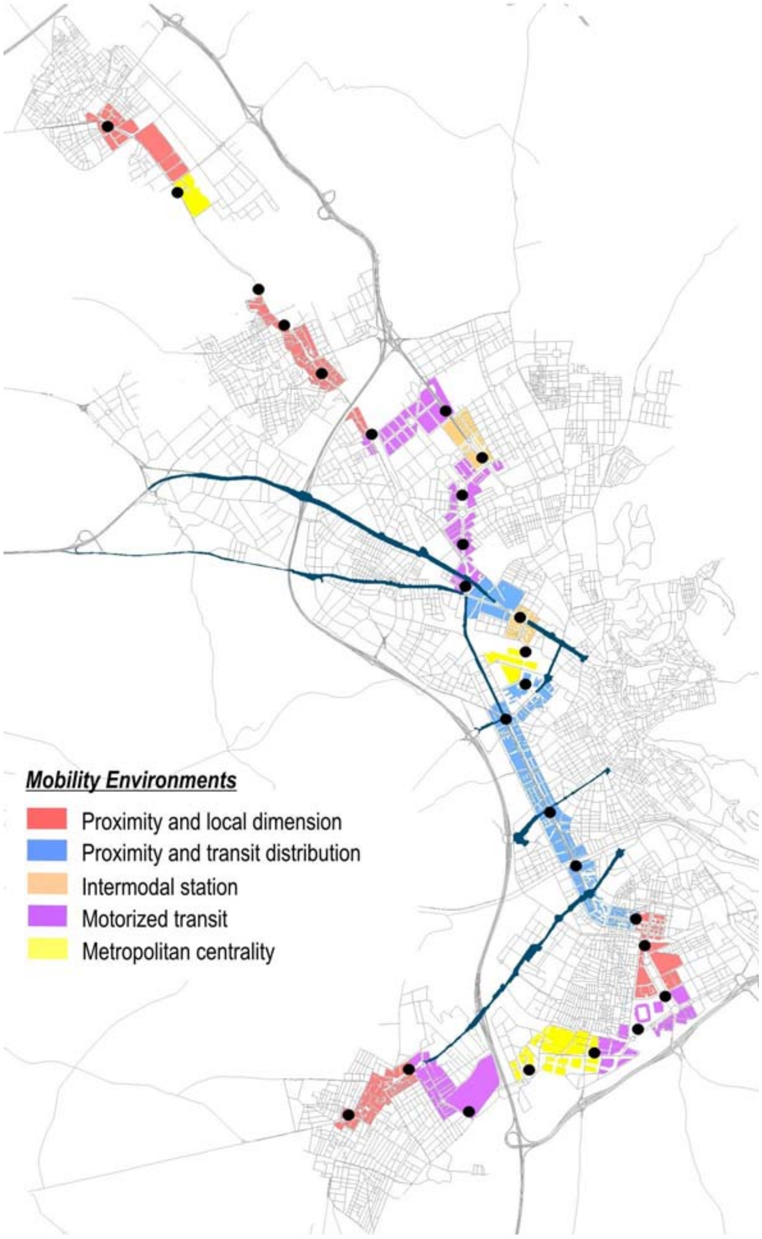


Figure 4. 'Mobility environments' in the corridor

Once applied these three sets of criteria (performance-based, reference values and integrated orientation) to the case-study, different conclusions could be underlined. Alternative S.1 (corridor with Light Rail System) seems to be more performing than Alternative S.0 (corridor without Light Rail System) when the results are valuated under the two first criteria (performance-based and reference values). Nevertheless, when these results are filtered through the specific requirements of the identified 'mobility environments', it could be asserted that Alternative S.1 is not always the most convenient according to the characteristics of each of them. Eventually, decision-makers chose Alternative S.1 for the corridor. However, the assessment indicates the need to modify this alternative in those 'mobility environments' where its urban integration was worse (specifically this was the case in the menbility vironments 'motorized transit' and s 'metropolitan centrality'). Following the 'PEID strategy', next a module oriented towards design support was developed. This is discussed in the next section.

Table 2. Relationships between performance indicators (see Figure 3) and 'mobility environments'

| 'Mobility environments' | Environmental performance of corridor | | | | | |
|---|---|---|---|---|---|---|
| | Inputs | | Outputs | | Integrated use | |
| | EE | SE | MPC | NE | PS | BE |
| Proximity and local dimension | ○ | ○ | ● | ● | ●● | ●● |
| Proximity and transit distribution | ●● | ●● | ●● | ●● | ●● | ●● |
| Motorized transit | ●● | ●● | ● | ○ | ○ | ○ |
| Metropolitan centrality | ●● | ●● | ● | ○ | ● | ○ |
| Intermodal stations | ●● | ●● | ●● | ●● | ●● | ●● |

○ Without influence ● Important ●● Very important

Decision-oriented:

According to the 'PEID strategy', the incorporation of decision-oriented tools into environmental evaluation could be an important way to promote proactive assessment instruments. One of the main problem of EIA is that while it allows to identify the alternative with the lowest negative impact, it doesn´t say how decisions of decision-makers could affect the environmental performance of the alternatives.

The last part of the ETV-model incorporates a decision-oriented module that allows decision-makers and practioners to know how their decisions can affect the environmental performance of alternatives. In our case-study this module will be used to analyse possible design modifications on Alternative S.1 in order to solve its integration problems in some 'mobility environments'.

To address this question, the ETV-model proposes two indicators labelled 'Absorption capacity' and 'Improvement capacity'. Both indicators are based on the respective reference values estimated for each performance indicator. The

'Absorption capacity' indicates the capacity of a mobility environment to absorb a reduction in its environmental performance without overcoming its Impact Critical Threshold. On the other hand, the 'Improvement capacity' indicates the capacity of one mobility environment to increment its environmental performance reaching its Quality Critical Threshold.

The development of these indicators has its origin in the growing use of sensitivity analysis in the social sciences (Geneletti and Van Duren, 2008). Both indicators evaluate the sensitivity of environmental performance to different characteristics of alternatives such as passengers, modal capacity, modal frecuency, etc. In this way, decision-makers could know how their decision can affect to the environmental performance of corridor.

Finally, these decision indicators were applied on Alternative S.1. They were used to check what elements of this alternative could be modified to increment its performance in those mobility environments where it was less convenient. Given the expected level of passengers in these mobility environments, the results showed that reducing the number of public transport lines could be acceptable and useful for incrementing the energetic efficiency and reducing the barrier effect. These changes would situate the environmental performance of Alternative S.1 at an 'acceptable level' in all 'mobility environments'.

## 4. Conclusion and discussion

This paper started with describing the problems of the EIA to assess urban transportation plans/interventions. It was hypothesized that this was partly due to the existence of the merely 'reactive' use of this assessment instrument. Substantive communication barriers between EIA-makers and transport planners were identified as responsible of this situation. These barriers were related to the types of results hoped for and the fact that transport planners scarcely receive inputs from EIA that can support their decisions. Accordingly, the objective of the paper was to present a strategy for proactive environmental instruments design ('PEID strategy'). According to this strategy, environmental assessment instruments must fulfil four key criteria: be (i) performance-oriented; (ii) reference value-based; (iii) integration-oriented and; (iv) decision-oriented. To illustrate and assess the worth of this strategy, an environmental assessment instrument (ETV-model) was developed following these criteria and applied to evaluate alternatives for a transit corridor in the city of Granada, Spain.

The 'PEID strategy' was implemented in two phases. The first phase (analytical and comparative) included three of the four key criteria of the 'PEID strategy', specifically, be performance-based, reference values-based and integration-oriented. Its central goals were basically two. On the one hand, to develop assessment and diagnostic methods oriented to the dynamic characteristics of urban transportation. On the other hand, to facilitate the involvement of other practitioners and decision-makers (non-environmentalist) into the evaluation processes. To follow the three key criteria above mention seems to be fundamental to achieve the goals of this first phase. The connection between these criteria was relevant when the ETV-model was applied in the metropolitan area of Granada. In this application, the outcomes of the model reflected in general that Alternative S.1 (corridor with Light Rail System) had less environmental negative impact than Alternative S.0 (corridor without Light Rail System), although this statement was dependent on the 'mobility environment' considered. During the application of the ETV-model the outcomes were related to dynamics characteristics of urban transportation, covering different temporal periods and including the interaction between urban transportation and urban structure. Another relevant aspect was that the outcomes of the model stimulated and facilitated the discussion between different decision-makers (environmentalist and non-environmentalist) to obtain comprehensive conclusions, being a relevant aspect of the development of more proactive environmental assessment instruments.

The second phase of the 'PEID strategy' (decision-oriented) aimed to support the practitioners in their decisions. In other words, complementing the assessment through tools that can be also useful to know how environmental performance of urban transportation can be modified by the decisions of planning practitioners. Following the fourth key criterion of the 'PEID strategy', designed a decision-oriented module was into the ETV-model. This module was completed with two indicators labelled 'Absorption capacity' and 'Improvement capacity'. These decision indicators were applied on Alternative S.1 in order to evaluate possible changes for improving its adaptation to the different 'mobility environments'. The outcomes obtained oriented decision-makers to modify the alternative with respect to the number of lines of public transport.

Following use of the 'PEID strategy' to develop proactive environmental assessment instruments, future research needs to analyse the impact of this strategy into planning practice and identifying ways of improving it. As a consequence of the results obtained in this paper, the case of Spain could be a representative context for this objective. The elaboration of sequential workshops following an 'experiential approach' (Straatemeier et al., 2010) with decision-makers and practitioners could be a useful way to analyse and improve the worth of this strategy and the impact of ETV-model in practice.

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