

ASSESSMENT OF ECONOMIC, SOCIAL AND ENVIRONMENTAL EFFECTS OF RAIL URBAN PROJECTS

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1. INTRODUCTION

Motorised mobility has increased in a significant way in last years, and this has brought too much congestion in urban areas. This situation has deteriorated city centres' liveable conditions. Therefore, urban areas need effective and flexible transport systems in order to develop policies integrating the three aspects of sustainability: economy, society and environment.

Current situation in urban areas could be described by the cycle of urban decline. The choice of travelling by car produces more traffic jams, thus reducing the efficiency of public transport and the quality of live in urban districts by increasing pollution and accidents levels. Firms decide to move out to suburban areas where the provision of public transport is very low, and again people decide to travel by car, producing the vicious circle.

In short, growing car traffic in urban areas makes necessary to cut this vicious circle by providing new public transport infrastructures. But, what kind of public transport infrastructures?

In many cities, rail urban projects (tram, metro and light rail systems) appear as the optimal solution in getting a sustainable mobility for the growing urban population, because they provide a modern image of the city among other benefits: fast, regular, safe and comfortable services, with medium-high capacity. Nevertheless, these kind of projects require large investments in order to be implemented, mainly in infrastructure construction and maintenance costs. These investments are much higher than for implementing solutions based on alternative transport modes, for example, a new bus line. Therefore, the financial profitability of the rail transport investments is very low.

However there exist other not economic benefits –social benefits and environmental improvements- induced by such rail projects.

Therefore, it is required to develop an ex-post evaluation considering economic, social and environmental effects in order to find the real benefit provided by these projects and to justify these large investments.

This evaluation procedure has been developed in the framework of a V FP European project called TranSEcon (Urban Transport and Socio-economic Development). The methodology is based on a multicriteria analysis which considers a number of criteria to achieve the global objective of sustainability.

The procedure was tested and applied in 13 European cities within TRANSECON. However, it has been changed and improved by the author of this paper in her PhD, thus focusing the results in seven case studies.

2. EXISTING ASSESSMENT TECHNIQUES

Public transport projects, at urban level, have increased their interest in the last years. Although there is a local perception that public transport generates many benefits, the feeling is that they are still poorly understood.

The traditional methods of benefit measurement have their roots in economic theory, offering an incomplete understanding about the local communities' perception of the value of public transport. Thus, there is a need to develop a new methodology in order to measure the socio-economic effects and impact produced by public transport investments in urban areas.

The transport evaluation literature reviewed (Leleur 1995, Turró 1999, Sugden and Williams 1978, Layard and Glaister 1996, Pearce and Hett 1999) some refer alternatively to *ex ante* evaluation, intermediate evaluation and *ex post* evaluation. Here, there will be developed an *ex post* analysis, because this is the only one that includes real information and it could detect both, the exogenous changes and the endogenous ones brought about the policy intervention.

There exists two main techniques for assessing transport investments: Cost-Benefit Analysis (CBA) and Multicriteria Analysis (MCA).

Cost-Benefit Analysis compares costs and benefits of an alternative and uses monetary values to measure all the effects. It seem to be more objective than MCA, but it doesn't include those effects which cannot be monetized. In short, CBA is not suitable to deal with our problem, because most environmental and social effects are difficult to monetise and cannot be included in the approach.

On the other hand, the Multicriteria Analysis evaluates simultaneously the achievement of some objectives by quantifying both impacts, quantitative and qualitative, not necessarily in monetary terms. The way for measuring the criteria has somehow a subjective component, but it allows the combination of quantitative and qualitative indicators. It is worth to mention the multi-criterion decision-making method ELECTRE (**E**limination et **C**hoix **T**raduisant la **R**éalité). It was conceived by Bernard Roy (Roy, 1991) in response to deficiencies of existing decision making solution methods. ELECTRE is underscored by two main concepts: thresholds (of indifference and preference) and outranking relations; that is, ELECTRE seeks to build an outranking relation using thresholds.

Taking into account all these considerations, MCA seems to be a more suitable technique for the assessment of transport investments under the objective of sustainable development. Despite its goodness, the method ELECTRE will not be followed in the development of a method for the assessment of economic, social and environmental effects o rail urban projects.

At this point, there is necessary to make a review of the existing assessment methodologies within the European Union, in order to see which one fulfils all the requirements for assessing all the effects produced by urban transport projects.

- **Review of existing national evaluation frameworks within Europe**

There has been reviewed the methodologies used in some of the European Union countries, and the main aspects of each of them are the following:

- In Netherlands, there exists some guidelines for the assessment of economic impacts of transport projects, which are based on CBA.
- In UK, there exists a Guidance on the Methodology for Multi-Modal Studies for scheme appraisal which is based in CBA and Environmental Impact Assessment. The approach is founded on the framework provided by five objectives: environment, safety, economy, accessibility and integration.
- In Germany, there exists some guidelines for economic evaluation of transport investments. All cost and benefits of quantifiable impacts are expressed in monetary units, and the qualitative analysis is only made where a quantitative assessment is not possible.
- In Austria, the evaluation method is a combination of CBA, cost-effectiveness analysis and an open discussion with responsible politicians.
- Finally, in Spain, there exists a methodology to evaluate transport projects in cities. The appraisal is carried out in two steps: first, a CBA is made to carry out the financial and economic evaluation. And then, it is complemented with a MCA, which includes the assessment of social and environmental impacts. It is an theoretical approach, and it doesn't express the guidelines in concrete terms.

The frameworks for evaluation of infrastructure assessment at national level are mostly used for *ex-ante* evaluation, and for the prioritising and phasing of projects.

Table 1: Assessment Methodologies in EU countries: comparison.

Country	Assessment Methodology	Comments	Suitability
NL	CBA	Categorization of direct, indirect and external impacts	No measurement of non-monetizable effects
UK	CBA + EIA	AST and supporting analyses	Schemes involving more than one mode.
G	CBA + qualitative assessment	Evaluation divided in topics	Regional & national level
A	CBA + cost-effectiveness + open discussion	3 groups of criteria	No environmental impacts
SP	CBA + MCA	Complementary	Theoretical approach

The conclusions drawn by the comparison between the methodologies reviewed are:

- all of them are ex-ante approaches
- there exists a tradition in the use of CBA for the appraisal of public transport infrastructure projects; normally, a global assessment is complemented with a MCA or some kind of qualitative procedure
- there exists some lack of uniformity in EU assessment methodologies
- the number of impacts included in the assessment is variable, and
- the assessments are mainly focused on regional and national level, but not on urban areas

In summary, none of the methodologies reviewed allows to quantify all the effects (economic, social and environmental) produced by transport projects in urban areas, so there is necessary to define a new methodology.

3. PROPOSAL OF THE NEW ASSESSMENT METHODOLOGY

3.1. Methodology description

As it has been stated before, the methodology will be based in a Multicriteria Analysis (MCA) approach, in order to measure the real benefits of the projects. The evaluation will be addressed under the objective of *sustainable development*, in its three dimensions: economic, social and environmental sustainability, so the objectives evaluated will be the economic benefits, the social benefits and the environmental improvements, which will be aggregated afterwards.

The assessment of the effects produced by a transport investment is based in their comparison in different scenarios. Within this methodology the benefits will be calculated by the variation between the reference scenario (situation without project) and the real scenario (with project), both scenarios are referred to the evaluation year (see Figure 1). This variation will be relative, in order to compare the case studies more precisely.

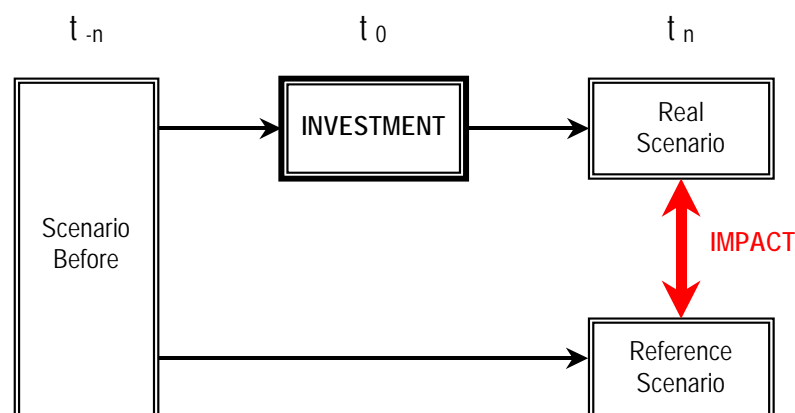


Figure 1: Evaluation scenarios.

Taking into account this consideration, and having in mind that a certain number of objectives must be evaluated, each objective will be measured in the two scenarios by one or more specific criterion, which receives in turn a value through one corresponding targeted indicator. The criteria could be quantitative and qualitative, and both criteria will be measured by choosing an appropriate indicator.

The level of achievement of each objective has to be expressed as a numeric value in order to quantify the final value of impact. Therefore, it is required from each topic under evaluation to define a procedure to convert the qualitative results into a numeric score.

The indicators defined for quantifying the criteria are calculated in the reference scenario and the real scenario, and the final impact will be the percentage of variation between reference and real scenarios.

When the individual effects have been measured, they have to be aggregated in a final single value: first of all, it is necessary to convert the range of every indicator's variation in an homogeneous one, from 0 to 1. This conversion will be done through value functions, one for each indicator. The value function will convert the indicator variation among scenarios in a homogeneous value scaled from 0 (no impact) to 1 (maximum impact). These normalized values will be the individual social utility for each criterion.

The second step in the aggregation procedure is to assign the homogenised indicators to each criterion to represent its relative importance to the overall objective of sustainability. The final impact will be the weighted sum of all indicators multiplied by the weight assigned to their corresponding criterion. The final formulation of the process will be the following:

$$\text{Socio – economic – environmental Utility} = \sum_{i=1}^n w_i \cdot \alpha_i$$

where w_i are the weights and α_i the individual social utilities of each of the n indicators.

3.2. Objectives, Criteria & Indicators

As it has been stated before, the evaluation will be addressed under the objective of *sustainable development*, in its three dimensions: economic, social and environmental sustainability, so the objectives evaluated will be the economic benefits, the social benefits and the environmental improvements to global sustainability in transport projects.

In order to measure the three main objectives it is necessary to determine a set of criteria. Table 2 shows the criteria defined and the indicators for measuring them.

There are 11 criteria: 9 of them are measured by quantitative indicators and the two remaining are measured by qualitative indicators, which have been calculated through a consultation process where a number of key actors of the different case study cities have taken part. They answered a semi-structured questionnaire designed for this end and afterwards the answers were coded in a numeric value in order to assign a final score to these qualitative indicators.

Table 2: Objectives, Criteria and Indicators for the overall assessment.

Sub-objectives	Criteria	Indicators	Quantitative/ Qualitative
Economic Benefits	Reduction of travel time	Total travel time saved by the project in both, public and private transport, between the scenarios	Quantitative
	Economic efficiency	Difference between 'Fare revenues' and 'Operation costs'	Quantitative
	Employment generation	Additional Regional Employment	Quantitative
	Economic growth	Economic Development Effect	Quantitative
Social Benefits	Social Equity	Quantified questionnaire responses	Qualitative
	Increase in the use of PT	Increase in public transport trips per day	Quantitative
	Urban regeneration	Urban regeneration in the vicinity of PT.	Qualitative
Environmental Improvements	Air Pollution	Reduction of pollutant emissions (Tons/year of CO, SO ₂ , NO _x , lead, PM)	Quantitative
	Noise	Percentage of persons that are less affected by noise.	Quantitative
	Greenhouse effect	Reduction of emission of CO ₂ (tons/year)	Quantitative
	Safety improvements	Reduction of accident costs per year (Euro/car-km.)	Quantitative

3.3. Homogenisation and weighting

Next step in the multicriteria evaluation is the normalization of the indicators. This can be made thanks to the value functions, which are real functions that transform the variation of one indicator in homogeneous values, in order to measure them in the same scale avoiding that way problems with the different units (MFOM, 1996). It has been chosen the scale [0,1] for the normalisation of the indicators, where 1 means maximum social utility and 0 means no social utility at all.

There will be one value function for each indicator. The form and the limits of the value functions will depend on the range of the scores for each single indicator among our case studies. The form of the value functions of all the indicators defined will be linear, because they are simplifications of the utility functions threshold being at the safety side (see Appendix for more detailed value functions). In those linear functions the upper limit (1) will be assigned to the best case study value (see Figure 2).

When all the indicators are normalised, it is time to assign to each criterion a weight to represent its relative importance to the overall objective of sustainability. Weights have been determined through a consultation process where key actors of the different cities and research teams have taken part. The criteria were scored from 1 to 10, where 10 was the maximum importance with respect to sustainable development.

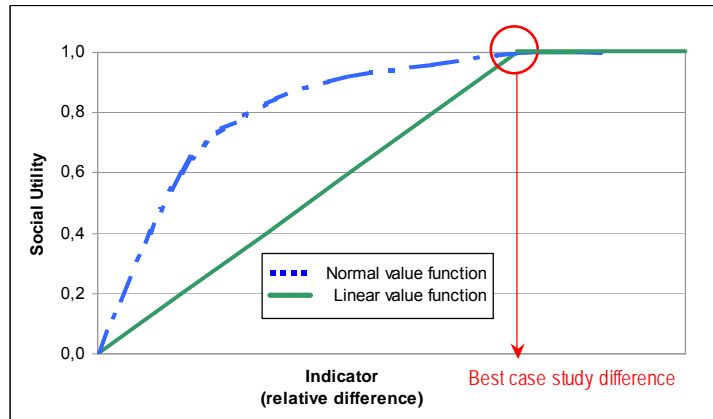


Figure 2: Value function for each indicator.

As different key actors assigned a weight to each criteria, there was applied the median of all these weights, in order to avoid incongruent values. Moreover, there were used the same weights for all the case studies.

Within this methodology it has been considered that the relative contribution of each sub-objective to sustainable development must be equal, and all the weights should sum 100 ($\sum_{criteria} weights = 100$). So, economic benefits must weight $100/3$, social benefits $100/3$ and environmental improvements also $100/3$. This requirement make necessary another normalisation of the medians (see Table 3). Thus, the final weights to apply afterwards in the MCA procedure are those which appear in the “median normalised” column.

Table 3: Relative weight given to each criteria to evaluate sustainability.

Objective	Criterion	MEDIAN	Median normalised (w_i)
Economic Benefits	Reduction of travel time	10.80	10.58
	Economic efficiency	7.72	7.56
	Employment generation	7.79	7.63
	Economic growth	7.73	7.57
Social Benefits	Social Equity	11.39	11.13
	PT Improvements	12.80	12.51
	Urban regeneration	9.92	9.69
Environmental Improvements	Air Pollution	8.44	8.44
	Noise	8.44	8.44
	Greenhouse effect	8.44	8.44
	Safety improvements	8.00	8.00
SUM		101.46	100.00

Source: TRANSECON survey in 13 European cities.

3.4. Contribution to sustainable development

The contribution to sustainable development of the projects is calculated by aggregating the weighted individual social utility of every indicator.

$$[\textit{Weighted Individual Social Utility}]_i = w_i \cdot \alpha_i$$

where w_i are the weight and α_i the individual social utility of every i indicator.

The aggregation means, in other words, the global impact of the project, and it will measure the changes in socio-economic-environmental utility between the two scenarios.

The final formulation of the process will be the following:

$$\textit{Contribution to Sustainable Development} = \sum_{i=1}^n w_i \alpha_i$$

where w_i are the weights and α_i the social utilities of the n indicators (in this case, $n=11$).

4. RESULTS OF THE METHODOLOGY APPLICATION TO THE CASE STUDIES

4.1. Description of the case studies

There has been chosen seven European case studies in order to validate the proposed methodology. The case studies represent an interesting range of different public transport systems, in particular metro, light rail and S-Bahn systems. Most cases are at least 10 years old, however there are some more recent.

The public transport systems distinguish themselves primarily by the *range and type of service*. There is one proper *S-Bahn systems* (Stuttgart), three proper *metro systems* (Lyon, Madrid and Vienna), *two types in between* (Tyne & Wear and Manchester) as well as one *surface transport system* (Valencia). Within this evaluation, Tyne & Wear will be considered as suburban rail system, and Manchester as a tram system.

Table 4 summarises the main characteristics of the case studies.

Table 4: Summary of case study characteristics.

City	LYON	MAD	MAN	STU	T&W	VAL	VI
<i>Project</i>	Metro	Metro	Metro / tram	S-Bahn	Metro / S-Bahn	Tram	Metro
<i>Areas concerned</i>	City	city	city and suburbs	city and suburbs	city and suburbs	city and suburbs	city
<i>Length (Km.)</i>	15.0	7.0	31.0	16.0	55.5	9.7	8.2
<i>% new project/ total network</i>	54.5%	4.1%	84.7%	14.5%	94.1%	7.3%	13.3%

<i>Total investment (M€ of 2002)</i>	524.4	283.0	270.0	352.0	1233.0	124.2	2487.0
<i>Investment/km. (M€/km.)</i>	35.0	40.4	8.7	1.88	22.2	12.8	303.3
<i>Operation since</i>	1992	1995	1992	1992	1984	1994	1991

4.2. Results

In this section there will be presented the main results obtained in the application of the assessment methodology described previously. The following table summarises the weighted individual social utility of each criteria per case study.

Table 5: Weighted individual utility per case study of all the criteria and their aggregation.

		Weighted Individual Social Utility						
Sub-Objectives	Criteria	LYON	MAD	MAN	STU	T&W	VAL	VI
Economic Benefits	Reduction of travel time	0,74	1,49	0,00	4,58	0,24	3,38	10,16
	Economic Efficiency	0,29	0,66	0,00	3,14	0,00	0,63	7,73
	Employment generation	6,42	5,38	8,14	0,93	7,87	6,86	4,14
	Economic growth	3,66	4,39	4,39	7,32	4,39	5,12	3,66
Economic Benefits		11,10	11,91	12,53	15,97	12,50	16,00	25,68
Social Benefits	Social Equity	7,39	7,86	8,09	7,54	10,06	3,77	8,80
	Increase in the use of PT	1,72	0,03	2,52	7,96	12,92	0,95	2,25
	Urban regeneration	7,76	7,76	5,17	7,76	10,34	10,34	10,34
Social Benefits		16,87	15,64	15,78	23,26	33,32	15,06	21,39
Environmental Improvements	Air Pollution	0,00	0,63	0,01	0,10	0,29	0,21	8,52
	Noise	3,77	2,37	0,44	8,51	3,30	0,78	5,88
	Greenhouse effect	5,51	3,50	0,05	2,05	1,30	1,17	8,51
	Safety improvements	3,55	2,25	0,42	7,80	0,42	0,75	5,46
Environmental Improvements		12,83	8,75	0,91	18,46	5,31	2,91	28,37
SOCIO-ECONOMIC AND ENVIRONMENTAL UTILITY		40,80	36,30	29,22	57,69	51,13	33,97	75,45

The maximum value of socio-economic-environmental utility is 100 per case study, and 33.33 per each sub-objective. Looking at Table 5, only 3 projects (Stuttgart, Tyne & Wear and Vienna) show more than 50 points in the global utility.

In addition, most projects present greater social benefits than economic or environmental ones, except Vienna and Valencia. Tyne&Wear is the case study with the highest social benefits of all considered, mainly due to the big increase in the use of public transport. On the other hand, environmental benefits are greater in the case studies with metro (Vienna, Lyon and Madrid), and also for Stuttgart. Vienna's metro is the project that produces greater environmental benefits, achieving almost the maximum, owing to the significant reduction of pollutant emissions between scenarios.

Figure 3 presents the global benefits of the projects but expressed in a way that can be compared the partial utility of each sub-objective with the final value of socio-economic-environmental utility. It is possible to appreciate that final utilities are similar by type of project, except Vienna, whose benefits are much higher than the rest of projects. Thus, metros -apart from Vienna-, Lyon and Madrid, present a final utility very similar, around 40; suburban rails show a little bit greater utility, about 50; and the lowest utilities are for the trams, around 35.

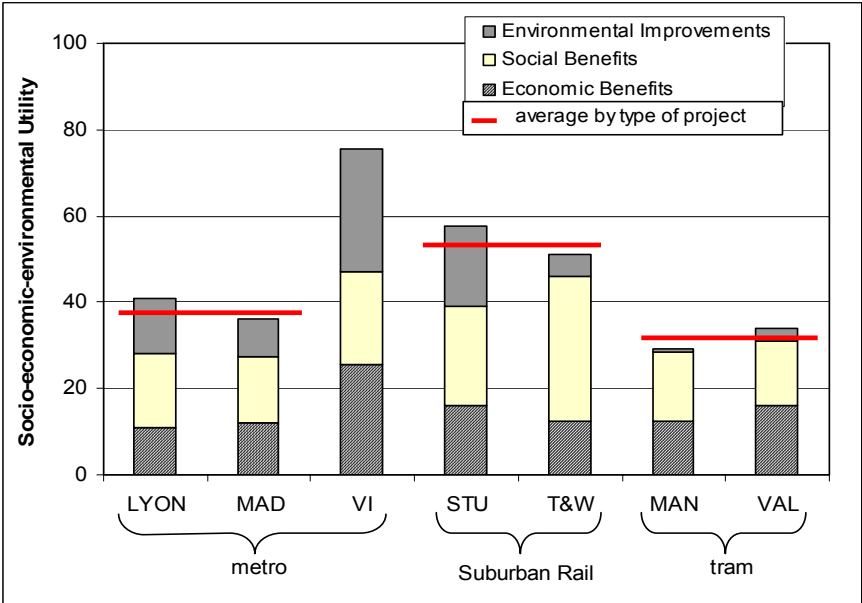


Figure 3: Economic, Social and Environmental Benefits referred to the total benefit.

Regarding the economic benefits (see Figure 4), the maximum value taken by these benefits is around 10. In general terms, employment generation is the economic benefit which has got the best results. However, in Vienna, the best economic benefit is the reduction of travel time, and in Stuttgart, the best is the economic growth.

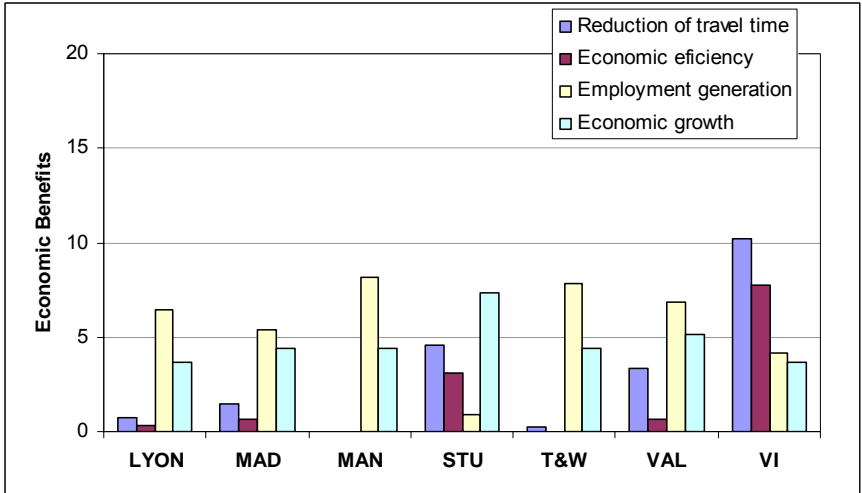


Figure 4: Economic benefits due to the projects.

Concerning the social benefits obtained thanks to the projects (see Figure 5), social equity and urban regeneration are two benefits well balanced in almost all the case studies. Nevertheless, the increase in the use of public transport is only significant in Tyne&Wear and Stuttgart.

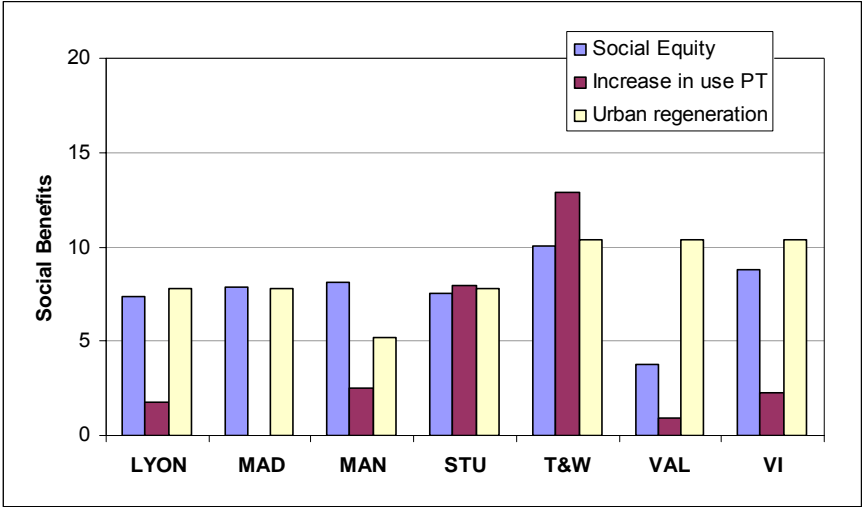


Figure 5: Social benefits due to the projects.

Finally, the environmental improvements are very different in the case studies (see Figure 6). Vienna seems to be the case study with better environmental benefits. Only Stuttgart has more noise reduction and better safety improvements. Manchester hardly presents improvements in terms of environmental benefits.

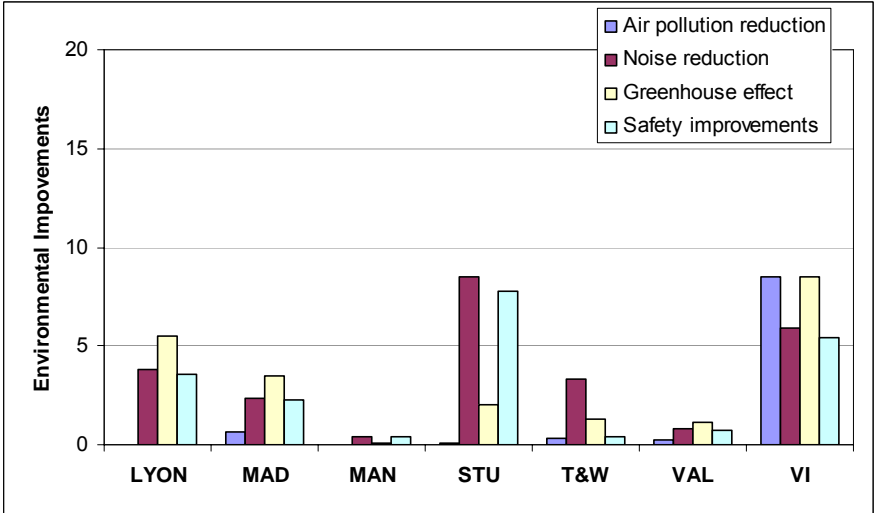


Figure 6: Environmental improvements due to the projects.

Very often, the benefits that transport projects produce depend on the investments that have been made. The following figure shows the relationship between the final contribution of the project to the objective of sustainability and the investment that has been carried out to put it in operation.

The regression curve adjusted to the inner city projects (those that run by downtown) is a linear one and the regression coefficient is very high, so the adjustment is very good. It means

that those projects are quite related to the investment costs, and that the efficiency increases with the investment, so the project with highest investment, in this case Vienna, is also the project with maximum socio-economic-environmental utility.

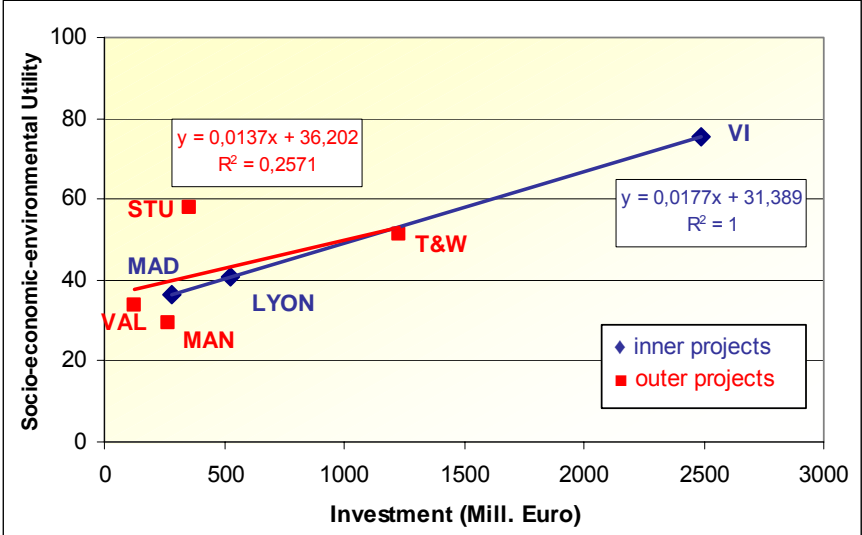


Figure 7: Socio-economic-environmental utility related to project investment.

In outer city projects (linking downtown with the periphery of the city), the regression line adjusted is not very good (R^2 is very low). It can be said that the socio-economic-environmental utility of the outer city projects is very similar regardless of investments. It means that there are many other factors influencing socio-economic impacts.

5. CONCLUSIONS

- All the case studies present a clear positive socio-economic-environmental utility, so they produce economic, social and environmental benefits and contribute to the overall objective of sustainable development.
- Rail projects (metro/tram/suburban rail) produce evident improvements in terms of social and environmental benefits. Therefore it is necessary to develop evaluation procedures to take into account those indirect effects, like the one developed in this paper.
- The investments made for the projects implementation induce a mobilisation of other resources, which produces relevant economic benefits in most cases.
- Social utility is higher than the economic and environmental benefits in most of the case studies. This fact justifies all the methodologies that include social and environmental aspects in the assessment.
- The higher environmental improvements are directly related to metro projects (Vienna, Lyon, Madrid), and also to the Stuttgart S-Bahn.
- High capacity rail projects (metros and suburban rail) provide an important increase in accessibility and also in the travel demand, which mean a big potential for urban development of the areas influenced by the project.
- In general terms, benefits of outer city projects are less dependent on the investment levels. On the contrary, inner city projects benefits are clearly related to the investment amount of the project.

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¹GOMMS: Guidance on Methodology for Multi-Modal Study