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Assessing the Economic Benefits of Transit Projects

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Introduction

The development of effective transit systems requires investments of millions or even billions of dollars in public money. Controversies often rage over whether such investments are efficient or whether the money would be better spent on other public projects or even returned to the taxpayer. Public servants charged with allocating investment dollars therefore need ways of assessing the economic benefits that arise from transit projects to see whether they are sufficient to justify the cost.

This paper seeks to provide an overview to the issues and methods related to the assessment of economic impacts from transit projects[1]. It has four broad and interrelated goals:

1. to provide a **taxonomy of economic impacts** (that is, to define a set of categories of benefits that might arise);
2. to review **conventional methods of assessment** that are currently used to by public agencies to measure economic impacts;
3. to introduce a class of **dynamic impacts** that occur indirectly and in the long run and which are often not captured by conventional assessments, and
4. to discuss some **special issues for Tren Urbano** concerning the benefits that might accrue to the San Juan economy.

Before we address these main goals, discussion of four conceptual issues is in order. First, some explanation is needed for the terms "impacts" and "benefits" as they are used in this paper. An economic impact is any economic change that is brought about by the creation of a transit system. A benefit is an impact that is unambiguously positive. For example, reductions in transportation

[1] We restrict ourselves to methods for evaluating individual projects. For a recent study evaluating the economic benefits of transit on a national basis, see Camph (1997).

costs are clearly benefits since everyone is either unaffected of better off because of them. Changes in property values adjacent to the transit infrastructure, on the other hand, may be a positive change for some people and a negative change for others.

Second, it is important to understand that "economic benefits" do not refer only to flows of money between economic stakeholders. They may include non-monetary outcomes for which the person benefiting would be *willing* to pay. For example, if a commuter gets a faster trip for the same fare, she is receiving a benefit equal to the amount she would be willing to pay to get to work faster. (Of course, determining how much value she places on the time she saved is one of the key problems of benefit assessment.) This means that the economic benefits may be sufficient to justify the costs even if the *revenues* are not.

Third, a first step in assessing economic impacts from transit (or any other type of transportation infrastructure) is adopting a perspective on what is the overall goal of the transportation system. The common, if somewhat naïve, view is that the transportation system is there to provide *mobility* – that is to make it easier for people to move around. From this perspective, the quantity of service delivered can be measured in terms of passenger miles traveled. An alternative perspective is that the transportation system is part of a broader public strategy to enhance *accessibility* – that is to make it possible for people to be where they want to be when they want to be there.[2] As we will see, these two views are not always consistent so your assessment of economic benefits may depend on your perspective.

Finally, there is controversy as to the *scope* of economic impacts that can be attributed to new transit projects. At one extreme are those for whom the objective of transit projects is only to improve the quality of service to existing transportation demands. To them, benefits accrue only because the new infrastructure can provide services to existing users that are faster, cheaper, and better. At the other extreme are those who believe that new transit infrastructure may unlock the potential of a society to achieve broad development goals, such as economic growth, improved quality of life, and expanded economic justice, especially for those who are economically or physically disadvantaged[3]. As we

[2] For a discussion of mobility vs. accessibility see Bureau of Transportation Statistics (1995).
[3] See Crain and Associates (1998) and Gardenshire (2000).

will argue later, assessments that take this broader view must incorporate dynamic benefits that may be harder to quantify than simple time or cost savings.

Taxonomy of economic impacts

The economic impacts of transit systems are so numerous and diverse that it may be difficult to make comprehensive benefit estimates. A good place to start is by organizing the potential benefits into categories – that is creating a taxonomy of benefits. We will therefore assign all benefits to categories according to two dimensions: the *project stage* during which they occur and their *incrementality*.

Every transit infrastructure project has two stages: the construction stage and the operation stage. We refer to changes that occur primarily during the construction stage as *project impacts* and those that occur during the operation stage as *service impacts*.

Project impacts include employment and income arising directly and indirectly as the result of construction activities. They also include the impacts of ongoing operation and maintenance activities throughout the lifetime of the infrastructure. Project impacts arise principally due to the flow of materials and labor into the project both directly and indirectly. (Indirect flows include all the materials and labor that are needed to produce those inputs used directly on the project.)

Project benefits may also include improvements to the productivity of a local economy because of capabilities developed during the construction phase. For example, a major transit project such as Tren Urbano requires the training of many skilled people – engineers, electricians, etc. Those people and their skills will be available for other economic activities after the project is finished. A related example is the "technology push" benefit whereby technological solutions to the problems encountered in a massive infrastructure project are spun-off to private construction, creating new construction sub-sectors that offer cheaper and more innovative services.

While project benefits may be substantial, they are not the only, nor necessarily the principal justification for transit expenditures. Rather, those expenditures may ultimately be justified on the basis of *service impacts* that accrue during the operation stage directly to the consumers of transportation services and indirectly to anyone who consumes goods and services that are better or cheaper because of improvements in transportation. The most obvious source of service benefits is reduction in transportation costs and savings in transportation time. These benefits accrue directly to transit users, but may also accrue directly to non-users (Camph, 1997). For example, in Tren Urbano reduces the number of automobile commuters by 10%, the remaining automobile commuters will have shorter trips because of reduced congestion. Even freight transportation within the San Juan Metropolitan Area will benefit from this reduction in congestion. This, in turn, can result in reductions in production costs.

Service benefits also include reductions in undesirable side affects of auto transportation, such as noise and air pollution. Taking the broader view, the service benefits of transit may include achievement of social goals such as improved accessibility for the economically and physically disadvantaged.

In the long run, service benefits may contribute to the productivity of the regional economy in a number of ways. Making it easier to connect jobs with compatible people (labor matching) will increase labor productivity. Also, the role of transit in reinforcing the economic strength of downtown districts leads to the agglomeration benefits associated with cities with high concentration of economic activities. The values of properties adjacent to transit facilities may increase and opportunities may be created for new types of commercial development.

Another way to categorize impacts is according to *incrementality* – that is the degree to which transit generates new benefits as opposed to redistributing existing benefits. We can assign all measurable economic impacts of transit to one of three categories: *generative impacts, redistributive impacts,* or *financial transfer impacts* (Cambridge Systematics, 1998). Generative impacts are those that create net increases in economic well being within the region served by the transit system. Distributional impacts are shifts in economic benefit from one place to another within the region. Financial transfer impacts refer to transfers of money from one person to another that produce no net benefit.

Table 1 creates a two-way classification of transit benefits according to project phase and incrementality. The assignments to incrementality categories are consistent with a recent report to the Transportation Research Board

(Cambridge Systematics, 1998) but we have place question marks (?) where we consider the incrementality of an impact to be subject to debate.

Note that most of the service impacts are also defined as generative impacts. These include all those effects that reduce the cost and improve the quality of transportation and all those spurs to economic growth that result from better transportation. However, a number of service benefits are listed as redistributional because they simply shift economic activity from one place to another. These include land development and locally improved competitiveness around station. This view is open to debate, however, since the type of development that is spurred by transit may not have occurred elsewhere if the transit did not exist. (We will return to this issue below.) Property tax revenues, which may be viewed as a major benefits by municipal governments, generate no new income and are therefore classified her as financial transfers.

Table 1: Two Way Classification of Transit Impacts

	Service	Project
Generative	User Benefits External Benefits - pollution - congestion Induced Economic Growth - productivity - labor matching - agglomeration Parking reduction	Skills creation "Technology push"
Redistributive	Land development (?) local competitiveness	
Financial Transfer	Property tax revenue	Construction / O&M employment/income (direct and indirect) (?)

As for the project benefits, the prevailing view is that only "technology push" and skills development impacts are generative. Employment and income generated directly or indirectly by construction is seen as a financial transfer.

This, of course, is open to considerable debate. If there is high unemployment, the creation of new jobs in construction may have a significant social benefit. In an environment of full employment, however, employees are simply diverted from other jobs, so there is no net generation of income.

Conventional Methods of Assessment

Given the huge investments made on transit and the requirements for economic justification under various federal and state legislation, transportation analysts have developed a toolbox for making quantitative assessments of the economic impacts of new or expanded transit systems.[4]

Project impacts

Despite the argument that income from transit construction may be non-generative, most public agencies consider it an important benefit. Therefore methods have been developed to estimate this type of project impact. Estimating direct flows of labor and other inputs to the project is a relatively simple process of calculation based on plans and specifications. However direct impacts tell only part of the story. The total economic impact consists of three components:

- *direct impacts*, which include the payments for labor, machinery, design/engineering services, and all physical inputs (concrete, steel, components) used in the project;
- *indirect impacts*, which include the payments for all inputs required to produce the direct inputs; and
- *induced impacts*, which includes all employment and other income generated as the new income (direct and indirect) is spent in the regional economy.

To make this more clear, consider the construction of a bridge. The costs of labor, machinery leasing, fuels, steel, concrete and other inputs are included in the direct impact. The labor and other inputs used to produce the steel, aggregates, cement, etc. are included in the indirect impacts. Part of the income that is generated both directly and indirectly will be spent on consumer goods, personal services etc. This will result in increased employment income for people working in retail and services. This is the induced impact.

Calculating indirect and induced impacts is achieved using *an input-output model*. This model is based on an accounting system that specifies the

[4] For a review of analyses conducted in 15 U.S. cities see Horowitz and Beimborn (1994).

interrelationships between different economic activities. The procedure for estimating total impacts is of the following form[5]:

Direct input requirements ⇒input-output model⇒ total impact

In most cases, the total impacts are two or more times as great as the direct impacts. For example, according to the Tren Urbano Environmental Impact Statement, each $1 spent on direct input requirements to the Tren Urbano project generates a total impact of $2.15. Thus the total economic impact is more than twice as great as the project cost.

While this type of total impact analysis is almost universally conducted for major transit projects, we are not aware of any attempts to quantify the more clearly generative skills creation and "technology push" categories of project benefits.

Service impacts:

In order to estimate service impacts it is first necessary to see how the new or improve transit system will affect all forms of travel activity in the region. This amounts to asking a number of fundamental questions, including:

- How many people will use the new service?
- How will it affect their travel time?
- How will it affect the travel time of non-users?
- What effect will it have on pollution, accidents?
- How much revenue will it generate?
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Before any of these questions can be asked, two basic research assets are required: a travel survey and a travel demand model. The travel survey is used to gather information on the travel needs, routines, and preferences of all the people in the region that the new transit will serve. The survey elicits information on a representative sample of either individuals or households within the region. Since a sample of 2% to 5% is required, many thousands of survey responses are

[5] A mathematical exposition of input-output modeling is beyond the scope of this paper. For a good technical reference see Miller and Blair (1985).

needed. Thus the travel survey tends to be the most expensive component in any impact assessment.

Surveys are generally of two types: *revealed preference* or *stated preference*. In a revealed preference survey, respondents are asked to describe the travel activities of all household members – where they go, what mode of travel they use, at what time they travel, how long it takes them to travel, etc. From this information, the preferences of individual travelers are inferred. Based on this inferred preference structure, a prediction can be made of how many travelers would use a new transit alternative.

A stated preference survey asks the respondent to speculate about what choice he would make when faced with a hypothetical travel choice. While revealed preference surveys are generally considered more reliable, stated preference surveys are necessary to see how travelers would react when presented with a travel option that is completely new to them.

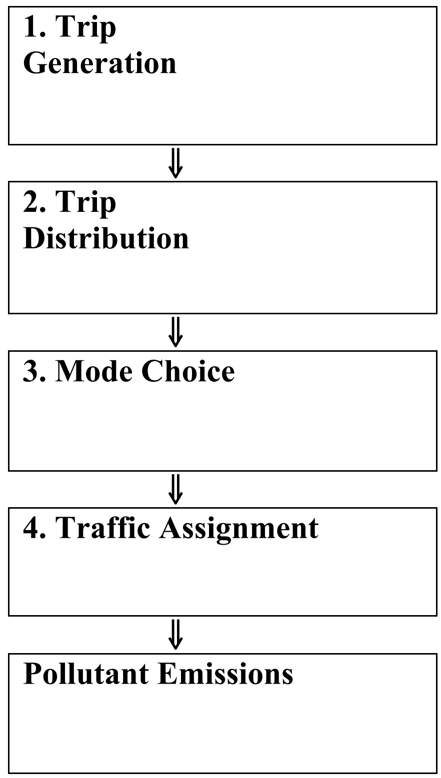
The transportation demand model comprises a set of mathematical relationships that predict aggregate travel behavior within a metropolitan region. The parameters of the relationships are based on statistical analysis of the survey results. So, for example, the affect of household income on the propensity to use public transportation is inferred by observing a large number of households with different incomes and estimating a statistical model with some measure of transit use as the dependent variable and income as the independent variable.[6]

The most common type of travel demand model is the "four step" model illustrated in Figure 1.[7] This is actually a sequence of four interrelated models. Before the model can be applyed, the entire metropolitan region must be broken down into a series of zones. The trip generation stage predicts the number of trips that will begin and end in each zone within a predefined time interval. This information is passed to the trip generation model, which predicts the number of trips that will occur between each pair of origin and destination zones. The mode choice model determines what proportion of trips between each origin-destination pair will be by made by private car (split into drivers and passengers), by non-

[6] This is an oversimplification. The actual practice is to estimate multivariate relationships whereby travel behavior is related simultaneously to a variety of household characteristics.
[7] For a technical overview of urban travel demand modeling see Sheppard (1995).

motorized means (walk, bicycle), and by different categories of public transportation (bus, rail, publico, etc.).

Figure 1: Four-Step Travel Demand Model



The final stage is the traffic assignment model. Here the zone-to-zone automobile trips are translated into traffic flows along the metropolitan road network. This makes it possible to predict the traffic flow along specific road segments and by comparing flow with design capacity predict the level of congestion. The traffic assignment model requires the creation of a digital network to represent the real road network and is generally the most computationally demanding part of the four-step model.[8]

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[8] Arnott and Small (1994) provide a good conceptual introduction to the modeling of urban traffic.

While it is not strictly a component of the four-step model, a model to estimate the emissions of air pollutants over the road network is often included to assess environmental impacts.[9]

The four step model provides a summary characterization of the functioning of the urban transportation system. It takes the state of both road and transit networks as given. Thus, the impacts of adding a new transit system can be assessed by making comparable predictions, one without and one with the transit system in place. For a new or improved transit system, the model can predict:

- The number of people using the new system
- the travel time savings of users
- the travel time savings of non-users
- changes in aggregate emission levels

While the four-step travel demand is a well-tested methodology, it has a number of significant shortcomings. For example, since the spatial distribution of urban activities (residences, workplaces, etc.) is taken as given, it is not able to predict the impacts of new transportation infrastructure on the urban form. In recent years, a number of more elaborate models have been developed to address this weakness.[10] Also, the general approach whereby the trip is the unit of analysis is criticized by proponents of "activity analysis," an approach to travel demand modeling that stresses the role of transport in facilitating daily activity schedules.[11]

Finally, it is important to recognize that the preferences of individual travelers are embodied in the parameters of the model. Therefore, the model cannot predict changes in attitudes toward public transportation. This may constitute a serious problem for a large scale project like Tren Urbano, which is likely to have an impact on how the public views alternatives to private automobile travel.

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[9] Anderson *et al* (1996a) describe the interface between the outputs of a traffic assignment model and EPA's MOBILE5 emissions model.
[10] See, for example, Scott, Kanaroglou, and Anderson (1997), Landis and Zhang (1997).
[11] A collection of papers on activity analysis is found in Ettema and Timmermans (1997).

Travel demand models can predict likely outcomes of the construction of transit infrastructure, but cannot provide "go / no go" answer as to whether the project costs are justified. Cost-benefit analysis is designed to provide such an answer. This method is generally regarded as the standard approach to impact assessment and is performed for nearly all proposed transportation infrastructure projects in the United States.

The essence of cost-benefit analysis is that all benefits and costs must be expressed in monetary units. This means that that the outcome of the analysis may be expressed as a simple benefit/cost ratio. If its value is greater than one, then the project yields a positive net benefit.

This clarity of outcome is achieved at the price of imputing dollar values for most types of benefits and some types of costs. For example, all time savings must be multiplied by a dollar value per minute saved to arrive at monetized benefit estimate. Since time savings often accounts for half or more of total benefits, the outcome of the analysis is highly dependent upon the dollar value chosen. Various theoretical approaches, including the cost of lost wages and willingness-to-pay, can be used to set this value, but in practice a rule-of-thumb value such as $10 per hour is often used.[12]

Table 2 shows the basic elements of a typical cost-benefit analysis. Note that the calculation of benefits is more complex than calculation of cost because the former are more numerous and heterogeneous. In particular, values to translate benefits into monetary units are needed for all but cost savings and fare revenues. Also, nearly all cost and benefit values must be adjusted by some discount factor to take account of the fact that a dollar spent or received at some point in the future is worth less than a dollar spent or received today. Selection of the discount rate, which is conventionally set equal to the rate of return on private capital, can have a very significant impact on the results of the analysis.

Cost-benefit analysis is so prominent in the transportation planning process that the U.S. Department of Transportation has made easy-to-use software available at no cost.[13]

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[12] A brief review of cost-benefit analyses revealed values of time varying from $6 to $14.
[13] See DeCourla-Souza (2000); DeCourla-Souza and Hunt (1998).

Table 2: Elements of a Cost-Benefit Analysis

Element	Basis of Measurement
Benefits	
User Travel Benefits	
Cost reduction	Discounted flow of dollar savings
Time savings	Discounted flow of time savings times dollar value per hour saved
Accident reductions	Discounted flow of damage cost reduction plus monetized value of injury and fatality reduction
Non-user Travel Benefits	
Time savings	Discounted travel time savings due to decreased congestion times dollar value per hour saved
External Benefits	
Metropolitan pollutant reduction	Discounted flow of reductions in grams times damage cost estimates.
Greenhouse gas reductions	Discounted flow of reductions in grams times damage cost estimates.
Fare revenues	Discounted flow of anticipated revenues
Costs	
Capital Cost	Construction, engineering and right-of-way costs (possibly inflated to service start date)
Operations and Maintenance Costs	Discounted flow of anticipated costs

Although cost-benefit analysis is widely used, it also widely criticized. Much of the criticism relates to the need to translate all benefits into monetary terms. Estimates of the dollar value of things like pollution reduction may vary significantly among analysts. In light of this, presentation of a simple benefit / cost ratio conveys a false impression if quantitative precision. Also, many of the dynamic benefits of transit (discussed below) defy monetization and are therefore usually left out of cost-benefit studies. This means that many of the economic benefits uniquely associated with transit are ignored. A further problem is that the weight of long term benefits are severely reduced by the practice of discounting, thus creating a bias for short term solutions.

At the conceptual level, cost-benefit analysis and many other methods applied in transportation analysis have been criticized for focussing on the *outputs* rather than the *outcomes* of transportation systems (Mazur and Zabierek, 1998). Outputs are throughput measures such as number of riders, passenger miles, fare revenues, etc. While these are important indicators of how the system is functioning, they do not tell explicitly whether the system is bringing about desirable outcomes, such as improving access to jobs, satisfying customer's expectation, and generally getting people where they want to be when they want to be there. Clearly, the distinction between outputs and outcomes is closely related to the distinction between accessibility and mobility.

An alternative to benefit-cost analysis that addresses some of these criticisms is called total cost analysis (TCA). It is based on the idea that most economic decisions – such as a consumer's choice among a number of alternative goods – are not based on calculation of a benefit / cost ratio, but rather on a trade off between the quantifiable costs and non-quantifiable (or at least non-commensurable[14]) benefits.

In TCA, more than one transportation alternative are always considered (one of which may be the "do nothing" alternative.) For each alternative, all elements that can be expressed in dollar terms are counted as costs. For example, travel costs, time costs, accident costs and environmental costs can be calculated

[14] Measureable in common units.

and summed to produce the total cost of each alternative. But the one with the lowest cost is not necessarily the best because each alternative also has a number of benefits that are expressed in non-monetary units or even described in words. While this method does not provide the "bottom line" answer of cost-benefit analysis, it makes it possible first to weed out inferior alternatives and then choose among the non-inferior alternatives based on cost benefit trade-offs. Thus, rather than providing a prescribed choice it provides information into a decision process that may involve public participation.

Perhaps the main criticism of exclusive dependence on cost-benefit analysis is that no analytical method can address all the issues that need to be included in a comprehensive economic assessment. For this reason, it may be advisable to apply a number of different methods to assessment of the same project in order to uncover as many types of economic impact as possible. The following are alternative approaches that can be applied to transit projects[15]:

- *Comparison studies*: A simple and intuitive way to anticipate the impacts of a transit project is to look at the experience of a similar project that has already been completed in another location. This is a good rough-cut method, but it does not allow the analyst to control for differences in context that might affect economic outcomes.
- *Expert opinion/ focus groups:* A variety of methods have been developed to elicit information from the opinions of experts who may be interviewed separately or asked to participate in a group setting. This seldom provides precise impact estimates, but it is at the very least a good way to articulate all the possible types of impacts.
- *Development support analysis:* Instead of measuring the benefits of a transportation project, this method specifies the range of development options that are possible only if the project is undertaken. It is thus a way of looking at the capacity of infrastructure to support growth.
- *Hedonic Price Models:* Since transit confers accessibility benefits, and since real estate values are affected by accessibility, one way of measuring the economic benefits realized is to measure increases in property values or rents that can be attributed to transit service.[16] [17]

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[15] Some further assessment methods are described in Weisbrod and Grovak (1998).
[16] See Weinberger (2000) for a review of past studies and a recent application to light rail in California.

- *Regional Economic Models:* These are rather complex models that may combine elements on input-output and econometric methods. While they have large data and programming requirements, they have the ability to predict outcomes of transit development such as economic growth and productivity enhancement.[18]

Dynamic Impacts:

Some of the impacts of public transit play themselves out over a long time affecting fundamental changes in the economic structure of the urban region. We call these *dynamic impacts* both because they occur in the relatively long run and because they involve complex patterns of interaction between economic variables. Dynamic impacts are sometimes manifested by changes in variables other than those typically associated with transportation and are frequently overlooked in economic impact assessments. We believe, however, that dynamic impacts are among the most important outcomes of transit infrastructure decisions.

One of the most important dynamic impacts is the effect of transit on the evolution of urban land use patterns. In the four-step approach to travel demand modeling the land use pattern (the spatial distribution of residences, workplaces, shopping, schools, etc.) is taken as given. So the assumption is that land use affects transportation but not the reverse. Urban geographers and historians, however, have long recognized that changes in transportation infrastructure and technology influences the spatial pattern of the city as it emerges over time. For example, in his classic book *Streetcar Suburbs*, Sam Bass Warner explains how the extension of rail lines beyond the Shawmut Peninsula influenced the spatial structure of the Boston metro area. Urban geographers have conducted numerous studies relating changes in urban form to transportation innovations.[19] Serious consideration of the land use effects of transportation projects, however, is a relatively recent trend.[20]

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[17] Care must be taken to avoid double counting when combining the result of a hedonic price model with those of other analysis. For example, the value of time saved may be translated into higher rents by market forces. If a time saving estimate is added to a rent appreciation estimate, the same benefit will be counted twice.

[18] The best-known of these models is the REMI model (Weisbroad and Treyz, 1998) although it is usually applied to highway rather than transit projects.

[19] Muller (1995) is a useful overview of this literature.

[20] A recent guidebook for assessing land use impacts was prepared by Parsons Brinckerhoff (1999).

The link between transportation and land use lies in the fact that land use patterns are largely driven by accessibility and new transportation infrastructure significantly alters the the pattern of accessibility within a metropolitan region. Changes in accessibility lead to changes in the land use pattern, which in turn lead to changes in travel patterns.

Transport Infrastructure	⇔	Accessibility Patterns	⇔	Land Use Patterns

Different types of infrastructure have different effects on land use. Highway and road infrastructure tend to create a dispersed pattern of accessibility, leading to a low density development pattern. Transit, by contrast, tends to concentrate accessibility around stations, leading to a denser, more nodal development pattern.

The transit – land use relationship is important because the spatial structure of development has important economic consequences. For example, the more dispersed pattern of development associated with heavy reliance on automobile transportation implies increased consumption of fuels and more land being transferred from agriculture or wilderness to urban uses. This may lead to environmental problems, especially air pollution and loss of habitat.[21] Also, it may be more expensive to provide public services such as water, sewage, and solid waste disposal to low density developments. (Office of Technology Assessment, 1995). Finally, low density development makes it difficult for people without cars to reach jobs, leading to unemployment among low income people even when there are jobs available (but not accessible).

In light of these problems, one of the main economic benefits of transit may be in preserving relatively dense urban development patterns. This does not necessarily mean that people must adopt traditional urban lifestyles to take advantage of the accessibility provided by transit. New approaches to suburban development known as "transit oriented development," which are at higher density than typical suburbs but still lower than typical downtown areas, provide

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[21] Discussion of the environmental impact of urban spatial structure are found in Anderson *et al* (1996b) and Bureau of Transportation Statistics (1996).

suburban lifestyles that are not exclusively dependent on automotive transportation.[22][23]

Despite the growing realization of the importance of land use impacts, they are not routinely incorporated into economic assessments of transit or other infrastructure projects. This is partly because our understanding of these relationships is as yet relatively poor, so analytical tools are not readily available and may not be considered reliable. Also, land use changes occur over a relatively long period of time, so even if their costs and benefits can be quantified they are diminished by discounting.

The provision of high quality transit may also have a positive effect on productivity in those economic activities that function best in highly concentrated commercial centers where thousands of employees are concentrated within a few city blocks. These activities included high order services such as finance, design, and consulting for whom the frequency of contacts among skilled employees and clients is of central importance. They tend to concentrate in downtown areas of cities such as New York, Chicago, Boston and Toronto.

One thing that all these cities have in common is a high quality, rail transit system providing excellent accessibility to the urban core. Were it not for those systems, such high concentrations of employment would be precluded because it would not be possible to deliver that many people to such a confined place using automobile transportation – streets would become clogged and there would not be enough space for parking. Thus, transit is the key to dense commercial development, leading to high productivity and competitiveness in higher order services.

Taking the notion of dynamic benefits a bit further, transit can play a positive role in creating social cohesion and promoting upward economic mobility. Transit systems naturally create a kind of public space where people of all ethnic backgrounds and economic levels interact. By contrast, the suburban professional commuting by car to an "edge city" or the inner city youth without

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[22] Transit oriented design principles are presented in Calthorpe (1993).

[23] It is important to realize that denser development does not necessarily lead to reduce auto dependency. Demographic factors also play an important role in determining travel behavior. See Dunphy and Fischer (1997).

transit access will interact only with people like himself. While it may stretch the definition of "economic impacts," we argue that this type of interaction among heterogeneous people is essential to produce the socioeconomic mobility that has characterized the most dynamic economies throughout history.

Finally, well-implemented transit projects have the potential to change the preference structure of the travelling public. In many cities, public transit is seen as the option of last resort for "transit captives" who do not have cars or are unable to drive. In other cities, such as New York, Boston, Chicago, and Toronto, high-income professionals routinely use transit. This is because they have long experience of dependable transit service, often extending back to childhood. Projects like Tren Urbano are faced with the challenge of overcoming prejudices against transit, but in the long run their existence can alter perceptions, possibly leading to more sustainable lifestyles.

Special Issues for Tren Urbano

Most of the economic impacts discussed above can apply to any major transit project. Each project, however, may give rise to more idiosyncratic types of impacts depending upon the characteristics of the project and the economic context of the region it will serve. The following are some special issues relating to the economic impacts of Tren Urbano:

- *Local multiplier effects*: Puerto Rican households currently spend a much higher proportion of their disposable income on automobiles and gasoline than do households on the U.S. main land. While the availability of Tren Urbano will not cause many people to abandon auto travel completely, it is likely to reduce auto related expenditures. This is not necessarily an economic benefit in the global sense, but it is in the local sense. Virtually all demand for cars and automotive fuels is satisfied from sources outside Puerto Rico. Thus these expenditures generate little local direct income, and no indirect or induced income benefits. If the proportion of consumer income spent on cars and gasoline goes down, the extra income will be diverted to other goods and services, some of which will have local multiplier effects. Thus, there will be a net increase in domestic income. (A preliminary analysis based on the Puerto Rican input-output accounts is included in the Appendix.)

- *Long-term benefits of skills development*: Tren Urbano is the largest and most sophisticated civil engineering project ever undertaken in Puerto Rico. As such, it will add substantially to the base of technical and analytical skills. (The UPR-MIT Professional Development Program is an example of this.) After the project is completed, the skilled people will not only contribute to future projects in Puerto Rico, but may also establish San Juan as the center for expertise in advanced civil engineering in the Caribbean, thus creating a new export sector.

- *Extending the benefits of tourism:* While tourism is a critical engine for the San Juan economy, it is limited to a few parts of the city. This is largely because of poor accessibility between Old San Juan and Condado and the rest of the city. Tren Urbano may eventually be a vehicle for extending tourist activities to traditional centers like Bayamon and Rio Piedres or for the development of tourist oriented facilties in other parts of the city.

- *Commercial center development*: As discussed above, rail transit will make it possible to assemble much larger numbers of employees in high density commercial areas. This may provide a superior environment for high order services, which may be an important step toward development of San Juan as a service center for the Caribbean.

- *Gentrification and affordable housing in station areas*: Tren Urbano may also result in some economic impacts that will have negative effects on segments of the population. One possibility is that rent will rise in the vicinity of stations, resulting in gentrification and displacement of local people.

Concluding Remarks

The goal of this paper is to provide an overview of the problem of assessing economic impacts of transit projects. Its main message is that the impacts of transit are pervasive and complex. Conventional cost-benefit analysis is a useful tool, but its scope is limited. Therefore, exploration and experimentation with new methods that seek to define a broader range of costs and benefits should yield valuable results. It is doubtful whether any one method can provide a definitive “go / no go” result for all projects. Instead, assessment of economic impacts is part of a process that should involve public participation and informed decision making by public officials.

Tren Urbano provides some unique challenges and opportunities. While decisions relating to the first stage have already been taken, economic impact assessment over the next few years will be of particular value to help inform decisions about system extensions over the coming decades.

APPENDIX

Input-Output Analysis: A method for estimating economic impacts of Tren Urbano.

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Economic Impacts

With the construction and operation of Tren Urbano in San Juan, the Puerto Rican economy will be affected in several ways. Because people now have an alternative mode of transportation, some will reduce their expenditure on cars. This means that they will be freeing up a percentage of their income, previously devoted to owning and maintaining one or more cars. They will then be able to spend this portion of their income on other things. On one hand, the reduction in demand for cars will have a negative impact on the economy, via the firms that support or produce goods that are complementary to cars. Yet, on the other hand, firms producing other goods will benefit from the increase in the new increase in the demand for their goods.

Additionally, domestic firms will supply some of the materials required for construction and maintenance of Tren Urbano (TU). These firms hire new workers to meet the increase in demand for these construction materials. Jobs in construction are added, as are jobs for people operating the system once construction is completed.

The people working in the construction and operation of TU will then have more of an income they can spend on goods and services, as will passengers of TU whose expenditure has now shifted away from cars. So they will demand more of these goods and services. At the same time, jobs will be created to increase the supply of goods in order to meet the increase in demand. As demand for these goods and services increases, a further increase in materials and labor, or inputs, will take place to produce the additional goods and services (an induced income effect).

Input-Output Analysis

So how can we say how much income will be generated, where it will be spent and how much additional income will be generated as a result? We can answer these questions by using Input-Output analysis. We can simplify these questions to the following: for each additional dollar spent in the economy of Puerto Rico, how much money will be generated?

In order to make the matter simple, for the moment, lets assume that there are only three sectors in our economy: one for agricultural products, one for manufactures and one for services. To answer our question we need to know how much of each product consumers are currently purchasing. We will also need to know how much of agricultural products are used as inputs into all the other sectors of the economy, including itself. Similarly, we need to know how much of manufactures go into agricultural production, manufactures and services, and how much of services go into agricultural production, services and manufactures. Because we cannot compare tons of corn to barrels of oil or to number of haircuts, we will have a common unit of measure for all these quantities, namely dollars. Table 1 is a summary of our hypothetical example.

Each row in this table represents a sector and how its output is distributed among all sectors and the consumers of end products. The other sectors comprise an intermediate demand, because they will use these inputs to produce a good and, thus, add value to these inputs. The column of final demand represents the amount of output that is consumed not by industries but by consumers of end products instead.

Table 1. A simplified input-output table

	Agriculture	**Manufs.**	**Services**	**Consumers of end products** *	**Total Output****
Agriculture	X11 = 25	X12 = 35	X13 = 15	Y1 = 25	X1 = 100
Manufs.	X21 = 40	X22 = 90	X23 = 80	Y2 = 90	X2 = 300
Services	X31 = 30	X32 = 50	X33 = 40	Y3 = 80	X3 = 200

*Includes exports. **Excludes imports.

Table 2. Matrix of structural coefficients

	Agriculture	**Manufs.**	**Services**
Agriculture	X11/X1 = A11 = 0.25	X12/X2 = A12= 0.117	X13/X3 = A13= 0.075
Manufs.	X21/X1 = A21 = 0.4	X22/X2 = A22 = 0.3	X23/X3 = A23 = 0.4
Services	X31/X1 = A31 = 0.3	X32/X2 = A32 = 0.167	X33/X3 = A33 = 0.2

If we divide the input requirements of each industry by its total output, we will get a measure of how much of a given input such an industry will need in order to produce one unit of its output.

For example, in this case, I know that for each dollar of output produced by the manufacturing industry, it will require 0.117 dollars of agricultural goods, 0.3 dollars of manufactured goods and 0.167 dollars of services. In other words, the values in this matrix are telling us what proportion of inputs are required by each industry for it to produce a dollar's worth of output.

Recall that what we wanted to do was find out how much money will be generated in the economy for an increase in demand. If demand for manufactured goods increases by one dollar, then, output form agriculture will need to increase by one dollar and so 0.117 dollars of agricultural goods will be needed, 0.3 dollars of manufactured goods and 0.167 will be needed, directly. However, indirectly, if agricultural goods output needs to increase by 0.117, then 0.117*0.25 of agricultural goods will be needed, 0.117*0.4 of manufactures will be needed and 0.117*0.3 of additional services will be needed. We could continue with this thought process to calculate these requirements, but this would be too overwhelming a task. Table 2 only contains the values of "direct requirements" for each industry.

A shortcut, however, is to solve the problem as a system of simultaneous equations. Then we can find the values of "direct and indirect" requirements.

We know that:

$$X11 + X12 + X13 + Y1 = X1,$$
$$Y1 = X1 - X11 - X12 - X13,$$

or because A11=X11/X1 and A12=X12/X2, and so forth,

$$Y1 = X1 - A11*X1 - A12*X2 - A13*X3,$$
$$Y1 = (1-A11)X1 - A12*X2 - A13*X3.$$

Similarly for the other two industries:

$$Y2 = - A21*X1 - (1-A22)X2 - A23*X3, \text{ and}$$
$$Y3 = - A31*X1 - A32*X2 - (1-A33)X3.$$

We can solve the system of equations for X1, X2 and X3, now that we know A', given that we also have any vector of final demands, because:

$$X1 = A'11*Y1 + A'12*Y2 + A'13*Y3$$
$$X2 = A'21*Y1 + A'22*Y2 + A'23*Y3$$
$$X3 = A'31*Y1 + A'32*Y2 + A'33*Y3$$

In matrix notation: X = A' * Y,

$$\text{where } X = \begin{matrix} X1 \\ X2 \\ X3 \end{matrix} \text{, and}$$

$$Y = \begin{matrix} Y1 \\ Y2 \\ Y3 \end{matrix} \text{,}$$

and finally, A' is the matrix of coefficients that represents the inverse of the matrix A, where A was:

$$A = \begin{matrix} (1-A11) & A12 & A13 \\ A21 & (1-A22) & A23 \\ A31 & A32 & (1-A33) \end{matrix}$$

Table 3 shows the A' matrix for this example. Each column of the A' matrix represents the required direct and indirect production from the industry in question, in order to satisfy a dollar of final demand for that industry's goods. The total for each column is called the multiplier. For Agriculture, for example, for each dollar of demand for agricultural products, $4.06 dollars of production will be required: $1.65 of agricultural production, $1.47 of manufactures and $0.92 of services. So $3.06 dollars are generated from increasing agricultural demand by one dollar.

Table 3. Matrix of direct and indirect requirements

	Agriculture	Manuf.	Services
Agriculture	1.65692401	0.35653094	0.3336021
Manufs.	1.4781966	1.94013304	1.10864745
Services	0.92992004	0.53870187	1.60653094
Total (Multipliers)	4.06504065	2.83536585	3.04878049

Now we can answer our initial question If the demand were to change, then how much money would be generated?

The changes we assume are incorporated into a new demand vector'. X = A' * Y'. We multiply our new demand by the A' matrix and obtain the required output to satisfy this new demand.

Data for Input-Output Tables:

Data is available for Input-Output Analysis. We recently obtained this data was from the Office of the Junta de Planificación, Government of Puerto Rico. Their Input-Output tables cover 94 industries grouped into 20 sectors. Currently, Input-

Output tables for 1986-87 are available. Due to the great amount of time and effort expended in gathering the data to build these tables, Input-Output tables for 1992 will not be available until the end of this year. Therefore, we need to assume that the production coefficients from each industry have not changed significantly since 1987.

Examples for Puerto Rico:

Using this data we can construct different scenarios and see what would happen to output. Here our examples will focus on the impacts to the economy of consumers shifting from expenditures on cars to expenditures on other goods and services. In the first scenario we assume that with the presence of Tren Urbano, a 10% decrease in demand for transportation equipment (cars) will take place. This 10% will “free” $6,073,000. These six million are divided into 93, and distributed to each of the other 93 industries by equal amounts. That is, demand for goods of each of the other industries increases by $65,304.4. Why does this happen? We are assuming that consumers will use the money that they would have spent on automobiles on purchasing each of the other goods available to them. The assumption serves the purposes of illustrating the use of Input-output analysis. The result of this scenario is presented in Table 4.

It can be seen that some sectors suffer losses while others experience increases in their output, as an adjustment to the new demand. Transportation equipment is an industry that is part of the manufactures sector. Output for transportation equipment decreases. Petrochemicals, another industry within the manufactures sector, increases its production slightly. This could happen given the increase in production which requires additional use of energy. In general terms there are losses of $4,134,773.76 and gains of $5,013,992.79. There is a “rearrangement” of output away from some industries and into others. The net effect, however, is a total gain of $879,219.03. So a 10% decrease in automobile consumption redistributed to other sectors has a benefit of this amount.

Table 4. Scenario 1

Change in total output given a 10% decrease in transportation equipment and a transfer of the amount of the decrease to the other sector by equal amounts

(thousands of 1987 dollars)

	IINITIAL OUTPUT X	OUTPUT SCENARIO 1	DIFFERENCE
AGRICULTURE	648601	648914.7766	313.7766146
MINING	53861	53923.03313	62.0331322
CONSTRUCTION	2082801	2082952.938	151.9382765
MANUFACTURES	23250388	23246253.23	-4134.77376
Transportation equipment	*80396*	*74292.82865*	*-6103.1714*
Petrochemical	*91,340*	*91351.29186*	*11.291861*
TRANSPORTATION	1525790	1526232.313	442.313344
COMMUNICATIONS	770801	771006.8827	205.8826887
ELECTRICITY, WATER, SANITATION	1196088	1196341.102	253.102174
COMMERCE (RETAIL)	5503413	5,503,612	199.2232805
BANKING,CREDIT	1719337	1719777.787	440.7867241
INSURANCE	574790	575085.2466	295.2465589
REAL ESTATE	3279302	3279544.46	242.4597143
HOTELS,GUEST HOUSES	350493	350637.9924	144.9923979
PERSONAL SERVICES	209061	209391.5851	330.5850766
COMMERCIAL SERVICES	1594850	1595047.334	197.333983
CAR REPAIR,RENT, PARKING	857063	857300.3392	237.3391711
RECREATION,ENTERTAIN MENT	168940	169330.7358	390.7358408
MEDICAL,HEALTH SERV.	1085808	1086158.274	350.2742654
OTHER SERVICES	1203412.5	1203883.981	471.4812339
GOVERNMENT	4399820.5	4400039.684	219.1839115
NON-CLASSIFIABLE	0	65.30441086	65.30441086
TOTAL	50474620	50475499.22	879.2190373
	SUMMARY	**LOSSES**	-4134.77376
	SCENARIO 1	**GAINS**	5013.992799
		NET EFFECT	879.2190373

Table 5. Scenario 2

Change in total output given a 10% decrease in transportation equipment and a transfer of the amount of the decrease to the other sector by equal proportions

(thousands of 1987 dollars)

	IINITIAL OUTPUT X	OUTPUT SCENARIO 1	DIFFERENCE
AGRICULTURE	648601	648703.584	102.584
MINING	53861	53855.16483	-5.835172078
CONSTRUCTION	2082801	2083103.835	302.835
MANUFACTURES	23250388	23247399.42	-2988.584289
Transportation equipment	*80396*	74292.76463	-6103.235367
Petrochemical	*91,340*	*91287.90028*	*-52.0997192*
TRANSPORTATION	1525790	1525901.735	111.7352129
COMMUNICATIONS	770801	770854.5879	53.58791922
ELECTRICITY, WATER, SANITATION	1196088	1196200.504	112.5038958
COMMERCE (RETAIL)	5503413	5504172.753	759.753253
BANKING,CREDIT	1719337	1719402.67	65.66978933
INSURANCE	574790	574856.8695	66.86949656
REAL ESTATE	3279302	3279807.892	505.8916141
HOTELS,GUEST HOUSES	350493	350537.9018	44.90175363
PERSONAL SERVICES	209061	209096.3544	35.35440261
COMMERCIAL SERVICES	1594850	1594935.553	85.55318656
CAR REPAIR,RENT, PARKING	857063	857108.8964	45.89635805
RECREATION,ENTER TAINMENT	168940	168963.0612	23.06123471
MEDICAL,HEALTH SERV.	1085808	1085990.895	182.8952217
OTHER SERVICES	1203412.5	1203566.882	154.3819044
GOVERNMENT	4399820.5	4400529.686	709.1856483
NON-CLASSIFIABLE	0	0	0
TOTAL	50474620	50474988.24	368.2404295
	SUMMARY	**LOSSES**	-2994.419
	SCENARIO 2	**GAINS**	3362.660
		NET EFFECT	368.2404295

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In scenario 2, the same 10% in transportation equipment is assumed. However, the $6,073,000 are re-distributed to the other sectors in proportion to the percentage that each represents of the total final demand minus the demand for transportation equipment. In other words, the demands for each sector are added to form a total, excluding transportation equipment, then the demand for a given sector is determined as a percentage of this total and this percentage is applied to $6,073,000.

What this means is that if people used to spend more on one good and less on a second, then they will spend their new income in the same way, more of it one the first good and less on the second. Their new income is, of course, the amount they were previously spending on automobiles.

There is a net effect of adding $368,240.42 to the economy. In this case, both output for transportation equipment and for petrochemicals decreases. This could be because the losses to energy intensive sectors are greater than before.

Conclusion:

It is important to note that the summary above contains only the twenty sectors that represent the 94 industries in the Puerto Rican economy. A sector may show a net gain of a few thousand dollars, but in fact, some industries within that sector may be suffering large losses while others are benefiting from large gains. Depending on how detailed an analysis we want, we will want to refer back to these industries.

We cannot exclude any of the industries if we want an exact picture of what happens to the whole economy. If we did we would have to make assumptions about that sector or our analysis would be incomplete.

Finally, the analysis relies on assumptions about final demand and output. Depending on what assumptions we make about these, we may obtain different results. Also, we may assume that more than one change takes place. In this sense, Input-Output is extremely useful, as it enables us to make one or several changes to final demand, and track down their net effect in the whole economy.

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