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Incorporating Agglomeration Economies in Transport Cost-Benefit Analysis: The Case of Proposed Light-Rail Transit in the Tel-Aviv Metropolitan Area

Dani Shefer* and Haim Aviram**

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Abstract

The economic evaluation of a transport project relies primarily on the impact of the project on road users. Economic benefits are calculated from a reduction in the aggregate value of time saved by the users, as well as from savings on vehicle-operation and maintenance costs, the reduction in traffic accidents, and more recently the ensuing negative environmental impacts of the project. Most often, the analysis assumes fixed demand.

Major mass-transit systems, such as the new Light Rail Transit (LRT) currently proposed for the Tel-Aviv Metropolitan Area (TAMA) in Israel, are expected to generate substantial, new (induced) traffic, most likely enhancing the agglomeration forces at work in major urban concentrations. Agglomeration economies could lead to an upward shift in the production function of the metropolitan area, thus generating substantial additional benefits for the transport project. This paper presents a methodology for estimating the benefits derived from agglomeration economies induced by the proposed LRT in the TAMA. An estimate is made of the resulting expected increase in the number of employees in the CBD and their potential contribution to its total annual production. Agglomeration economies could add a significant amount of additional benefit to the transport project. In our case study, the extent of these benefits increased the benefit-cost ratio from 1.15 to 1.40.

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1. Introduction

One of the principal objectives for investing in intra-urban transportation projects is to increase travelers' access to economic, social and cultural activities in the central business districts (CBD) and other urban sub-centers.

Most operational transportation models assume fixed demand. Consequently the results of expanding the capacity of a road network system or, alternatively, introducing a new transport mode, such as a light rail system (LRS), will inadvertently reduce the total travel time in all routes used. Since each traveler seeks to minimize travel costs, he/she will choose a route in such a way that no alternative route could further reduce the travel cost. This situation defines "user equilibrium" as espoused by Wardrop's first principle of route choice (Wardrop, 1952). If no externalities exist (notwithstanding congestion, which generates negative externalities), then the transportation system's new equilibrium (steady state) will reduce the average trip time to a minimum. This new condition describes Wardrop's second principle of "system equilibrium" (or optimal system), which corresponds to "pareto optimum," so that no traveler can change a route without increasing the total time traveled by all users; i.e., the average travel time will increase. This latter condition rarely, if ever, exists because of the prevailing congestion that continuously plagues our urban centers. In order to circumvent these negative externalities, an imposed marginal cost road-pricing system could bring about the socially desired "system equilibrium."

In such circumstances, an evaluation of the benefits derived from intra-urban transport projects usually consists of the travel time saved, the saving entailed in operating and maintaining the fleet of vehicles, the reduction in the cost of all types of traffic accidents, and, more recently, the still very qualitative assessment of the benefits derived from the expected reduction in environmental pollution (air pollution, noise pollution, etc., all of which affect the quality of life in general, and health in particular).

With the increase in accessibility that follows from the investment in intra-urban transport projects, we can expect a steady rise in land values in central cities, followed by strong market forces pressuring for an increase in the allowable built-up area. If allowed, this increase will further push up the value of land, which development will naturally be followed by an increase in rents. Market forces eventually will also put pressure on

decision-makers to raise the capital-land ratio. The long-term result will be a gradual change in the skyline of our growing cities.

Nevertheless, it has long been recognized that expanding the capacity of transport systems in congested urban areas will inadvertently be followed by an increase in the demand for travel. The nature of this increased demand can be divided into two major components. The first is due to “traffic diverted”: travelers will switch to the improved road, thus attaining a new user equilibrium, whereby their total travel cost is minimized. The second component is termed “induced traffic”: since travel demand is elastic with respect to transport systems, capacity expansion will increase the demand for travel (Hills, 1996; Goodwin, 1998; DeCorla-Souza and Cohen, 1999; Pickerell, 2001; Lee, 1998 and 2004).

It should be noted that with induced traffic, the new system equilibrium may not result in the long term in a substantial reduction in the level of congestion; thus, in the end, the cost of travel may not change appreciably compared to the pre-project condition. This phenomenon was well recognized by Mogridge (1990), who maintains that traffic tends to expand to meet new capacity (Say’s Law of the Market: “Supply creates its own demand”). Mogridge convincingly supported his supposition with time-series traffic data for London. Nevertheless, it should be emphasized that expanding transport-system capacity will increase the number of travelers who are now able to reach the urban center. The access provided to new travelers presents a net (social) benefit accrued by the transport project.

The ramifications of the increase in travel demand to the center are a further exacerbation of economies of scale and a consequent growth in the multitude of activities located there.

The objective of this paper is to show how agglomeration economies fostered by investments in intra-urban transport projects could be introduced in cost-benefit analysis. We will employ the proposed Light Rail Transit (LRT) in the Tel Aviv metropolitan area (TAMA) as a case for illustration.

Section 2 of this paper presents a synopsis of the concept of agglomeration economies. Section 3 describes the relationship between innovation and agglomeration. Section 4 ties agglomeration economies to innovation and economic growth; and Section 5 presents a short synopsis of the relatively new concept of endogenous economic growth. Section 6 briefly discusses the process of evaluating a transport project. Section 7 presents an

urban-economics approach to intra-urban transport project evaluation. We present the case of the proposed Light Rail Transit (LRT) in the Tel Aviv metropolitan area (TAMA) in Section 8, and our conclusions in Section 9.

2. Agglomeration Economies

Agglomeration economies are perceived as enhancing the innovative capacity of firms. They are considered a cost-reducing factor that diminishes uncertainty and increases production efficiency. There is ample theoretical and empirical evidence demonstrating the effect of agglomeration economies on production efficiency. Indeed, modern location theory posits the significant role that agglomeration economies play in explaining the growth of cities (Baldwin and Martin, 2004; Gordon and McCann, 2005; McCann and Shefer, 2004; Quigly, 1998; Acs, 2002). These economies form the hubs that generate new ideas and innovations leading to technological progress. Agglomeration tends to increase the productivity of most factors of production, particularly that of labor. Assuming that input and product markets are perfectly competitive, the increase in labor productivity will cause the labor-demand curve to shift. In such circumstances, this curve reflects the value of the marginal product of labor. Technological advances, which most often originate in the concentration of economic activities, as well as other positive externalities raise the marginal product of labor, which, in turn, increases the demand for labor. The improved accessibility of the center of the urban area would, concomitantly, increase the supply of labor at the hub.

Figure 1 presents a schematic shift in the production function that is due to an increase in the level of the marginal productivity of labor (with other inputs held constant) at three different levels of agglomeration economies. The curve labelled A3, for example, represents the most efficient agglomeration of economies.

Figure 1: Hypothetical effect of agglomeration economies on productivity

Agglomeration economies and the rate of innovation are affected by the density, diversity and specialization of the labor force and economic activities. Density is highly correlated with the concentration of economic activities in selected locations, such as the CBD and other sub-centers in the urban area (Duranton and Puga, 2000, and 2001; Glaeser, 1996; Ciccone and Hall, 1996; Carlino et al., 2005). The increase in the price of land (owing to an increase in the demand for land in view of its virtually inelastic supply) will cause

density to increase in order to optimize the use of land. Several decades ago, Chinitz, in a seminal paper, “Contrast of Agglomeration,” (1961) described two types of agglomeration: one of the diverse nature of activities as found in New York City, and the other, more specialized, as found in the Pittsburgh area. Clearly the concentration of economic activities in a few locations provides the opportunity both to diversify and to specialize. Business services, such as banking, legal accounting, marketing, and computing, often become very specialized in urban areas. Still, diversity is the catalyst for the cross fertilization of ideas, transformed into technological advances.

3. Agglomeration and Innovation

Agglomeration economies are very important in fostering innovation activities and in providing the necessary *milieu* for new ideas to spawn. This was well noted by Alfred Marshall in his well-known treatise, *Principles of Economics* (1920) and later echoed by Jane Jacobs’ literary and descriptive work, *The Economy of Cities* (1969). In the past fifteen years or so, Jacobs’ work has been frequently quoted by urban economists as a source of inspiration for their attempts to better understand the innovative forces within cities and to statistically estimate, while delineating the factors affecting, agglomeration and innovation (Audretsch and Feldman, 2004; Feldman and Audretsch, 1999; Feldman, 1994).

Knowledge spillover constitutes one of the most acknowledged phenomena responsible for the rate of generating new ideas leading to innovation. It is most often associated with universities and institutes engaged in research and development. The type of human capital that is required for such activities is highly educated and/or technically skilled. A study by Glaeser and Saiz (2003) concluded that “skilled cities are growing because they are becoming more economically productive....” A study by Shefer and Frankel (2004) found that 83% of the initiators of new ideas that were admitted to the technological incubator program in Israel had a Master’s degree and 62% held a Ph.D. These statistics provide hard evidence of the importance of knowledge and skill in generating new ideas, some of which may eventually lead to innovations, whether of new products or of production processes.

Agglomeration economies foster market and non-market interactions (Glaeser, 1999). Formal and informal interactions take place in the workplace, in the conference room, around the coffee machines, in the specially constructed fitness room (in the modern

office building), as well as during lunch hours and at bars, during off working hours and outside the office. The synergy developed among people of similar and diverse backgrounds, education and skill often allow for the interchange of new ideas. The face-to-face, formal and especially informal interaction and the flow of information among people are paramount to the process of creating new technologies that generate the prime contributors to economic growth. More than forty years ago, Raymond Vernon, in his outstanding study of the *New York Metropolitan Region* (1960) alluded to the importance of face-to-face interaction, especially in such industries as fashion, design, publishing, filming, banking, art and entertainment. These human interactions are essential to the present-day process of technological advances (see Gaspar and Glaeser, 1998 ; McCann, and Simonen, 2005).

5. Endogenous Economic Growth

Innovation has been recognized as a major source fostering economic growth. The resurrection of interest in economic growth models, prompted by the seminal work of Romer (1986,1990) and Lucas (1988), brought to the fore the importance of endogenous technological progress. This new development was contrary to the neoclassical model of growth theory espoused by Solow (1956), in which technological progress was assumed to be exogenous. Furthermore, Solow focused his attention primarily on the process of capital accumulation and its relationship to a steady state, not on the process of generating technological progress. Thus, under the assumptions of constant returns to scale and fixed technology, a diminishing marginal productivity of capital sets-in as capital per worker rises, and capital investment will be made at a rate sufficient only to replace depreciation and provide capital for new workers.

The restrictive assumptions embedded in the neoclassical model - exogenous technological progress, constant returns to scale, and diminishing marginal productivity of capital in a perfectly competitive market - do not provide good explanations for the observed process of continuous growth in per-capita income.

The endogenous economic growth models that emerged in the 1980s suggest that firms may invest in new technology through expenditure on research and development if they perceive an opportunity to make a profit (Stokey, 1995; Aghion and Howitt, 1998). Thus, technological progress could explain the persistent growth in income and, consequently, in income per capita or standard of living (Romer, 1990; Grossman and Helpman, 1991).

Since economic growth is driven to a large extent by technological progress, it is essential that public policy provide incentives and sometimes even subsidize the under-investment in research and development in situations of market failure.

Open economies can take advantage of an expanded market and, through increasing returns to scale, enjoy greater production efficiency and a higher rate of economic growth (Krugman, 1991, Romer, 1986 and 1987). Greater production efficiency enables industries to expand their domestic market share through import substitution and increases in local consumption and, at the same time, to penetrate new foreign markets and increase their export share (Grossman and Helpman, 1990, 1991; Porter, 1990; Krugman, 1991a, 1991b, 1995).

Innovation transfer involves a component of risk or uncertainty. The importance of information lies, among other things, in its ability to reduce uncertainty. Greater importance must be placed on the uncertainty component as it pertains to innovation activity than is presently afforded by popular economic models. Uncertainty is concerned not only with the lack of information regarding the exact income and expenditures associated with the various alternatives but also, and most often, with the limited knowledge of the nature of the alternatives.

We can presume that a greater amount of uncertainty and limited bits of information are transmitted in space to locations at a distance from the concentration of people and economic activity. In this connection, there are two major processes that may be distinguished: the first is the movement from the center to the boundaries, or the outer-ring (suburbs), of the metropolitan area; the second is the strong connection, in spite of the distance separating them, between centers of activities – the metropolitan areas. This affinity between centers skips intermediate areas, which could be considered peripheral to the metropolis. Given these knowledge-diffusion processes, we would expect that the rate of innovation will follow similar spatial patterns; that is, a gradual decline in the rate of innovation activity as one proceeds from the center toward the periphery.

Indeed modern location theory posits the significant role that agglomeration, localization and scale economies play in explaining the growth of cities. These processes form the hubs that generate new ideas, innovations and, subsequently, technological progress. Agglomeration economies, localization and the economies of scale are, then, the principal forces that foster the continuous concentration of people and economic activity in selected

points in space. Agglomeration economies, though, do not constitute a very tangible concept, since they encompass several loosely defined factors

5. Innovation and Economic Growth

The contribution of innovation to regional growth has been widely discussed in the literature (Davelaar, 1991; Feldman, 1994). Regional development, as a location where technological innovation takes place, is usually accompanied by new economic activities, market expansion, and technological adaptation. Urban areas with a high level of innovative activity have become a destination for highly skilled labor and an impetus for improved social and physical infrastructures (Lucas, 1988; Glaeser and Mare, 2001). From a technological point of view, advanced economic activities improve competitive advantage and increase market share at least during the first stage of the innovation-diffusion process. Thus, compared with other urban areas, those areas characterized by a high level of technological innovation will show a greater acceleration of economic growth (Grossman and Helpman 1990, 1991; Krugman, 1991, 1995; Gleaser et al., 1992; Stokey, 1995).

The ability of a firm to innovate is contingent on two major groups of variables, the first group internal, and the second external to the firm or location-specific. The latter creates the *local innovative milieu* or the economic environment conducive to innovation. (Shefer and Frenkel, 1998; Audretsch and Feldman, 1996 and 2004; Feldman 1994; Jaffe et al. 1993; Porter, 1996). This *local innovative milieu*, which is perceived as enhancing the innovative capability of firms, is considered a cost-reducing factor that diminishes uncertainty and increases production efficiencies. Agglomeration economies help create the *local innovative milieu* or the economic environment conducive to innovation (Acs, 2002).

6. Evaluating an Intra-Urban Transportation Project – Overview

The economic evaluation of transportation projects is a well-known procedure, based primarily on the impact of the project on road users. In small projects, such as an independent road improvement or rehabilitation, in which the impact is reduced to the users of the specific project, the analysis assumes a fix demand. The economic benefit is then calculated as the difference between “with project” and “without project” situations,

with benefits consisting of the value of the time saved by the users, the reduction in vehicle operating and maintenance costs, and the expected reductions in all types of car accidents (VTPI, 2003; Litman, 2000).

When more than a single road is involved, traffic-demand estimation becomes a major issue in the cost-benefit study, and a transport-network analysis is required. Tools such as diversion curves or traffic assignment are used in order to carry out such an analysis. When more than one mode is involved (e.g., private cars and public transport), a modal split model is also applied to compute the share of each of the different transportation modes considered (Litman, 2000; DeCorla-Souza and Cohen, 1998).

All the above-mentioned methods assume a fixed demand, and hence they are known as “fixed-demand models.” The need to evaluate mass transit projects highlighted two additional major issues. The first issue is that real time savings do not exist everywhere. The use of a fixed-demand model (with no diverted traffic) and the application of a modal split model show that an increase in a passenger’s value of time may result from the proposed project. The second issue is associated with the possibility that major mass transit projects could generate substantial, new induced traffic, which is not counted in the fixed-demand analysis (VTPI, 2003; Litman, 2000).

The number of users of the urban transportation system by itself has no additional value in the traditional economic evaluation of transport projects. Similarly such evaluations do not account for the impact of agglomeration economies on urban productivity and growth in the estimation of benefits. At times, moreover, a certain justification may exist in a separate, independent transportation project for ignoring diverted and new generated traffic. This omission is totally unacceptable in a network-related project, especially when one dealing with areas adjacent to the Central Business District (CBD).

At this point, a brief theoretical analysis is needed in order to explain the lacunas that exist in the current procedure for estimating transportation benefits. Diagram 1 presents schematically the four types of transport analysis, progressing from simplicity to complexity of analysis. The four types illustrated in the diagram will then be discussed in turn, albeit in a very rudimentary way.

Diagram 1: Transportation Analysis – From Simplicity to Complexity

Figure 2 describes the estimate of the benefits of a single autonomous road project, using a fixed-demand model assumption. This situation represents any project that has no influence on the rest of the network.

Fig. 2: Benefits of a Single Autonomous Project

Ac_0 and Ac_1 are the average costs curves “before” and “after” the improvement, respectively. Point B is the equilibrium before the improvement, and point A is the equilibrium after the improvement. Hence, area ABP_0P_1 is the benefit accruing to the project. Note that D, the demand curve, is totally inelastic in accordance with the assumption of the fixed-demand model.

When the project is connected to other links of the network, an elastic demand must be considered. Two types of travel changes are likely to occur with an elastic demand curve:

- A switch in the modal-split in favor of the mode in which the improvement took place.
- Diverted traffic, within the same mode, from some of the links that were not improved to the improved link.

The results in the case of an elastic demand are depicted in Figure 3.

Fig. 3: Benefits Derived from Traffic

In Figure 3, the demand is elastic. Total travel demand indicates that some changes occur in the modal split or in route choices because of the improvement and that the equilibrium moves from point E to point F. The triangle ECF, which refers to the benefits derived from the traffic, is estimated by the “Rule of the Half.” (When using the assignment procedure, we compare overall traffic before and after the improvement; for more on that specific point, see VTPI, 2003, Ch. 7, page 4.)

Figure 3, though, depicts only part of the picture. The other part belongs to the other links (or modes). Thus two inter-connected links are presented in Figure 4, and then the deficiencies of the assumption of the fixed-demand model become clear.

Fig. 4: Two Links with Fixed Demand

Figure 4 shows that the increase in traffic volume on the improved link is actually a result of the diversion of traffic from the unimproved link. This result is due to increasing travel demand on the improved link (or mode), and it refers only to **diverted traffic**, not

to **induced traffic**. It is obvious that in order to include induced traffic in such a diagram, the distance between O and R, which represents fixed demand, has to be changed. One way of including this induced traffic is to consider the elasticity of the induced traffic in the angle between the volume and the cost axes, as shown in Figure 5; i.e., the demand for travel is smaller at a high travel cost than at a lower travel cost.

Fig. 5: Two Links with Induced Demand

A simple interpretation of Figure 5 is now in order. If the transport cost falls from P_0 to P_1 owing to the new improved project, then an induced traffic volume would be equal to $T - T_0$, and the diverted traffic would be $T_1 - T_2$. The “without project” total traffic volume is equal to $T_0 - T_1$; note that the cost axis is not necessarily linear.

7. The Urban Economics Approach

How can we determine the precise angle of the cost axis that incorporates the induced traffic? It is difficult to answer this question when considering only the transport-supply side. The key variables needed to determine the extent of the induced traffic are related to the demand for these trips in the urban areas and the capacity of the transport network to satisfy these trips. The demand for travel is related to the urban land uses rather than to the transportation system. In an extreme case, in which the capacity of the transportation network “without project” is fully utilized and the proposed project improves it to infinity, the entire problem becomes a question of urban analysis.

- **The Theoretical Model**

Let us assume a mono-centric urban area. One road leads to the center, and every morning everybody who works in the center uses that road to reach individual work places. The number of employees in the center is M , which is also the capacity of the road. Hence, the number of employees in the center could grow only if the road capacity expands.

Suppose that the urban center has a quasi-Cobb-Douglas-type production function of the following form:

$$Y = AL^\beta \quad (1)$$

Where L is the quantity of Labor, and β is the elasticity of output Y with respect to labor.

$$dY/dL = \beta(Y/L) \quad (2)$$

$$\beta = (dY/dL)/(Y/L) \quad (3)$$

If $\beta > 1^1$, then the production function is typified by increasing returns to scale. This situation can be due to agglomeration economies that are present at the center of the city. An increase by one employee will increase the total production by an amount equal to the per-capita production multiplied by the returns-to-scale coefficient, as shown in Eq. (2). If this employee works somewhere else, and not in the center, then the person's output will merely be Y/L , or average production (since everywhere else, by assumption, $\beta = 1$).

Let us now assume that a new transport link is proposed to enable all employees to reach the center. Suppose that the predicted increase in travel demand results in a total of N employees instead of M employees without the project (a net increase of $N - M$ employees).

The "with project" production will be AN^β ; and the product per capita $AN^{\beta-1}$, which is the marginal productivity of the last employee. Total production at the center will increase by a ratio of $(N/M)^\beta$, and the net increase will be $A(N^\beta - M^\beta)$. Since N and β are positive values, this function increases with N and β . However, if we assume that $\beta > 1$, then the first and second derivatives with respect to N are both positive. That means that production is increasing at a faster rate (i.e., doubling employment will more than double the output). This theoretical model was used as a rationale for estimating the benefits to accrue from the construction of a new Light Rail Transit (LRT) in the Tel Aviv Metropolitan Area (TAMA).

8. Estimating the Benefits of LRT

The Tel Aviv Metropolitan Area is the most urbanized area in Israel. It lies on a flat plane along the Mediterranean coast and covers a total area of 1,520 square kilometers.

Today more than three million people, constituting over 45% of Israel's total population,

1. The classic Cobb-Douglas-type production function is $Y = AK^\alpha L^\beta$. The analysis made here implies the use of only one factor of production—labor.

reside in this region, which provides more than 1.2 million jobs, or about 53% of the nation's total jobs. Overall population density is over 19,000 people per square kilometer, and the job density is approximately 780 jobs per square kilometer (CBS, 2004). TAMA is considered a global city and is emerging as a viable node in the global economy. It provides a high level of both quantity and quality of producer-driven services, as well as consumer-driven activities, thus making it a place that attracts new residents as well as new economic activities. The traffic problem in the Metropolitan area is rapidly becoming worse, particularly in the center and sub-center of the Metropolis. Today buses provide the only means of public transportation for all who wish to enter the city for work, for consuming public and private services, or for cultural and entertainment activities.

According to forecasts, more than 4.1 million people will reside in the TAMA by the year 2030, and more than 1.9 million jobs will be offered. There is no doubt that in order to meet the consequent rapidly growing demands for housing, jobs, and services without jeopardizing the growth of the region, the introduction of a high-capacity transport mode like the LRT that is currently being proposed is of paramount importance for the TAMA. The proposed LRT connects three cities within the region: Petah-Tiqva, Tel-Aviv itself and Bat-Yam. (See Map 1).

Map 1: Proposed LRT Routes in TAMA

- **Calculating Agglomeration Benefits**

The evaluation of agglomeration benefits to be derived from the proposed LRT is based on three major components:

- Preliminary Engineering design
- Trips and Traffic analysis
- Economic evaluation

All three components are related to one another; in fact, they intertwine. System design and travel demand are related to the headways of the trains. The number of units of rolling stock and the location of stations are a function of the estimated demand. The economic evaluation employs basic data concerning costs related to the infrastructure and

rolling stock and concerning benefits derived from the passengers' choices, as well as from the level of service offered by the system.

The complete economic evaluation is based on the following phases:

- Determination of alternatives
- Projection of the generation/attraction of trips on a traffic-zone basis
- Distribution of trips, identifying the origin-destination connections
- Application of the modal split model
- Estimation of construction, operation, maintenance and replacement (OMR) costs of the transportation sub-systems
- Estimation of the time saved and its value
- Assessment of "other" transport-related costs and benefits (parking, accidents, pollution, etc.)
- Addition of external urban benefits to the evaluation
- Calculation of the economic feasibility of the project

As stated above, most transportation analyses are based on a fixed-demand model assumption, and hence the benefits of "induced traffic" are not incorporated into the cost-benefit analysis. Furthermore, external urban benefits, to the best of our knowledge, have never been calculated. The following exercise is concerned with the calculation of these benefits, which represent the economic benefits generated by the "induced traffic."

The economic analysis of the proposed LRT is based on a comparison of the urban transportation costs in two situations: "with" and "without" the proposed transport project. The differences in the level of service for users between these two situations form the basis for estimating the benefits. The assumption is that under these two situations, the transport network system, including that directed to the center of the city, is capable of "clearing the market"; i.e., bringing all passengers to their chosen destinations. The road network has a limited capacity, and therefore will probably not be able to respond to additional travel demand in many future situations. This restriction will result in changes in the travel habits of the travelers. Moreover, since a large proportion of the morning peak-hour travelers are commuters, these changes will bring about in the long run a change in the spatial structure of the urban area, resulting in a shift in land uses, primarily from the center to the outskirts of the urban area (thus leading to urban sprawl). This new situation will decrease the size and intensity of the city's center and reduce the size of its employment.

Several studies that investigated the effect of urban size on the efficiency (production) of the urban area have found that urban areas enjoy **increasing returns to scale because of agglomeration economies**. This means that if the size of the urban area doubles, output will more than double. This extra growth in output is due to agglomeration economies, or increasing returns to size (scale).

Attempts have been made in the past to estimate empirically the returns to scale to the urban-size parameter. Selected results of these studies are presented in Table 1 below.

In general, the results indicate that the gain in efficiency (productivity) owing to agglomeration economies ranges between 3% and 7%. In the majority of the studies, these figures refer to agglomeration economies on a metropolitan-wide scale. To estimate the impact on the CBD in the present study, we have decided to employ somewhat lower figures (between 2% and 6%).

An LRT system will enable more people to commute to the center of the TAMA, hence increasing the production capacity of the CBD. It is clear that not all the additional production should be counted as benefits, only that in excess of the production in alternative locations.

Table 1: Effect of Agglomeration Economies as Derived in Various Empirical Studies

Source	Percentage Increase from Agglomeration	Notes
Shefer (1973)	5	By major economic branch (2 digits SIC), in large U.S. metropolitan areas
Nakamura (1985)	3	By major economic branch in Japan
Ciccone and Hall (1996)	6	Based on employment density (U.S.)
Quigley (1998)	3, 6, 7, 8	Survey of several studies
Faberman (2000)	2.6-5.9	By economic branch (U.S.)

A considerable number of “ex-post” studies have dealt with the impact of transport facilities, mainly transit stations, on land uses and land value. Our economic evaluation of the LRT does not consider long-term shifts in land uses. Yet, a shift in the spatial distribution of land uses could result in a reduction in trip length, thus cutting travel costs to users. Improved access to these land uses reveal itself in the increase in land values (Aviram, 2001; Weinberger, 2000) Of course, not all the increase is due to the shift in land uses, and we have to be aware of double counting. Part of the increase in land values is due to the reduction in transportation costs even without changing trip origins and/or destinations. This specific result may be calculated directly by estimating the savings in transportation costs, comparing the time and distance of two different O/D matrices, one with fixed trips and the other with changes in trip origins and/or destinations. This additional source of benefits is not discussed in this paper.

The procedure for calculating the urban benefits derived from the LRT in TAMA, presented in Diagram 2 below, includes the following steps:

- Estimating income per employee, utilizing national income statistics.
- Assessing the rate of increasing returns to scale, utilizing parameters obtained in previous studies.
- Estimating urban benefits based on an evaluation of induced traffic.

**Diagram 2: The Process of Computing Urban Benefits Accruing to New
Transportation Projects**

Table 2: Commuter Trips in TAMA During Morning Peak-Hours

Time period (a.m.)	Total trips	Commuters	% Commuters
7-8	846,503	472,247	56%
6-7, 8-9	791,889	366,061	46%
Total 6-9	1,638,392	838,308	51%

Table 3: Number of Commuters by LRT to the Tel Aviv CBD

LRT Line	Station	Number of Passengers	Commuters (51%)
Red	Elite	5,942	3,030
	Arlozorof	15,983	8,151
	Azrieli	6,869	3,503
	Hashmonaim	8,444	4,306
	Beit Hadar	10,899	5,558
Green	Arlozorof	4,630	2,361
	Weitzman	7,865	4,011
Shuttle	Elite	3,420	1,744
	Arlozorof	3,523	1,797
	Azrieli	1,229	627
	Hashmonaim	2,698	1,376
	Beit Hadar	3,395	1,731
Total			38,195

Based on Israeli Central Bureau of Statistics data for 1997, we assume that the output per employee can be derived from the average household (money) income per month, which was 9,400 New Israeli Shekels (NIS). Since the number of wage earners per household was 1.2 and the dollar exchange rate was about NIS 3.5 per \$1, the annual income per employee was equivalent to about \$26,800², or about \$27,000 ($[9,400/1.2]*12/3.5$).

² We assume that per-capita income in the CBD is similar to that everywhere else; this is a very conservative assumption.

Currently there are approximately 200,000 employees in the CBD, whose total income is roughly 5.36 billion dollars a year (based on the average income computed above). In order to estimate the incremental benefits to be derived from agglomeration, the increase in the number of employees in the CBD caused or facilitated by the LRT has to be estimated. This figure can be computed from the number of LRT commuters or “Home Base Work” trips in the morning hours. Accordingly, the estimated incremental annual benefit is as presented in Table 3.

Because of the new LRT system, it is estimated that approximately 40,000 new commuters will join the labor force in the CBD. Hence, the increase in the value of the total annual production from agglomeration economies will be³:

$$\text{Value of total output} = 27,000 \times [240,000^{\beta} - 200,000^{\beta} - 40,000^{\beta}]$$

Thus, the computed value of the incremental urban benefits derived from agglomeration economies will be between 73 and 355 million dollars per annum⁴, depending on the value of the agglomeration parameter employed.

The results of the economic evaluation of the proposed LRT, using an increasing returns to scale figure of 4% ($\beta=1.04$), showed a benefit-cost ratio of 1.40. Evaluation of the project without urban benefits resulted in a benefit-cost ratio of 1.15. Thus, the average value of the agglomeration benefits is equal to 25% of the total investment.

³ It is assumed that employees unable to reach the CBD will be located elsewhere and will also enjoy increasing returns to scale, but on a reduced level.

⁴Based on agglomeration benefits of 2% and 6%, respectively.

9. Conclusions

The methodology for calculating the urban benefits developed in this paper expand the benefits derived from urban transportation projects. This approach is particularly important in the evaluation of mass transit projects because of their impact on the spatial distribution of land uses in the urban area. Further research is required in order to determine narrower margins for the increasing returns-to-scale parameter or models that will explain these returns as a function of the urban structure and the clustering of economic activities.

Nonetheless this paper has demonstrated that the component of what we called “urban benefits” is indeed quite significant, and therefore it should be incorporated into the benefit-cost analysis of new transport projects, such as an LRT.

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Fig. 1: The Effect of Various Levels of Agglomeration Economies on Productivity

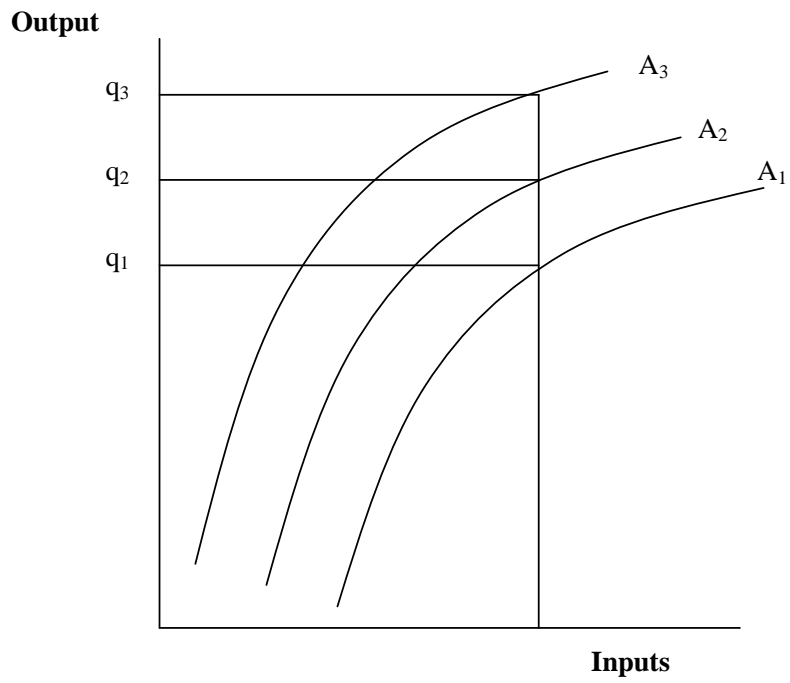


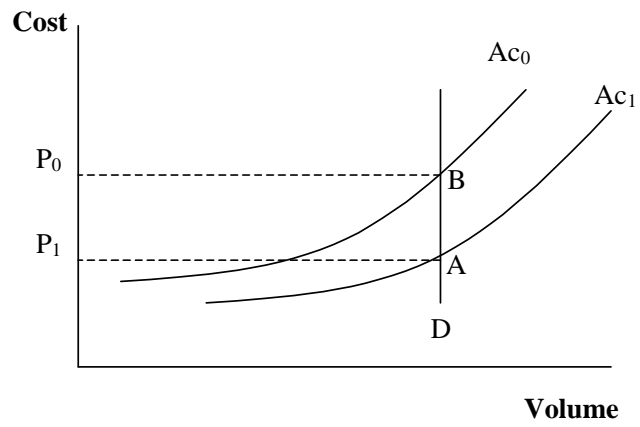
Fig. 2: Benefits of a Single Autonomous Project

Fig. 3: Benefits Derived from Traffic

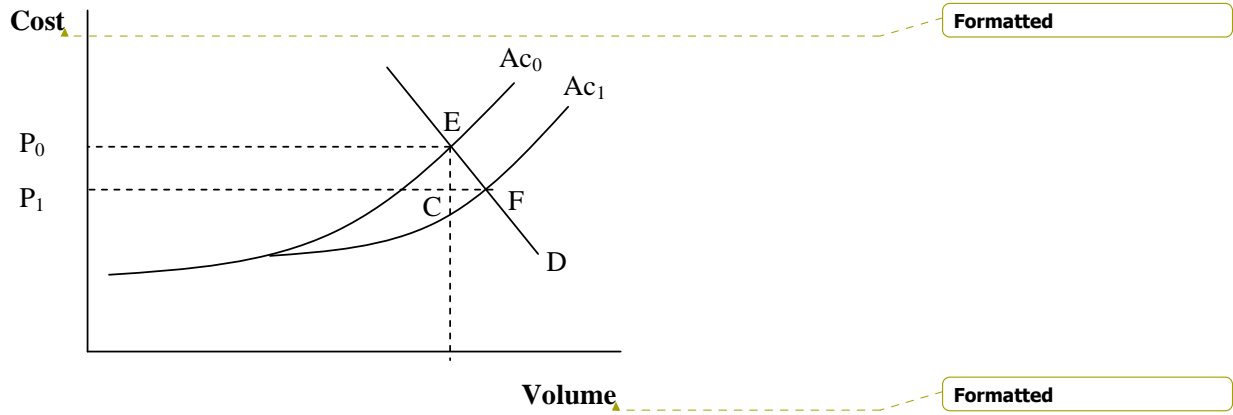


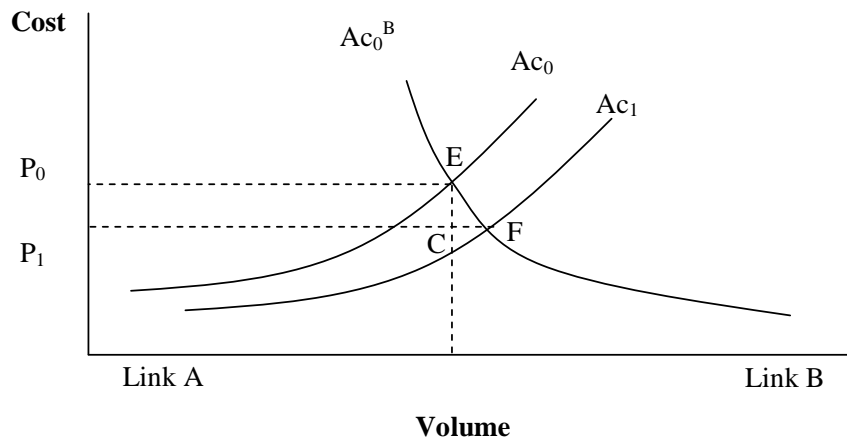
Fig. 4: Two Links with Fixed Demand

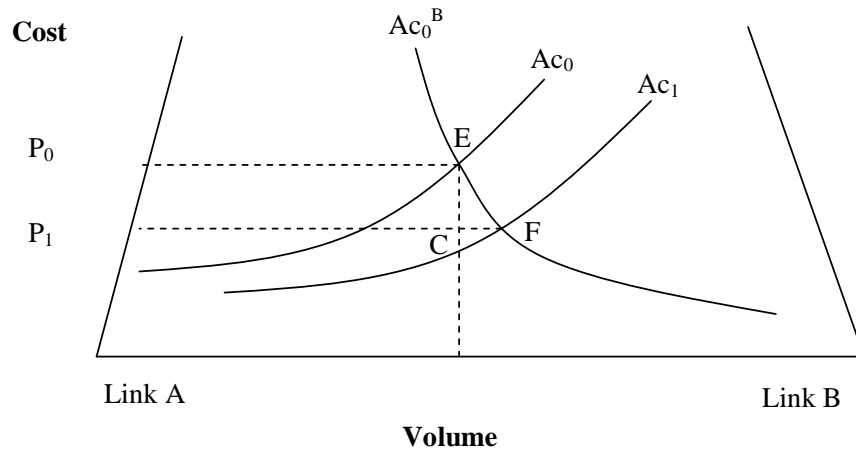
Fig. 5: Two Links with Induced Demand

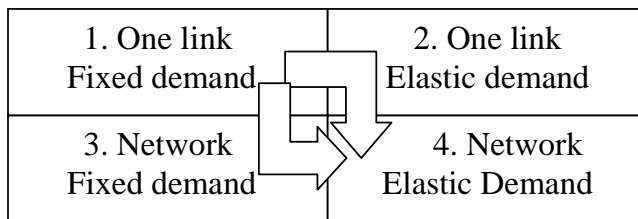
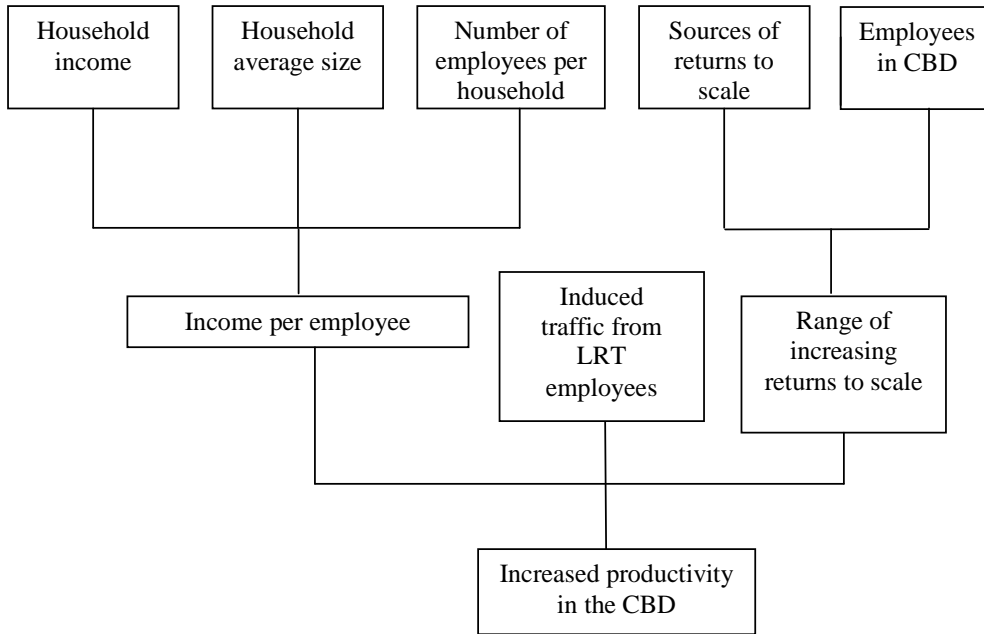
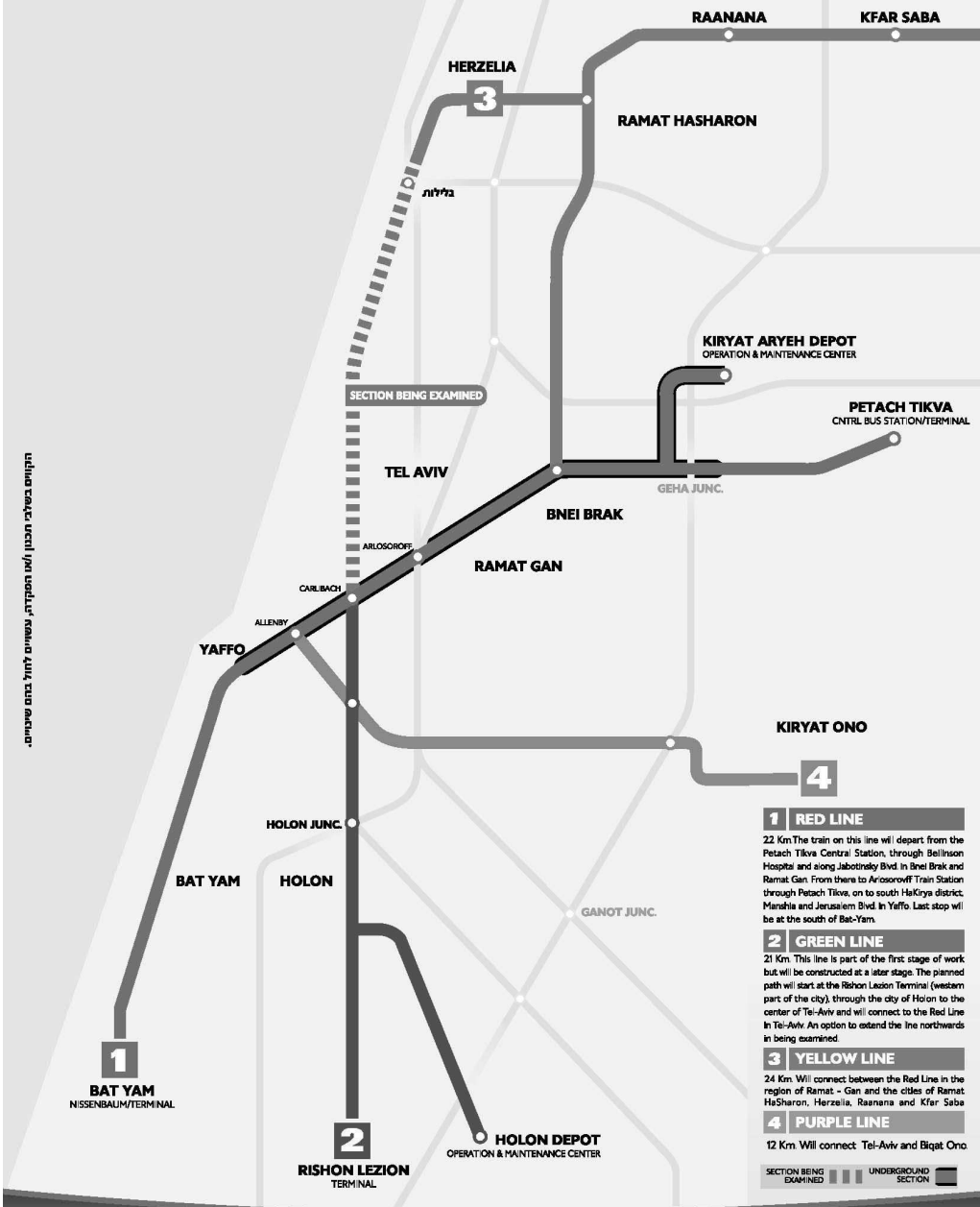
Diagram 1: Transport Analysis – From Simplicity to Complexity

Diagram 2: Procedure for Computing Urban Benefits



FUTURE PLANNED LINES

STAGE 1 THE RED & GREEN LINES
STAGE 2 YELLOW & PURPLE LINES



התכנון והקמת הרכבת תל אביב-יפו תבוצע בשלבים

- 1 RED LINE**
22 Km. The train on this line will depart from the Petach Tikva Central Station, through Bellinson Hospital and along Jabotinsky Blvd. in Bnei Brak and Ramat Gan. From there to Arlosoroff Train Station through Petach Tikva, on to south HaKiryat district, Manasia and Jerusalem Blvd. In Yaffo. Last stop will be at the south of Bat-Yam.
- 2 GREEN LINE**
21 Km. This line is part of the first stage of work but will be constructed at a later stage. The planned path will start at the Rishon LeZion Terminal (western part of the city), through the city of Holon to the center of Tel-Aviv and will connect to the Red Line in Tel-Aviv. An option to extend the line northwards is being examined.
- 3 YELLOW LINE**
24 Km. Will connect between the Red Line in the region of Ramat - Gan and the cities of Ramat HaSharon, Herzlia, Raanana and Kfar Saba.
- 4 PURPLE LINE**
12 Km. Will connect Tel-Aviv and Biqat Ono.

SECTION BEING EXAMINED UNDERGROUND SECTION