Cost–Benefit Methods for Underground Urban Public Transportation Systems

ITA Working Group on Costs–Benefits of Underground Urban Transportation*

Abstract—*This report of the International Tunnelling Association provides an overview of considerations in appraisal studies for urban public transport projects. It describes and compares methods used for calculating costs–benefits of urban transportation systems in four countries: Belgium, Czechoslovakia, West Germany, and France.*

Résumé—*Ce rapport de l'Association Internationale des Tunnels donne une vue générale des considérations à prendre en compte lors des études des besoins pour des projets de transport urbain publique. On décrit et compare les méthodes utilisées pour calculer les coûts-avantages des systèmes de transport urbain pour quatre pays: Belgique, Tchécoslovaquie, République Fédérale d'Allemagne, et France.*

This final report by the International Tunnelling Association Working Group on Costs–Benefits of Underground Urban Public Transportation describes specific methods used in four countries — Belgium, Czechoslovakia, West Germany and France — to evaluate public transport projects. An introductory section deals with general considerations in planning and evaluating urban transportation schemes. The summary section compares the evaluation methods used in the aforementioned four countries.

General Considerations† [1]

Public transport needs have increased greatly during the last few decades. In spite of the numerous and prestigious projects that have been constructed to meet these needs, a great gap remains between transportation needs and existing systems. This gap exists not only because of the extent of the needs, but also because of the high costs of such projects. Indeed, in most cases, city travel needs imply high-capacity transportation systems such as metros and railways. Furthermore, environmental considerations entail increasing difficulties with regard to public transportation projects, whether urban or suburban.

A trend to consider only underground infrastructures acceptable has been observable in recent years. Such a situation inevitably leads to conflicts and, consequently, to delays in project achievement, especially when a choice appears possible between aboveground and underground infrastructures (see Fig. 1). Therefore, it should be obvious that transportation infrastructure projects concern city planning, above all; and that appraisals of such projects must take into account not only transportation considerations, but also many other aspects, as specific benefits of underground infrastructures.

In order to fulfill transport needs, project plans are developed and then submitted to different decision-making authorities. At certain stages of the decision-making process, the question of whether to accept, modify, postpone or abandon such a project must be resolved. Appraisal studies, performed at each of these stages, are intended to bring to the fore the project's importance to and overall consequences for the community.

The aim of appraisal studies is to help in the decision-making process and to suggest how scarce funds may be best used to meet people's transport needs. A goal of such studies must be to avoid wasting money, either by identifying the most effective solutions or by providing data in order to rank the various competing projects.

Appraisal studies are justified by the great number of parties involved in the decision process. These parties obey different logics; their points of view may be divergent and, often, contradictory. Faced with this diversity, decision-makers may be tempted to apply the notion of "public profitability", and to try to formulate an objective description of this notion.

In this context, it is useful to examine the problem of underground transport project evaluation within the wider scope of the decision-making process. In this respect, three questions must be asked before turning to specific considerations for underground projects:

(1) What are the different parties involved in urban public transportation projects and, therefore, in their appraisal?

(2) Why is it necessary to appraise such projects?

(3) What should the appraisal of such projects consist of?

Each of these questions is discussed below in detail.

What are the different parties involved in urban public transportation projects and, therefore, in their appraisal?

In general, the following parties are involved in public transportation projects:

- Users of public transport.
- Promoter(s) of the project.
- Operators of other public transport systems.
- Public transport authorities.
- City planning and management authorities.
- The following urban space users, with regard to traffic:
  - — Pedestrians.
  - — Motorists.
  - — Bicycle and motorcycle riders.
  - — Physically handicapped persons.

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†Portions of this report were published in the 4:1 issue of *Tunnelling and Underground Space Technology*.

[1]This section of the report was prepared by J.P. Godard, Vice-Chairman of the ITA Working Group on Costs–Benefits of Underground Urban Public Transportation, and Chairman of the French Tunnelling Association (AFTES) Working Group; and J.C. Hugonnard, Reporter of the AFTES Working Group.

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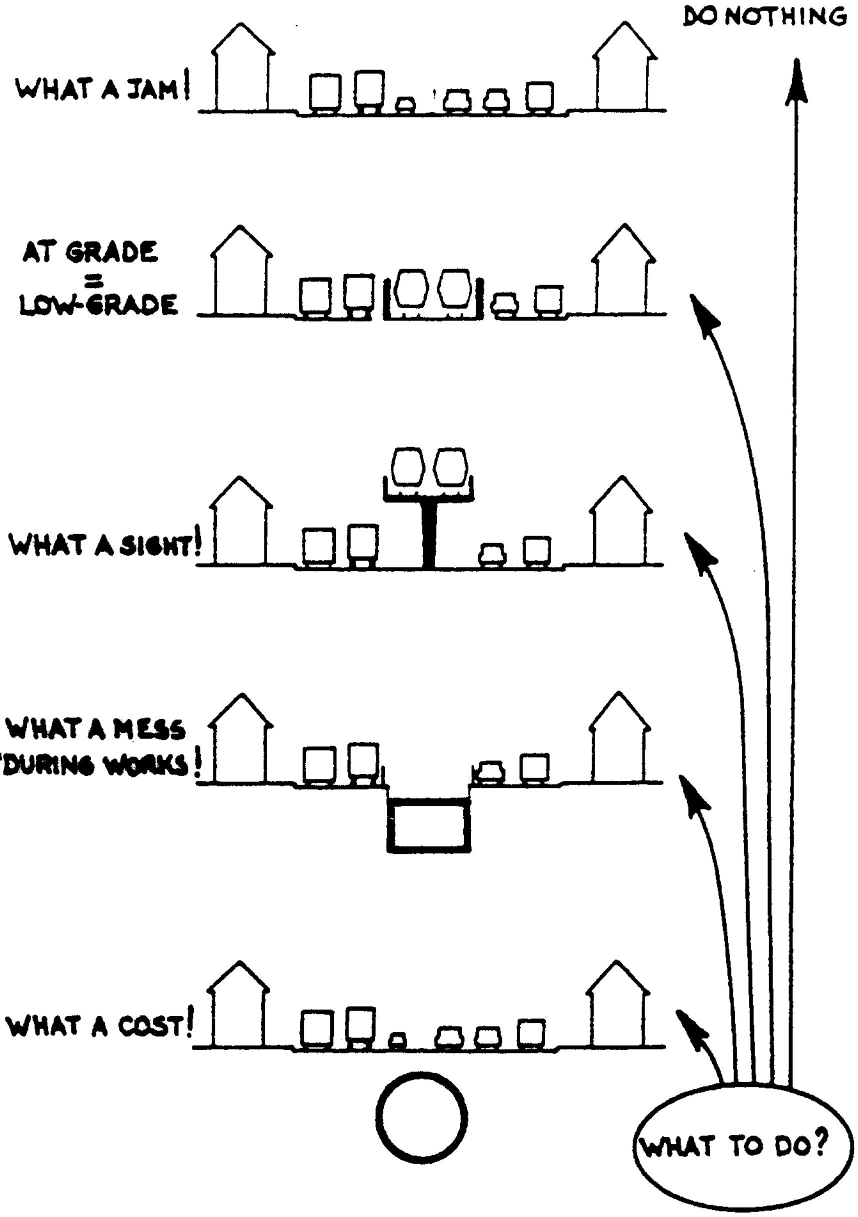


Figure 1. Urban transportation problem.

— Public transport operators (for systems using the public roads).
— Refuse disposal services.
— Taxi operators.
— Fire brigade.
— Police force.

- The following urban space users, with regard to the management of public works:
  — Public utilities services.
  — Public highway department.
  — Public transport operators (for systems on exclusive rights-of-way).
- Land and real estate owners.
- Developers.
- Neighborhood activities representatives.
- Neighborhood residents and associations.
- The following political authorities:
  — Local (mayor, city council).
  — Regional (prefect, region council).
  — National (ministries, etc).

Why is it necessary to appraise urban public transportation projects?

Among the main reasons for appraising projects are the following:

(1) The decision to undertake the realization of any project must be preceded by an evaluation of (a) the "quality" of the project, i.e., its ability to meet user needs; and (b) all of the effects associated with its realization.

(2) Because urban transport needs are out of proportion to financial resources available, it is necessary to define priorities for satisfying these needs.

(3) Urban transport projects generally imply large investments, which cannot be provided by transport operators alone. Because public funds from national, regional and/or local communities are necessary, transportation projects must compete with other public investments. Data must be available to public authorities to help them make informed choices.

(4) Urban public transportation projects entail significant external effects that justify intervention by public authorities. Data relating to these effects must be provided to the appropriate authorities.

(5) The planning process for urban transport projects involves numerous parties. Because the different points of view are not always reconcilable, decision-makers must arbitrate among the various parties; and they need sufficient data to do so successfully.

(6) In most cases, the project studies do not result in a straightforward "best" solution with regard to the different criteria to be taken into account. Therefore, it is necessary to be able to compare the different possible solutions with respect to the "quality and interest" associated with each.

What should the appraisal of urban public transportation projects consist of?

Appraisals of urban public transportation projects should deal with the following four aspects of the projects:

(1) Estimating the capital cost of the project.

(2) Appraising the "quality" of the project, i.e., its ability to meet user needs.

(3) Appraising all of the effects or impacts of the project on the environment.

(4) Defining and appraising the measures that tend to avoid, ease or eliminate the potential negative effects associated with the project.

The act of "appraising" involves one or more of the tasks listed below, expressing the effect of the project in terms of monetary estimates, quantitative evaluations, and/or verbal (qualitative) explanations.

Estimating capital costs. In estimating the capital costs of a transportation project, *knowledge of the total cost generally is not sufficient for decision-making.* In order to make a pertinent appraisal of the project, it may be necessary to divide the total capital cost among the different technical specialities, the different works, and the different cost items corresponding to the main functions fulfilled by the project ("value analysis"). The appraisal must include a schedule of the expenses.

Appraising the "quality" of the project. The "quality" of an urban public transportation project is defined as its ability to meet user needs. In this respect, the criteria for assessing the quality of such projects include:

- Areas served.
- Number of inhabitants and employees affected.
- Time savings.
- Accessibility to the transport system.
- Interchange facilities with other transport modes.
- Transport conditions: safety, comfort, speed, reliability.
- Environmental conditions: climatic, aesthetic, cultural.
- Coherence with the general transportation planning.
- Ability to adapt to fluctuations in transport needs.
- Scheduled date of start-up operation.

Appraising the effects of a project on the environment. The effects of a project on the environment can be rated as positive (favorable) or negative (unfavorable). They may be generated by the construction of the works, the works themselves, the operation of the transportation system, or the maintenance of the infrastructure associated with the system. The environmental impacts may be geometric (interferences) or physical, economic or financial, ecological, or aesthetic.

The environment of the project comprises physical, social/economic and political/institutional aspects. Factors involved in evaluating the effects of transport systems on the physical environment include geology/hydrogeology, ambient air, daylight, landscape, rivers, buildings works, and flora. Considerations related to the social/economic environment include effects on public transport, other traffic, industrial and trading activities, and cultural and leisure activities. Political aspects of transit projects relate to positive or negative impacts on elected officials' public images. Institutional aspects relate to the possible changes in the management of the transportation system resulting from implementation of a new infrastructure.

Appraising measures to deal with negative effects of a project. The task of describing and appraising the measures taken in order to avoid, ease or eliminate potential negative effects of a project must take into consideration all of the negative impacts identified above.

For each measure evaluated, the following information should be included: a description of the measure, its location, its cost, and its power to mitigate negative impacts.

[2]This section of the ITA Working Group's report was prepared by M. Gochet, Ministry of Communications, Brussels.

Descriptions of Methods

Belgium: Evaluating the Socioeconomic "Rentability" of Investments in Urban Underground Structures for Public Transport[2]

The construction of urban underground structures often requires very high investments due to numerous technical, city planning and social constraints that must be taken into account.

While such investments could be accepted easily by the collectivity in the 1960s, the outlook for such projects is different today, in the context of a general development which seems to be exponential. The economic crisis obliges all countries to make very strict choices in the field of investments in order to confine themselves to the most "rentable" investments. As a consequence, designers have to calculate the rentability of their projects more accurately than in the past.

The public transit evaluation method developed by Belgium's Urban Transport Promotion Service of the Transport Department has been applied to justify the installation of a metro line in a city hitherto served exclusively by buses.

Defining the problem

The transport evaluation method described herein applies to the most general case of an arrangement of underground structures that significantly transforms the scheme of an existing network, mostly by introducing different means of transport.

This method is perhaps even more applicable to the case of a punctual structure that modifies neither the structure nor the type of the rolling stock—e.g., an underground structure crossroads. The method can be applied to the case of a city where no transport system has yet been organized.

This evaluation method assumes that the route, as well as the features of the structures and of the rolling stock, already have been optimized. These elements, in addition to traffic expectations and development, are considered input data.

Principles of the evaluation method

The socioeconomic rentability of a given project is determined by the bill diary method, with chronological registration of receipts and expenses on their actual date, during a predetermined period.

At the end of this period, the structures and the equipment in service are booked as receipts, based on their recuperation value; the structures and equipment to be introduced in view of a predicted recovery of the previous situation are booked as expenses.

These receipts and expenses will be influenced by the future evolution of prices. Because this evolution is difficult or even impossible to estimate, especially over a long period, future receipts and expenses are estimated in *constant francs*.

Nevertheless, the "constant francs" approach cannot be likened to the "constant prices" approach. Salaries, energy costs, equipment costs, etc., evolve quite differently. Therefore, variations in the relative value of the different receipts and expenses entries, i.e., their evolution in relation to the general index of prices, should be taken into account explicitly. In this matter, the elaboration of hypotheses is generally not so hazardous as in matters of nominal price fluctuations.

On the other hand, the fact that the receipts and expenses under consideration are dispersed over several years introduces the notion of time reference. According to this concept — and leaving aside the evolution of the purchasing power of money — a receipt or an expense of 1 franc effected now does not correspond to a receipt or an expense of 1 franc effected a certain number of years later.

For this reason, the actualization principle must be applied. This principle involves multiplying future receipts and expenses by a factor $(1 + i)^{-t}$, where i represents the actualization rate and t represents the time during which the receipts and expenses being considered appear. This concept is expressed in terms of the number of years following the reference year chosen.

Two procedures for applying this principle are possible:

(1) The balance is drawn on the basis of an actualization rate chosen beforehand. If the balance is positive, the operation is rentable; if the balance is negative, the operation is not rentable.

(2) The actualization rate is determined so that receipts and expenses can be balanced. In this case, the actualization rate is called the "internal actualization rate". The internal actualization rate permits priorities between different projects to be set. On the other hand, this rate should be higher than the actualization rate generally used in applying this method. Thus, a reference actualization rate has to be chosen in both cases.

The nominal rate of interest registered at a given time on the capital market covers two different data:

(1) The real rate; and

(2) the inflation rate.

The real rate can be defined as the rate that would exist in the hypothesis of a constant purchase power of the monetary unit over the course of time. This real rate is represented by the following:

p = a present value
i = the real actualization rate (i.e., at constant price level)
S_1 = a future value at constant prices
S_2 = a future value at present prices
b = the nominal rate of interest (i.e., at present prices)
a = the annual inflation rate
n = the number of years

giving the following equations:

$$S_1 = (1+i)^n p \quad (1)$$

$$S_2 = (1+b)^n p \quad (2)$$

$$S_2 = (1+a)^n S_1. \quad (3)$$

Comparing equations (2) and (3), we have:

$$(1+b)^n p = (1+a)^n S_1$$

$$(1+b)^n p = (1+a)^n (1+i)^n p$$

$$\frac{1+b}{1+a} = 1+i$$

$$i = \frac{b-a}{1+a}.$$

If "a" (the inflation rate) and "b" (the nominal rate of interest) are known, the last equation above can be used to calculate the reference actualization rate "i", which is applicable in the hypothesis for a constant purchase power of the monetary unit.

A survey conducted in some Western European countries in the interval between 1970 and 1980 shows a considerable dispersion of the actualization rate, i, at constant prices. The values varied between –9% and +6%, with an average value apparently between 0 and 4%.

In conclusion, it is recommended that a relatively small value between 0 and 4%, and preferably between 1 and 3%, be selected for the actualization rate.

For Belgium, if we refer to a period of favorable economic growth — for example, between the years 1960 and 1971 — we note that the average rate of interest was 7% with an inflation rate of about 3%, yielding an actualization rate of about 4%.

On the other hand, an average actualization rate of 2.5% has been calculated for the recession period 1971–1983.

In the absence of more accurate indications, it seems that if we wish to compare investments calculated in the hypothesis of a constant purchase power of the monetary unit, the spread in the reference actualization rates can be restricted to an interval *between 3 and 4%*.

Determination of parameters

For any study in the field of economics, a number of parameters must be defined. These parameters can be fixed in advance, or they can be made variable within the scope of sensibility studies.

The variable parameters may include:

(1) Construction and paying out calendar.

(2) Operations program and traffic development.

(3) Technical features.

(4) Unit costs and their evolution in relation to the general price index.

(5) Financing organization.

Each of these parameters is examined below.

1. Construction calendar

Underground structures are generally constructed and put into service in successive phases. Additionally, each section of the works involves the following:

- Studies.
- Preliminary works (soil investigations, displacement of underground installation of public service concessionaires, eventual expropriations and demolitions, etc.).
- Civil engineering works.
- A variety of equipment: track, current collection, signalization, telecommunications, lighting, ventilation, escalators, etc.

A particular section, comprising the maintenance depot, generally forms part of the first phase and should be operational when the rolling stock is delivered by the manufacturer.

The rolling stock should be ordered following a delivery plan that permits vehicles to be run in when the successive sections are taken into operation. The terms of payment determine the paying out dates.

In addition, the rolling stock (buses or tramcars) taken out of service when a new underground network is introduced should be evaluated according to either the mean age of the rolling stock, or the age of the material effectively withdrawn from the service and not re-used. The corresponding receipt is charged when the vehicle(s) are taken out of service.

2. Operation program and traffic development

An operation program should be defined for the different phases corresponding to new sections of the network put into service. The operation program should comprise:

- An initial traffic evaluation: (1) at peak hours, (2) at low traffic hours during the day, (3) at low traffic hours during the evening, and (4) of traffic on Saturdays and Sundays.
- Vehicle capacity.
- The frequency considered to be satisfactory at peak and at low traffic hours.
- Commercial speeds.

Based on knowledge of these elements, the required rolling stock — including a stand-by reserve and vehicles in the maintenance workshops — can be determined.

It is also possible to deduct the km vehicle/year, loaded and empty, which essentially depends on the location of the depot.

When the underground network under study is intended to replace an existing network, it is necessary to determine for each phase:

(1) The lines totally suppressed.

(2) The lines for which the route or frequency is subject to modification.

From these elements, the amounts saved on line vehicles and rolling stock, as well as on km vehicles/year can be deduced.

An increase in traffic generally follows the introduction of a new underground network with higher performances. This is one of the best justifications for such operations.

This increase, which affects both the total traffic and the peak traffic, can be estimated on the basis of traffic studies concerning the potential users in the operation area and the evolution of traffic during the following years (as regards both residential and work areas), the relative attractiveness of the different means of transport, etc.

Such studies are rather delicate, especially when they bear on long-term situations. It may be more sensible to combine different growth assumptions with a study of the sensitivity of this parameter.

As a matter of course, the capacity of the system should be verified with each assumption and the operation program, as well as the required rolling stock, should be adapted accordingly.

The increase in peak traffic is not necessarily proportional to the increase in total traffic. The greater attractiveness of a transport system is indeed felt more strongly by slack hours users than by peak-hour users, a great many of whom are already "captives" of the existing transit system.

3. Technical engineering

3.1. The *civil engineering* aspects to be considered in evaluating a transit project include:

- Type of structure (i.e., underground, elevated or surface).

- Soil conditions.
- Surface and underground occupation.
- Internal profile.
- Location and size of the stations.

Based on these elements, a good mean approximation of the cost of civil engineering works can be obtained. The depot is considered separately.

3.2. The costs of *finishing works* for the depot and the stations depend on the features chosen — e.g., materials, floor covering, etc.

3.3. In order to evaluate *equipment* costs, the following items must be defined:

- Track and substructure.
- Track apparatus.
- Track network in the depot area.
- Current captation apparatus.
- Transformer stations.
- Signalling and traffic regulation equipment, eventually comprising a control center.
- Telecommunications and public information equipment.
- Lighting for stations and underground structures.
- Escalators, lifts.
- Ventilation equipment.
- Water supply (i.e., for fire protection).
- Maintenance, control and repair equipment for the depot.

3.4. Costs of *rolling stock* depend on the main characteristics of the vehicles with regard to, e.g.:

- Overall dimensions.
- Composition.
- Number of bogies (motorized or not).
- Maximum speed.
- Maximum deceleration.
- Total capacity.
- Number of seats.

4. Unit costs and evolution in relation to the general index of prices

The costs to be considered in a socioeconomic study concerning the introduction of urban underground structures for public transport fall into three categories:

(1) Investment costs.
(2) Operating costs.
(3) Social costs.

4.1. Investment costs. For studies using a constant monetary unit, the investment costs are constant. This means that the increase in manpower costs is compensated by a higher productivity, while the cost of raw materials is held constant.

The unit costs chosen (with the possibility of further refining if preliminary studies are available) are as follows:

4.1.1. Permanent way. This category includes costs associated with both the new network and the existing network.

The breakdown of such costs associated with the new network — for main walls, depots and workshop infrastructure, finishing works, track and power collection, and equipment — is shown in Table 1.

Accessory renewing charges associated with the existing permanent way should appear as receipts in the bill diary, on their normal dates. This procedure is applied, for example, in the case of the equipment for the maintenance depot, surface tram tracks, reserved bus lanes, etc.

4.1.2. Rolling stock. Costs for new material are calculated in terms of cost per unit (comprising spare parts).

For existing material, two approaches are possible:

(1) If the planned operation has little influence upon a homogeneous existing stock, the cars taken out of service are booked as receipts with a residual value, taking into account the *mean* age of the stock. They also appear as receipts at the time of renewing operations that would have been necessary if no modification had been effected.

(2) If the influence of the operation upon the existing stock is important (e.g., sometimes the operation affects the total stock), the cars withdrawn from service cannot be used again. They are booked with a recuperation value corresponding to the end of their life. The renewals are handled as in the first case.

4.2. Operation costs. The operation costs include the costs of:

(1) The staff itself.
(2) Maintenance.
(3) Energy consumption.

Generally speaking, the real cost of the driving and inspection staff is assumed to have a regular annual growth of a certain percentage per year (working time reduction and social policy). However, other approaches can be used for this calculation and may eventually become the subject of a sensibility study.

On the other hand, maintenance

Table 1. Investment costs associated with a new transit network.

Main Walls of:
- — Underground structures: /km
  - Normal execution
  - Difficult execution: + %
  - Very difficult execution: + %
- — Elevated structures: /km
- — Normal station:
  - Terminal station (special track equipment)

Depot and Workshops Infrastructure:
- — Constant term + term proportional to number of coaches to be handled (with reserve)

Finishing Works:
- — Per station
- — Maintenance depot: constant term + term proportional to number of coaches

Track and Power Collection (e.g., power rail or aerial contact line) for:
- — Double track line: /km
- — Switches
- — Depot and workshops equipment: constant term + term proportional to number of coaches

Equipment:
- — Depot and workshop: constant term + term proportional to number of coaches
- — Stations (lighting, telecommunications, escalators, etc.): /station
- — Transformer stations: /transformer station
- — Signalling and traffic regulation: constant term (control center) + term proportional to number of stations

manpower cost is assumed to be constant, because it is linked with an improving productivity.

The cost of materials is assumed to be constant.

The real cost of energy is assumed to grow regularly by 1.5% a year for mineral-oil products, and by 1% a year for electricity.

Operating costs for a new network are summarized in Table 2.

4.2.1. New network. Table 2 breaks out the costs for the operations staff, maintenance, and energy costs associated with a new transit network.

4.2.2. Existing network. All of the costs given in Table 2 (for a new network) can be used both to calculate costs associated with the existing network and to introduce the saving resulting from the substitution of systems in the bill diary at the proper dates.

4.3. Social costs. The social benefit to be applied on the assets side of new urban underground structures for public transport concerns, on the one hand, the users themselves and, on the other hand, the urban collectivity.

4.3.1. Public transport users. The first benefits of a new underground public transportation system are associated with the travellers already using public transport facilities and deriving a direct advantage from their operation.

These advantages may be expressed in terms of time savings, greater regularity and greater comfort. Only the first of these factors is measurable and can be taken into account accurately. Therefore, the mean traffic flows concerned must be determined in order to calculate for each route the average time saved by travellers. Such calculations must take into account an eventual extra interchange (i.e., actual transfer time and average waiting time at the connection point) and an evaluation of the time saved on the basis of a fixed "cost" of a "user-hour".

If the distribution of traffic between the great usual categories (work — school — leisure) is available, a different cost can be evaluated for each category.

New public transport users also benefit from operation of a new underground transit system. Here we should distinguish people who have already been making the journeys under consideration, but by other means, from people who have never made the journey and whose habits have been transformed by the new means of transport placed at their disposal.

For the first type of user, we can assume that the travel time is divided between travel time on the existing public transport network, and travel time on the new network.

For lack of other elements, we can assume that real time saved (whether real or simply felt as such) in this category amounts to half the time saved by the users of the existing system.

Of course, the notion of "spared time" is meaningless for those who did not use the existing system to make these journeys. Nevertheless, the new system brings them to a level of "satisfaction" at least equal to the expense they expected to incur. Thus, the receipt corresponding to these new users constitutes a minimal approach of the social benefit of the new system.

4.3.2. Urban collectivity. For the urban collectivity, the realization of underground structures comprises two phases.

The first phase is that during which the works are performed. During this phase, the traffic restrictions and the resulting impact on commercial activities are, of course, a negative element in the overall balance. Estimating the degree of this negative bias is difficult. A rational approach resulting in an evaluation criterion for examining the contractors' technical suggestions would be very useful.

The second phase begins after the works have been completed and the system has been put into operation.

The most important benefits for the urban collectivity result from the modal

Table 2. Operating costs for a new transit network.

Operations Staff

Annual costs (all charges included) of driving staff: /agent

- Annual cost (all charges included) of supervision staff (controllers on the line or at the control center): /agent.

The real driving prestations required are determined on the basis of:

- The operation diagram defined in preliminary planning stages.
- The real number of prestations per year per staff member (comprising agents on leave, at rest, invalid, etc.).

The prestations of supervision staff are defined as a function of estimated work charges with a sufficient reserve, when the system is started.

Maintenance

For the permanent route:

- Annual cost (all charges included) of technical staff: /agent (two levels will be distinguished eventually).
- The prestations are defined on the basis of:
  - The extension of the network.
  - The number of stations.
  - The complexity of the control center.

For the rolling stock:

The following should be defined, to the extent possible on the basis of existing references:

- The maintenance cost of cars: a term proportional to the number of cars + a term proportional to the car/km performance.
- The cost of consumed materials for maintenance: /km.

Energy consumption

- Unit cost of energy (diesel fuel: /l)
  (electricity: /kw).

The following also should be distinguished:

- Maintenance depot consumption (a fixed amount).
- Network consumption per km and per station.
- Rolling stock consumption per car/km.

transfers recorded and the impact of public transport improvements on urban life.

The importance of modal transfers can be estimated by observing similar cases or by performing studies to measure the attractiveness of the urban environment, using behavior models and simulations.

The anticipated benefits for the collectivity take the form of (1) investment reductions and (2) savings in operating expenses.

(1) Investment reductions. Modal transfers bring about a reduction in the flow of private vehicles. In contrast, public transport coaches using common roads participate in the general traffic flow. An underground transit system helps reduce this general traffic flow by alleviating the need for coaches, and thereby providing supplementary surface road space for private circulation vehicles. The same holds true for surfaces previously reserved exclusively for public transport (separate structures, embarkation platforms, etc.).

The surface space thus recovered can be used in several ways that will benefit the collectivity, e.g.:

(1) **Increased road capacity.** The general traffic becomes more fluid and more rapid, thereby saving time for users and energy for the vehicles. Investments required to cope with increasing traffic can be postponed.

(2) **More parking spaces.** Provision of additional parking is an element favorable to the development of urban activities, commercial or otherwise. It also avoids, or at least postpones, the need to construct underground parking.

(3) **Street arrangements favoring pedestrians.** Pedestrian walkways provided as part of urban renovation projects are also favorable to the development of commercial and other urban activities.

It would be difficult to make an accurate determination of the importance of the investments saved by such means — and all the more so in regard to evaluating the quality of urban life. However, a first approach could evaluate:

- The importance of modal transfers;
- The flow of private vehicles which, as a result of the operation, disappear from general traffic at peak hours;
- The number and length of the traffic lanes corresponding to this flow;
- The average construction cost of such roads in urban areas;
- The corresponding number of parking and standing spaces;
- The average cost of such spaces.

As a matter of course, these investments will lead to periodical renewals that should also be booked in the diary of bills.

Finally, at the end of the period considered, these investments appear with a non-amortized value.

(2) Savings in operating expenses. A number of benefits can be evaluated on the basis of statistical observations which should be performed frequently and should be normalized to facilitate comparisons and to elaborate general norms.

The benefits related to savings in operating expenses include:

(1) Savings by users of private transport who have shifted to using public transport, in terms of vehicle maintenance repairs, fuel costs, etc.

(2) Savings for road administration, in terms of operation and maintenance costs, need for police, etc.

(3) Savings resulting from improved security, in terms of material damage, and direct and social costs resulting from casualties.

Other benefits, the existence of which cannot be denied, are nevertheless difficult to evaluate, such as the impact of the planned works on air pollution, noise and landscape degradation, etc.

The different unit costs playing a part in the evaluation of the social benefit vary as a result of the following assumptions:

- The investments are evaluated at constant prices;
- The value of a travel hour increases by 1% a year;
- The savings realized by the collectivity increase by 1% a year, with the exception of savings related to maintenance and consumption of private vehicles, where an increase rate of 1.5% should be applied to the "energy expenses" item.

5. Financing arrangements

The realization of underground structures for public transport in urban areas often requires very important investments.

The urban transport operating companies generally do not have the option of proceeding to make such investments because the direct rentability of underground public transit project, at the level of the company, is not sufficient.

Because the realization of such structures has an impact on urban life, participation of the collectivity in the financing of these investments is considered normal.

Thus, the bill of receipt and expenditure permits the identification of two distinct economic balances.

(1) The economic balance of the operating company, calculated on the basis of operation expenses, receipts and financial charges related to the company's investments.

(2) The total economic balance of the collectivity, including the aforementioned elements, the total investments, and the social benefit of the operation.

Investments (and renewals) can be shared between the operator and collectivity according to several schemes.

On the other hand, we may discriminate between the local collectivity, which draws direct benefit from some social aspects of the operation, and the national collectivity.

The schemes to be chosen depend on the administrative structure of the specific country. In the case of Belgium, it is assumed that the operating company will take over rolling stock investments after deduction of the stock withdrawn from service as a consequence of the operation. The State Department of Transportation is expected to take over all investments associated with the permanent route after deduction, for the latter, of a portion amounting to approximately 20%, which should be taken over by the operator.

Czechoslovakia: Economic Evaluation of Transport Projects in the CSSR[3]

In Czechoslovakia, the Guidelines No. 17 of the Federal Ministry for Technical and Investment Development have been in force since January 1, 1982. These guidelines determine the procedure for evaluating the effectiveness of all transport investments; and are binding for all the investors, projection institutes, and approving bodies. They determine the basis for expressing and evaluating the effectiveness of the investments in the planning and preparation of projects and transport constructions throughout the republic.

The total evaluation of the effectiveness of an investment comprises several stages. One stage involves generating and evaluating the alternatives that provide the means to reach the stated goals, from the standpoint of the economic effectiveness of the investment.

The criterion for choosing the most effective alternative is the minimum converted costs (P), which, with regard to the time factor and production resources limits, include the complex requirements of the construction and operation of the investment during the economic life of the project.

Converted costs (P) are expressed in Kcs/year and are calculated using the following formula:

[3]This section of the ITA Working Group's report was prepared by the Working Group of the Czechoslovak National Committee of ITA, headed by Ing. Jindrich Hess.

$$P = J \cdot /a_1 + k_f / \cdot k_v + N_{pr} + a_2 N_m + a_3 \cdot N_{pe} + N_{si} = \min, \quad (4)$$

where

$J \cdot /a_1 + k_f / \cdot k_v$

= the average annual share of the investment costs (direct and indirect) according to the construction period and service life of the project

J = the total investment costs of the individual alternative

k_f = coefficient to convert investment costs (j) into average annual share ("depreciation")

$$k_f = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (5)$$

i = rate of interest

n = number of years of economic life of the alternative

(Note: Equation (5) is also known as the capital recovery factor [see, for example, Winfrey 1969].)

k_v = the coefficient for economic losses incurred for the idle portion of the investment during construction, depending on length of the construction period

a_1 = the coefficient expressing the scarcity of investment funds in the economy ($a_1 = 0.05$)

N_{pr} = vehicle operating costs in a typical year (Kcs/year) [i.e., a typical year in the operation phase]

$a_2 N_m$ = means of expressing average additional social, medical and other costs, financed from public funds

N_m = wages in a typical year

a_2 = coefficient ($a_2 = 0.6$)

$a_3 N_{pe}$ = means of expressing average additional subsidies on energy resources from public funds

a_3 = coefficient ($a_3 = 0.6$)

N_{pe} = fuel and other energy costs in a typical year

N_{si} = social effects of the construction in a typical year

N_{si} = $N_t + N_{ne} + N_{zp}$

N_t = value of passengers' time (Kcs/year)

N_{ne} = losses due to accidents, including material damages (Kcs/year)

N_{zp} = undesirable effects on the environment (Kcs/year).

The transit option having the minimum P is deemed the most effective option. Alternatives that are not comparable in time (e.g., due to differences in the beginning or the end of construction, differences in length of service life, etc.) are assessed by means of an alternative indicator, present worth of converted costs (P_a):

$$P_a = J \cdot (a_1 + k_f) \cdot k_v \cdot r^{-t_1} + (N_{pr} + a_2 \cdot N_m + a_3 \cdot N_{pe} + N_{si}) \cdot r^{-t_2} \quad (6)$$

where

P_a = present worth of converted costs

r = $1 + i$

t_1 = number of years in construction phase

t_2 = $t_1 + t_x$

t_x = number of years from first full year of operation to the typical year for assessment.

The above calculation implies the obligation to evaluate the social effects of the transit system (N_{si}). In solving public transport problems, taking into account the social effects makes advantageous the underground options, which are otherwise — i.e., from the point of view of immediate costs (J) — usually more expensive than the surface variants.

At present, problems remain in expressing, in a consistent way, the undesirable effects of transit systems on the environment and on the rate of accidents. The guidelines do not address these effects. It is illustrative enough to start by expressing, at the least, for example, the reduction in noise levels (dB) and reduction in concentrations of harmful substances in the air (%) related to the operation of underground transit systems. The aforementioned guidelines recommend the use of the sum of 15 Kcs to quantify the effects of the free-time growth.

To calculate the cost savings related to reduction of accidents, different rates are set to express the damages to health and material associated with a single accident (e.g., 80 400 Kcs). An accident occurs, on average, every 40 000 km of operation of a tram or a bus.

In the meantime, the concept of development of public transport is being used in other cities in Czechoslovakia. One such city is Brno, which, with a population of 360 000, is the biggest Moravian town and the venue of international machinery fairs.

The Regional National Committee has approved a complex study for an integrated public transport system in Brno, the primary element in which is "rapid tramways". This governmental body also has been instructed to design the first part of diameter A of the system. At the same time, the Regional National Committee was asked to decide, in cooperation with the state expert body, whether, with respect to the present state of the environment, it would be more advantageous to construct the tunnels for the system by tunnelling or by the cut-and-cover method.

In accordance with the Guidelines No. 17 of the Federal Ministry for Technical and Investment Development, the two tunnelling methods were evaluated by the designer for 1 km of definitive line (see Table 3).

In Table 3, item 5 includes only the time savings of passengers influenced by the fact that the tunnelling option permits a higher average speed. The costs for the cut-and-cover option, under item 1, are higher because 29% of the construction costs for this method are associated with re-laying of technical systems, trams, communications, costs of demolitions, and adaptations. For the tunnelling option, this work represents only 15.7% of overall costs.

The advantages of creating the

Table 3. Comparison of cut-and-cover vs. tunnelling options for a definitive section of line for the Brno, Czechoslovakia, transit system.

	Cut-and-cover (in thousands of crowns)	Tunnelling (in thousands of crowns)
1. Average annual share of investment costs: $J/a_1 + k_f / \cdot k_v$	109.000	102.000
2. Vehicle operating costs N_{pr}	15.400	15.010
3. Additional costs financed from public funds: $a_2 \cdot N_m$	2.320	2.060
4. Fuel and other energy costs: $a_3 \cdot N_{pe}$	1.450	1.750
5. Social effects: N_{si}	10.700	—
	139.270	120.820

tunnels by tunnelling may be documented convincingly by evaluating the impact of the construction work on the existing rail and non-rail transport. This comparison shows clearly that the impact of the cut-and-cover method is more important in economic figures than the impact of the tunnelling option, owing to the longer diversions and, thus, greater consumption of passengers' time with the former method.

Figures for the cut-and-cover method are shown in Table 4. To this total must be added the higher consumption of electricity by 1500 MWh and of oil by 804 000 liters. The impact of higher noise levels, as well as a more deteriorated environment, is more significant with the cut-and-cover option, although it is not yet economically quantified.

The breakdown of the budget for construction of the underground portion of the system is shown in Table 5. At present in Czechoslovakia, when evaluating different options, all planning bodies are obliged to take into account and evaluate the positive or negative impact of each option in the social sphere as well as the economic sphere. In the next phase of our study, it will be necessary to determine a unified means of economic evaluation for each social improvement (e.g., reducing noise, toxic emissions, rate of accidents, etc.) that will be accepted by all decision-making parties and, most importantly, by all opponents of underground public transport.

Gradual extension of methods and range of economic evaluation[4]

Partial results are available of analyses of two factors used in evaluating underground public transport projects — i.e., increased travel speeds and reduced accident rates. In Czechoslovakia, the increased spare time resulting from introduction of an underground urban transportation system is assessed at 15 Kcs per hour. With respect to accident rates, it has been found that in surface public urban transport, an accident occurs every 40 000 km per car, on the average; damage to property and health resulting from such an accident amounts to more than 80 000 Kcs.

Recently, attention has been focused on two other aspects of public transport projects — noise levels and air pollution.

Social consequences of excessive noise levels are reflected in a negative impact on the health of the population. These effects are the subject of long-term health, hygiene, social and psychological studies by research and development centers. Effects and consequences of damaged health in human beings also have an *economic character*. They are reflected in the area of social process in the form of economic losses caused by a loss of productivity and by additional social expenditures and costs associated with higher disease rates in the population.

In simplified form, the average effects of excessive transport noise level can be evaluated as shown in Table 6.

The goal of the basic social effort is a healthy environment. Such a claim does not contradict the fact that the basic outcome of reduced noise level is an economic effect expressed in monetary terms. Depending on the methods and procedures used, this indicator can evaluate the economic efficiency of anti-noise measures — in this specific case, the transfer of the main lines and routes of urban public transport to the underground. Thus, such measures can be appreciated not only in terms of their social and health effects, but also in terms of the economic advantages they represent.

Similarly, studies of air pollution and exhaust are evaluating the following items from the viewpoint of the whole society:

- Life and health of human beings.
- Damage caused to basic building funds.
- Plant and animal production.

Table 7 expresses unit losses from air pollution, based on the results of long-term national studies and analyses.

Taking into account these and other findings, as well as the specific charac-

Table 4. Impact of construction costs for cut-and-cover option for a definitive section of the Brno, Czechoslovakia, transit system.

1.	Operation costs of rail transport	595.000 Kcs
2.	Operation costs of non-rail transport	2 504.000 "
3.	Loss of passengers in rail transport	3 921.000 "
4.	Higher rate of accidents	1 039.000 "
5.	Increased emissions from vehicles	14.000 "
	Total per year	8 074.000 Kcs
	Total for six years of construction	48 444.000 Kcs

Table 5. Structure of the budget for construction of the underground option for a section of the Brno, Czechoslovakia, transit system.

	% Costs for					
Construction	**Structures of the Underground Itself**	**Communications**	**Re-laying of Technical System**	**Trams**	**Adaptation, Demolition**	**Demolitions**
I B	88,2	3,0	3,2	1,2	3,6	0,8
III C	80,3	4,2	2,6	1,1	4,3	7,5
I A	89,7	1,9	4,5	0,8	3,1	
II A	91,6	2,4	2,9	1,7	1,4	
II C	90,9	6,6	2,3	—	0,2	
SH	87,8	7,4	3,8	0,3	0,7	
III B	91,2	4,5	2,3	0,1	1,9	
I C	86,7	4,3	3,8	0,5	4,4	
TOTAL	88,6	3,6	3,4	0,8	2,9	0,7

[4]Sources for this portion of the report include the Central Institute of Transport, "Economic evaluation of negative effects of transportation systems in CSSR"; and Ministries of Interior of the Czech and Slovak Socialist Republics (USH, Assoc. Prof. Cihak), "Methodological instructions to evaluate the efficiency of underground communications investments."

Table 6. Economic effects of excessive noise levels.

Noise level dB (*A*)	Losses per 1 inhabitant-Kcs/year
50	0
55	141
60	282
65	447
70	611
75	775
80	916

Table 7. Unit losses resulting from air pollution.

Type of Pollutant Released into Atmosphere	Amount Lost (Kcs)
1 t of carbon monoxide	300 Kcs
1 t of hydrocarbon compounds	1400 Kcs
1 t of nitrogen compounds	2800 Kcs

ter of city transport, the loss from one city bus kilometer has been calculated as 0.04 Kcs. Given the annual volume of 60 million car km of the Prague buses, the losses from air pollution amount to 2.4 mil. Kcs — a not insignificant sum of money.

The above aspects of social effects of modern, fast and ecology-minded city transport could influence to a considerable extent well-reasoned arguments for or against a given construction, based on economically quantifiable values.

An example of such direct application is the analysis of efficiency and economy of a new sector of the Prague Metro that extends line *B* from the station Sokolovska to the industrial quarter of Vysocany. Thus it could be proven that:

- The economy of time, in comparison with tramway transport in this 4.5-km-long sector, represents 10 minutes per trip. That is, knowing the transport density 10.3 million hours annually, and using 15 Kcs per hour as savings, we obtain economies amounting to 154.5 million Kcs/year.
- The accident rate will be reduced, based on the calculated assumption that 266 accidents per year will not take place, amounting to a saving of 21.4 million Kcs/year.
- The cancelled surface public transport will reduce the noise level by approximately 5 dB; for 10 000 directly affected inhabitants, this amounts to an overall loss reduction of 1.4 million Kcs.
- The reduced bus transport volume of 6.4 million km will reduce the losses associated with air pollution by 0.3 million Kcs.

The quoted common benefit amounts to 178 million Kcs annually; for the financial life of the metro (77 years), the savings amounts to 13.700 million Kcs.

The construction of this underground sector of the metro is estimated to cost 3.700 million Kcs.

It can be concluded that the quantified common benefit will compensate for the underground construction costs of this sector in just 21 years, i.e., after 27% of the underground life has passed. If other effects are added into the analysis, such as reduced operating costs, reduced traction power consumption and reduced labor requirements, the efficiency of such an investment can be clearly proven.

In addition to the quoted social and other effects of the underground construction, there may be many other positive aspects that cannot be easily quantified economically, e.g., impact on the overall appearance of the city, new transport system capacities opened up, individual point constructions (subways, crossroads) — and, last but not least, the improved overall mental and physical state of the passengers who, at the end of the construction, will have a reliable, safe, pleasant, fast, and less stressful means of transport available.

All of these attributes are incorporated in the overall efficiency by applying the methods of value analysis.

Evaluation of the negative effects of transport[5]

This section comprises a brief explanation of the procedures used in evaluating losses to the national economy that result from traffic noise and the exhaust fumes of motor vehicles in the Czechoslovak Socialist Republic. These procedures were elaborated within the framework of a uniform method for evaluating the specific external effects of transport on the road network. In this evaluation, the same sources were used, together with additional statistical data, so that the evaluation could compare the various influences.

1. Method of calculating economic losses due to traffic noise

The method elaborated on herein is based on the results of research that included:

- Investigations of the negative effects of traffic noise on the state of health of the population subjected to various noise levels.
- Investigations and selected statistical examinations of the economic and social results of a deteriorated state of health in the population.

The basic information obtained was used to elaborate procedures permitting the quantification of individual types of socioeconomic losses caused by a deteriorated state of health, to the following extent:

(1) Losses in the form of increased expenditures for health care.

(2) Losses in the sphere of social expenditures.

(3) Losses resulting from reduced productivity related to deterioration in health.

1.1. Economic losses arising from the influence of increased health care expenditure from the State budget. According to the research carried out, the influence of traffic noise takes the form not only of specific diseases directly connected with damage to hearing, but also of non-specific disorders such as neuroses, high blood pressure, coronary thrombosis, gastrointestinal disorders, insomnia, etc. The latter forms of illness in particular resulted in a deterioration in health over the course of illness, length of treatment, etc.

This deterioration in health gives rise to economic losses in the form of increased expenditures for outpatient care, hospital treatment, laboratory tests, possible spa treatment, etc.

1.2. Economic losses arising from an increase in social expenditures resulting from the level of aforementioned diseases. Deterioration in the state of health due to traffic noise also is evidenced through additional costs in the social sphere. Decisive social expenditures in this connection include, in particular, sickness benefits paid to affected persons. In cases where illness passes into permanent inability to work, payment of an invalid pension is envisaged.

1.3. Economic losses resulting from productive inactivity. Deterioration in the state of health due to traffic noise also is

[5]This section of the report is extracted from more extensive basic material carried out by Dozent Dr. M. Cihak, CSc.

seen in the form of losses in the creation of resources resulting from absence from work during illness. Such losses may be temporary or permanent, e.g., in the case of invalidity. These losses are calculated with the use of data on the creation of national income per worker.

All the aforementioned types of losses — i.e., losses due to increased health care expenditures, social expenditures and production losses — constitute general economic losses, expressed by the appropriate indices.

The calculation of individual types of losses is carried out with the use of state-wide statistical data (age and professional structure, average period of treatment and costs of individual medical procedures, average social benefits, etc.), which are updated regularly. The same applies to the calculation of losses due to productive inactivity (data on the creation of the national income, proportion of productive workers, etc.).

1.4. Applicability of the method. This evaluation method is intended to simplify the evaluation of socioeconomic losses due to traffic noise under conditions in which groups of the population in large cities are exposed constantly and for long periods to excessive noise levels. This method can also be used in cases involving smaller agglomerations, in which heavy transit traffic passes through areas that previously were residential zones.

The values calculated express the lower limits of the losses arising from traffic noise, because they do not encompass the losses resulting from the reduction in working efficiency associated with the disruptive effects of noise in large groups of the population showing no evident health disorders but nonetheless suffering from disruption of good mental and emotional humor, ability to concentrate on work, etc.

2. Method of calculating economic losses resulting from motor vehicle emissions

The procedures described herein are based on an analysis of the influence of selected types of motor vehicle emissions on the population, based on various published sources and selected statistical investigations of economic losses arising in this connection. In this regard, further influences were also analyzed, especially influences on buildings and on agricultural production.

The basic information given above was used to develop a methodical procedure by which to express in monetary terms the socioeconomic losses associated with certain quantities of different types of emissions. The procedure comprised the following phases:

(1) Determination of the share of emissions from motor vehicles in the total losses from air pollution.

(2) Calculation of economic losses from emissions on the health of the population.

(3) Calculation of economic losses related to damage to buildings resulting from toxic emissions.

Each of these aspects is discussed below.

2.1. Determination of the share of emissions from motor vehicles in the total losses from air pollution. Due to the complex influence of emissions that arise from various sources, it was necessary to develop a method for determining the share of emissions from motor vehicles in the total air pollution and thus, in the total economic losses.

According to this method, the individual types of emissions are translated into weight quantities of harmful substances indistinguishable in type with the use of so-called relative toxicity factors (i.e., extent of harmfulness of individual substances). The starting point here was, in particular, Czechoslovak and foreign standards defining the highest permissible concentrations of the given type of harmful substance in the atmosphere (mg/m^3 over 24 hours).

2.2. Economic losses from the emissions of motor vehicles, associated with the deterioration of the population's state of health. As in the case of noise, the starting point was the study of the negative effects of emissions on various types of illness. Although it is still very difficult to arrive at a general definition of the influence of vehicle emissions on health, the starting point is the finding that the main danger is the long-term effect of emissions at concentrations which, although they do not cause acute poisoning, nevertheless worsen the course of certain non-specific illnesses and also cause certain specific troubles. Included in these calculations are:

Economic losses due to increased sickness (respiratory diseases, asthmatic difficulties, pulmonary inflammation, pulmonary emphysema, etc.). These economic losses can be seen, on the one hand, in a direct increase in health service expenditures on the above diseases. They include the costs of outpatient care and institutional treatment (including any necessary operations), expenditures on laboratory tests and spa treatments, etc. Included as social expenditures in this category are sickness insurance payments. Economic losses from productive inactivity are deduced analogically to the case of noise, i.e., with regard to the average contributions of studied groups of workers and the period of their absences from work.

Economic losses due to death (especially due to lung cancer). Included in these losses, in particular, are production losses (reduced by the so-called savings due to non-consumption) and social expenditures in the form of pensions to surviving relatives.

Economic losses from emissions resulting in deterioration in the state of health, leading to invalidity. Such losses include production losses from productive inactivity as a result of a person's invalid status, and increased social expenditures resulting from the payment of invalid pensions.

2.3. Economic losses from emissions causing material damage to buildings. The influence of motor vehicle emissions is also reflected negatively in the material sphere. It has an unfavorable effect on the structure of the building portions of basic funds, on metal structures, and on other objects (decorations, statues, etc.). From this phenomenon arises the need for additional expenditures associated with maintenance and repairs or reconstructions of basic funds.

Included in these calculations are losses (or extra expenses) associated with additional maintenance of buildings, repairs to roofs, facades of houses, etc.

The evaluation of the harmful effects of emissions on buildings has taken into account the degree of atmospheric aggressiveness present. Czechoslovak State Norm (CSN) 038240 differentiates among five different degrees of atmospheric aggressiveness, as well as a further possible three degrees of atmospheric humidity. Again, the resultant values are summarized for the expression of total losses.

2.4. Applicability of the method. This method is intended to simplify and approximately evaluate the socioeconomic losses resulting from motor vehicle emissions under conditions similar to those for the case of traffic noise in large cities or agglomerations, with mainly constant and long-term average amounts of exhalations and with increased atmospheric aggressiveness.

The values calculated express the minimum levels of loss arising from vehicle emissions. At present, this method is being expanded for use in evaluating other types of harmful substances, based on the development of knowledge concerning the mechanism of their effect on the external environment. A more precise definition of the method also will include a transition to the general study of emissions; the existing model is based on emissions of traffic fumes only.

Reference

Winfrey R. 1969. *Economic Analysis for Highways.* International Textbook Company.

West Germany: Standardized Evaluation of Traffic Route Investments for Public Commuter Transport[6]

Introduction

In West Germany, within the scope of the Communal Transport Financing Act, the federal government in Bonn and the various state governments (donors of funds) provide major portions of the financing required for traffic route investments of the communities (recipients of funds). As a consequence, it is essential that Bonn and the states have an evaluation method at their disposal to aid in setting up an objective yardstick for allocating these funds to rival projects.

Since 1982, such an evaluation method has been available in West Germany. It comprises a number of preliminary stages and permits the advantages of traffic route investments for public commuter transport to be compiled as objectively as possible. This task is achieved by obtaining the data required to assess an investment from the communities by means of a standardized method. The data is also appraised by the donors of funds via a standardized method. The flowchart in Fig. 2 shows the process of assessing and financing a traffic route investment in West Germany.

In this way, it is possible to compare projected investments with one another and thus arrive at a pertinent decision in favor of or opposed to a particular investment, or at least to decide upon priorities.

Determination and attainment of goals

In order to appraise the effects of an investment measure properly, it is essential to determine the goals to be attained. These goals can be categorized in three target groups:

(1) Users of means of transport.
(2) Operators of means of transport.
(3) General public.

For all three groups, the chief goal is optimization of advantages resulting from the investment measures.

In order to determine as many as possible of the effects of an investment measure that is intended to benefit these three groups, a number of sub-goals must be defined. These sub-goals are linked to indicators that permit a quantitative assessment of the degree of goal attainment. For this purpose, the forecasted indicator data for the case in question *without* investment are compared with the data for the case *with* the planned investment. Figure 3 provides insight into the sub-goals and the relevant indicators.

[6]Prepared by: F. Blennemann, STUVA, Cologne.

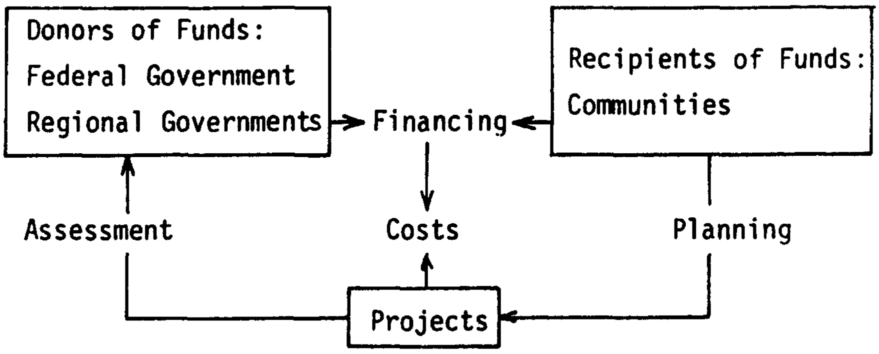


Figure 2. Assessment and financing of a traffic route investment in West Germany.

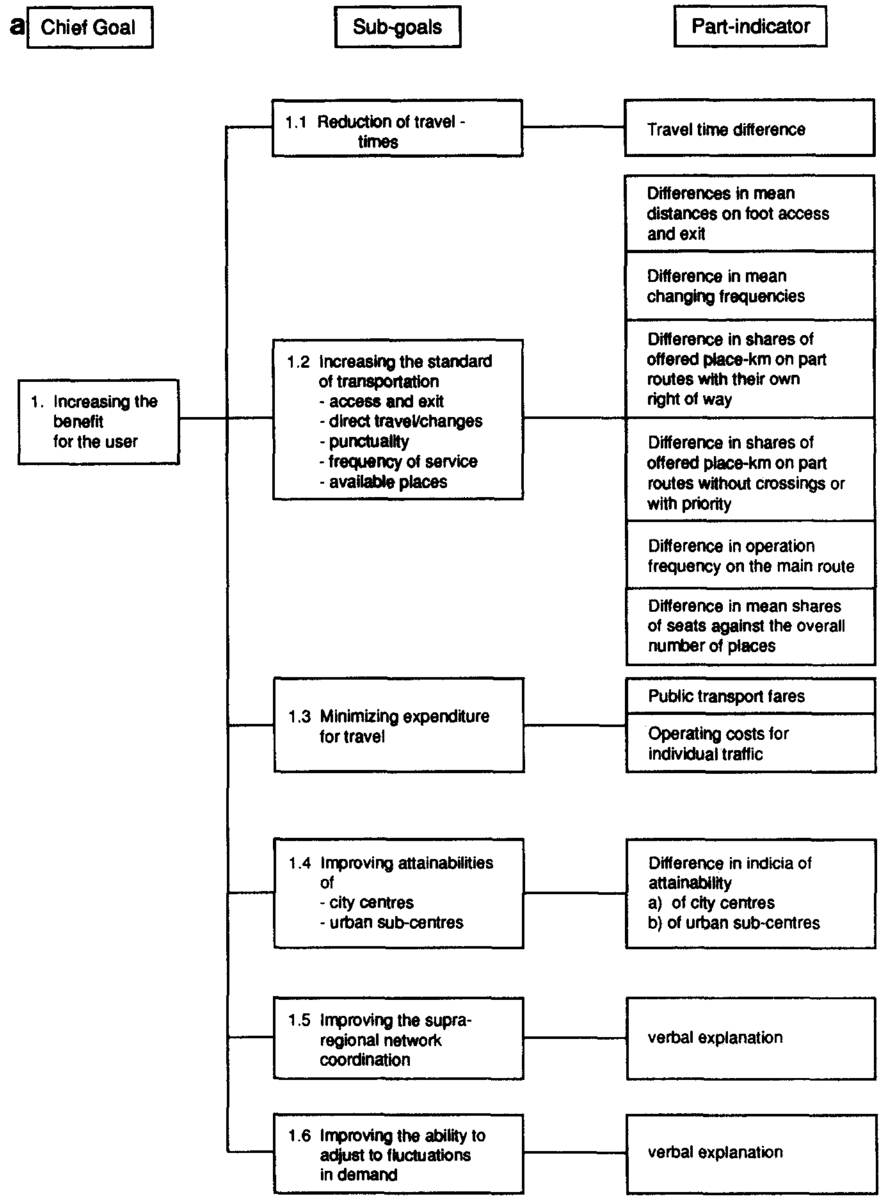
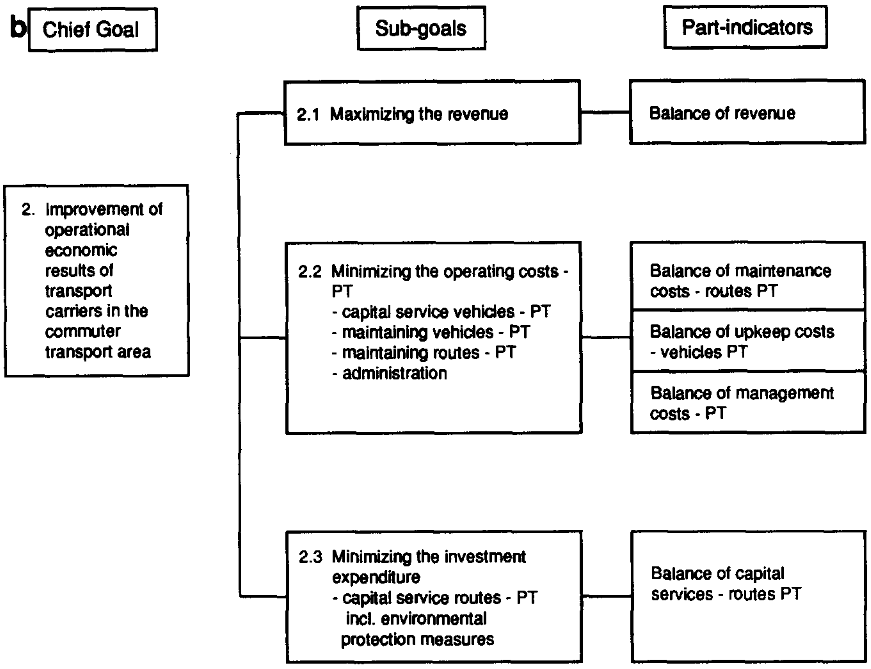
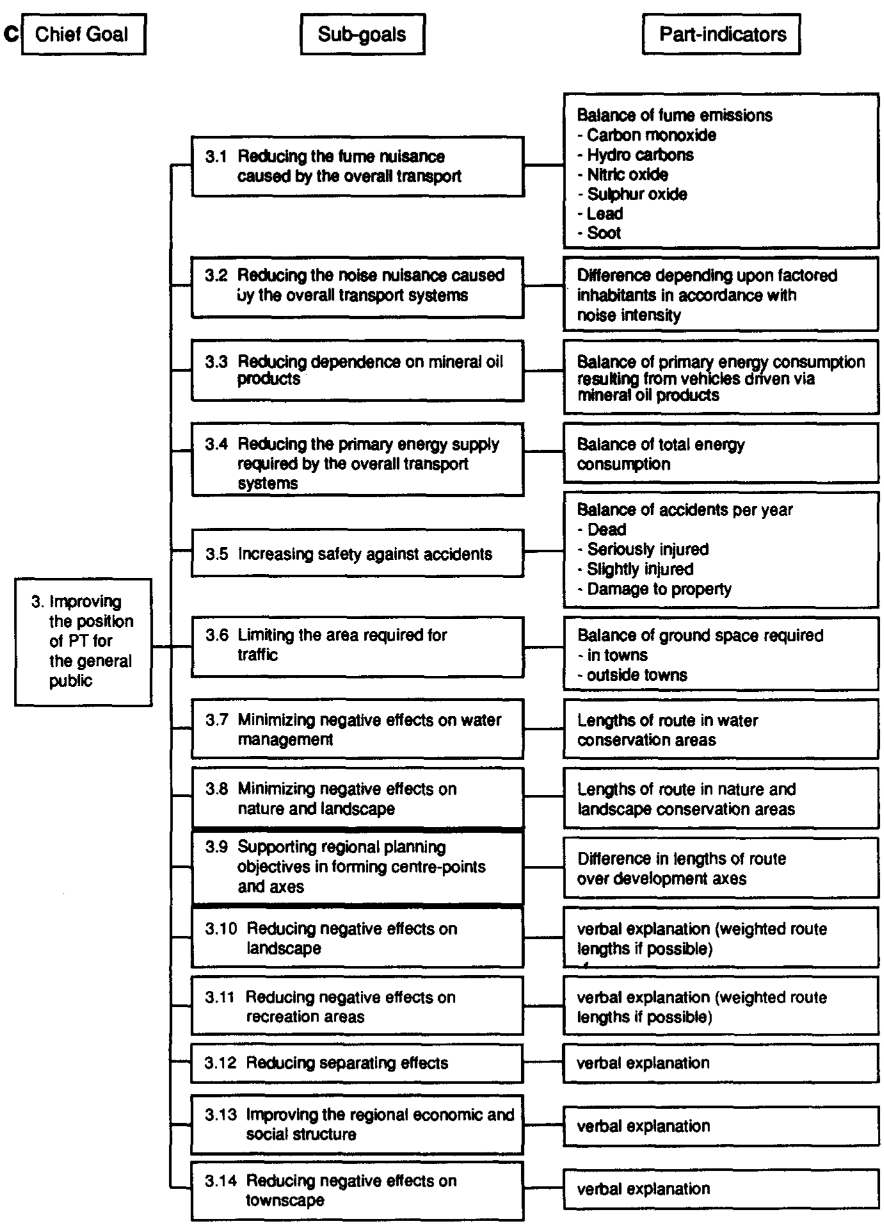


Figure 3. System of goals for transport assessment. 3a: Sub-goals and partial indicators for Chief Goal 1: Increasing the benefit for the user. 3b: Sub-goals and partial indicators for Chief Goal 2: Improving the operational economic result for the carrier(s) in the commuter transport area. 3c: Sub-goals and partial indicators for Chief Goal 3: Improving the position of public transport for the general public.





Data collection

The data material that is customarily available receives major consideration in selecting the sub-goals and the corresponding partial indicators. It should be ensured that the amount of work involved in arriving at a standardized evaluation through the transport companies/communities be kept to a reasonable level. Therefore, the partial indicators selected are those for which data collection is possible on the basis of already existing data, or for which the required data can be obtained in a relatively straightforward manner (simplified method). The operating data of the transport company concerned serve as the main source for these data, together with traffic survey data based, for example, on cross-sectional polls and planning concepts of the public transport network in question for a "case with" and "case without" investment.

Data that are difficult to compile (e.g., modal split) are included in the method only if a maximum reduction in traveling time of more than five minutes in the "case with" is arrived at in comparison with the "case without" investment (extensive method), as a result of the planned investment measure. The introduction to the method identifies binding starting points for data collection in order to ensure that the greatest possible standardization is attained.

Processing the data

1. General considerations

The processing of the data necessary for carrying out the standardized evaluation method comprises three steps:

(1) Setting up an investment concept.

(2) Detail conception, as well as data collection with regard to transport supply and traffic demand for the "case with" and "case without" investment.

(3) Formulation and discussion of indicators.

Between these individual steps are coordination phases between the donors and recipients of funds in order to prevent a unilateral interpretation of standards of judgment (see Fig. 4). The nature and extent of the detail to be provided by the recipient of funds are set forth precisely in the introduction to the method, and these details are entered on special forms. All working steps for the simplified method (which is considered adequate in the case of a traveling time reduction of less than five minutes) can be carried out by hand.

2. Setting up an investment concept

The applicant is, first of all, charged with defining the limits of the project. The definition of the investment pro-

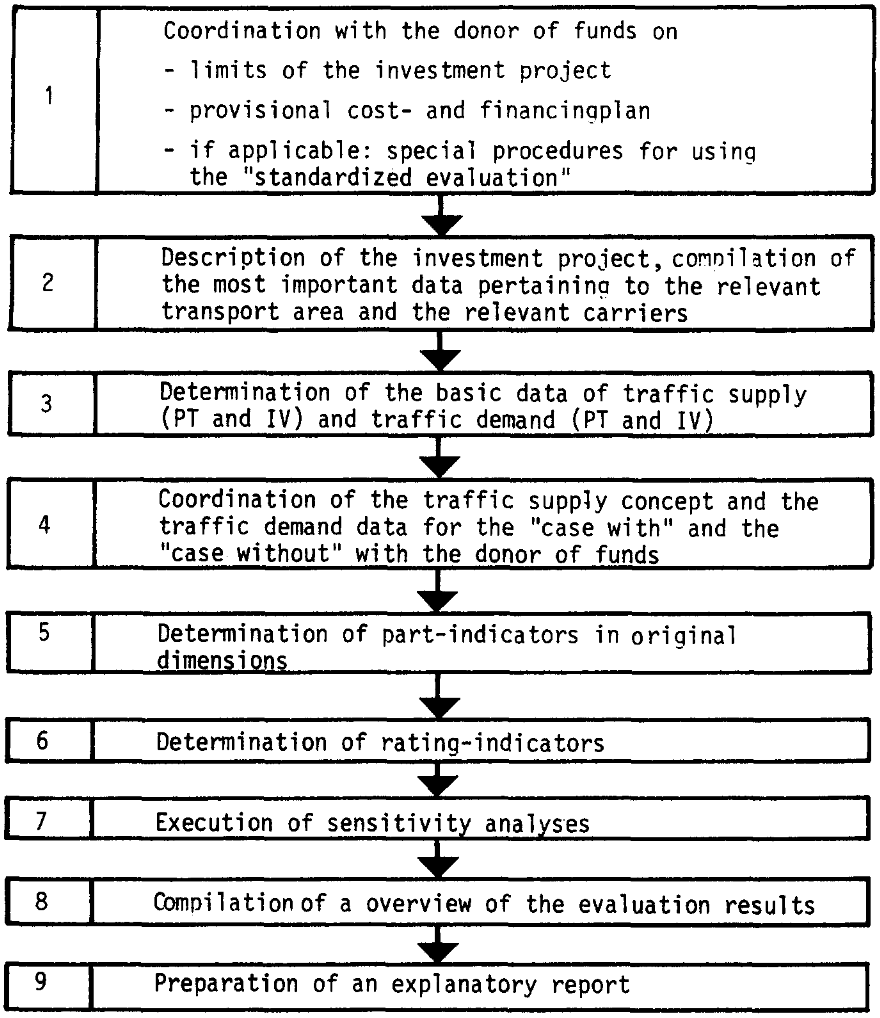


Figure 4. Phases of the standardized evaluation. PT = Public Transport. IV = car traffic.

ject has considerable influence on its subsequent assessment. Therefore, it is advisable to incorporate standardized rules at this stage in order to restrict the standards of judgment on the part of the applicant as far as possible.

However, this process soon may become mired in difficulties resulting from the major regional differences that are encountered. As a result, the introduction to the method contains only a few guidelines, which must be taken into consideration when defining the investment project. On the other hand, the method foresees a compromise between the recipient of funds (applicant) and the donor of funds with respect to the definition, as well as a revision, should this turn out to be necessary.

The provisional cost and financing plan, as well as the decision to use the simple or the extensive assessment method, also must be coordinated in conjunction with the donor of funds. The decision about which method should be used must be based on a rough estimate of the anticipated difference in traveling time between the "case with" and "case without" investment.

3. Detail conception and data collection pertaining to transport supply and traffic demand

At this stage of the method, the recipient of funds provides information pertaining to the affected routes, as well as the projected operating performance for the "case with" and "without". Parameters for the transport supply are worked out from this information in accordance with predetermined formulae.

A distinction is made between the simplified and the extensive method in compiling the data relating to traffic demand. The extensive method must be applied if the anticipated reduction in traveling time amounts to more than five minutes. Surveys carried out, for example, at the time when the application is made serve as the basis for the simplified method. The introduction to the method includes formulae by means of which the empirically determined actual values for the "case with" and "case without" investment can be calculated.

The changes in demand resulting from the investment measure are also included in the extensive method. Although such quantification calls for more comprehensive traffic investigations than does the simplified method, records of these investigations are available for most transport regions in West Germany.

4. Formulation and discussion of indicators

Quantification of the partial indicators is carried out in the next working step (the original measurable variable is retained). The compilation of all data as original measurable variables makes the method more transparent and easier to follow for the donor of funds. The forms for this stage, as well as the introduction to the method, include detailed instructions for the calculation of such items as power consumption and annoyance caused by excessive noise or fumes. Tables — e.g., for assessing the costs of individual parts of plants — are also included.

Effects of the project that cannot be quantified are presented verbally at the end of the application. After the data collection has been completed, the applicant and donor of funds can jointly carry out variations in individual data in order to determine just how sensitive the model is to alterations in the marginal conditions that have been accepted as fixed conditions in the interest of standardization.

Evaluation

The partial indicators, which are available as original measurable variables, must now be assessed. In this connection, the partial indicators must be divided into four groups, in accordance with their degree of accuracy, in order that they can be expressed in financial terms, thereby forming rating indicators (see Fig. 5 and Table 8). The four categories of indicators are:

A. Operational economic indicator. All partial indicators can be measured cardinally and are available in the

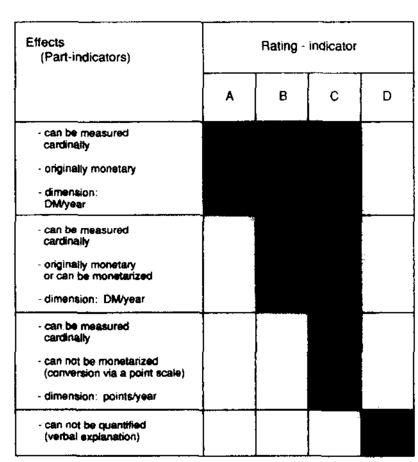


Figure 5. General formation of rating indicators.

Table 8. Compilation of partial indicators and their relationship to rating indicators.

Partial Indicators	Dimension of the Original Measurable Variable	Relevant for Indicator* (A)	(B)	(C)	(D)
Balance of Public Transport (*PT*) revenue	TDM/year	*A*			
Balance of capital service — routes *PT*	TDM/year	*A*	*B*	*C*	
Balance of maintenance costs — routes *PT*	TDM/year	*A*	*B*	*C*	
Balance of upkeep costs for vehicles — *PT*	TDM/year	*A*	*B*	*C*	
Balance of management costs — *PT*	TDM/year	*A*	*B*	*C*	
Balance of operating costs — car traffic	TDM/year		*B*	*C*	
PT — difference in travelling time	h/year		*B*	*C*	
Balance of fume emission					
— Carbon monoxide	t/year			*C*	
— Carbon hydroxide	t/year			*C*	
— Nitrogen monoxide	t/year			*C*	
— Sulphur oxide	t/year			*C*	
— Lead	t/year			*C*	
— Soot	t/year			*C*	
Annoyance through noise (difference in factored inhabitants based on noise intensity)	inhabitant factors		*B*	*C*	
Balance of accidents per year					
— Dead	Pers/year		*B*	*C*	
— Seriously injured	Pers/year		*B*	*C*	
— Slightly injured	Pers/year		*B*	*C*	
— Damage to property	TDM/year		*B*	*C*	
Balance of primary energy consumption resulting from vehicles driven via mineral oil products	MWh/year			*C*	
Balance of total energy consumption	MWh/year			*C*	
Difference in indicia of attainabilities					
— Of city centres	1000 inhabitants · min			*C*	
— Of urban sub-centres	1000 inhabitants · min			*C*	
Balance of ground space required					
— In towns	ha			*C*	
— Outside towns	ha			*C*	
Partial indicators to assess transportation comfort					
— Difference in mean distance on foot	km · trips/day			*C*	
— Difference in mean transfer frequencies	transfers/day			*C*	
— Difference in the offered place - km on route sections with their own right of way	1000 trips/day			*C*	
— Difference in the offered place - km on route sections without crossings or with priority	1000 trips/day			*C*	
— Difference in the operating frequencies	1000 trains/day · trips/day			*C*	
— Difference in mean shares of seats against overall number of places	1000 trips/day			*C*	
Difference in lengths of route over development axes	km			*C*	
Difference in lengths of route in water conservation areas	km			*C*	
Difference in lengths of route in nature and landscape conservation areas	km			*C*	
Ability to adjust to:					
— Network requirements	presented verbally				*D*
— Fluctuations in demand	presented verbally				*D*
Effects on the landscape	presented verbally			(*C*)	*D*
Effects on recreational areas	presented verbally			(*C*)	*D*
Separation effects	presented verbally			(*C*)	*D*
Effects on regional economic and social structure	presented verbally				*D*
Effects on the cityscape	presented verbally				*D*

**A* = operational economic indicator. *B* = general economic indicator (cost–benefit indicator). *C* = cost–benefit analytical indicator. *D* = quality indicator.

form of DM/year. This indicator is formulated both with and without taking into account the capital cost of the public transport routes, because the transport operator and the investor are different authorities.

B. General economic indicator (cost–benefit indicator). All partial indicators are either available originally in financial terms, or can be monetarized by means of secured calculations. This indicator, which is expressed in terms of DM/year, comprises all partial indicators of A except the public transport revenues (these balance the fares paid by the passengers). Additionally, monetarized values for travel times, noise annoyance and safety aspects are taken into account (see Table 9).

C. Cost–benefit analytical indicator. The partial indicators of this nature can be measured in cardinal terms; however, their expression in financial terms is not sufficiently ensured. By weighting the importance of the different partial indicators and converting them into a point scale, more aspects can be taken into account, e.g., comfort of travel, use of energy, effects on the landscape, and ecological effects (see Table 10).

D. Quality indicator. This category includes indicators that can only be measured by ordinal means — i.e., by verbal description.

As a result of the total evaluation, a set of figures for the rating indicators A, B and C is available (see Table 11), complemented by the discussion of the benefits identified by rating indicator D.

The method is used for different tasks, e.g.:

- The decision on the absolute cost–benefit ratio of a project.
- A comparison of different alternatives for a particular project.
- Ranking of different independent projects.

Figure 6 shows the cost–benefit ratios for several public transport projects in West Germany. It can be seen that in most cases, indicator B summarizes the main benefits.

Table 9. Monetary conversion factors for travel time, noise annoyance and accidents.

	Original Dimension	Money Value
Difference in travel time public transport	h/year	15,—DM/h (1985)
Balance for noise annoyance	no of inhabitants	65,—DM/inh.
Balance of accidents		
— dead	pers./year	1.160.000,—DM/pers.
— seriously injured	pers./year	55.000,—DM/pers.
— slightly injured	pers./year	4.200,—DM/pers.

Table 10. Weighting factors for effects of investment in public transport projects (examples only).

	Original Dimension	Weight[1]
Balance of total costs for public transport without capital costs for the track	TDM/year	– 0,0371
Difference in travel time public transport	h/year	– 0,0006
Balance of operating costs private transport	TDM/year	– 0,0371
Balance of fumes		
. carbon monoxide	t/year	– 0,0065
. carbon hydroxide	t/year	– 0,6746
. nitrogen monoxide	t/year	– 0,3260
. sulphur oxide	t/year	– 0,4782
. lead	t/year	– 0,3712
. soot	t/year	– 0,1856
Balance of noise annoyance	no. of inhabitants	– 0,0024
Balance of accidents		
. dead	pers./year	– 43,0585
. seriously injured	pers./year	– 2,0416
. slightly injured	pers./year	– 0,1559
. damage to property	TDM/year	– 0,0371
Capital cost for the public transport infrastructure	TDM/year	0,0371

[1]points per unit, 1985

Table 11. Rating indicator for the characterization of costs and benefits for urban public transport projects.

A. OPERATIONAL ECONOMIC INDICATOR	
a) *Without* capital costs for the infrastructure taking into account	
Difference	...... TDM/year
b) *With* capital costs for the infrastructure taking into account	
Difference	...... TDM/year
Ratio	......
B. COST–BENEFIT INDICATOR	
a) Difference of benefits and costs	...... TDM/year
b) Ratio of benefits and costs	......
C. BENEFIT VALUE ANALYTICAL INDICATOR	...... Points/year

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Heimerl, G. Standardisierte Bewertung von Verkehrswegeinvestitionen des öffentlichen Personennahverkehrs; Erstellt im Auftrage des Bundesministers für Verkehr, Bonn; Arbeitsgemeinschaft Prof. Dr.-Ing. G. Heimerl, Verkehrswissenschaftliches Institut an der Universität Stuttgart/Intraplan Consult Gmbh., München.

Heimerl, G. 1987. Der ÖPNV als Gesellschaftliche Aufgabe – Beurteilung seiner Nutzen und Kosten. *Jahrbuch des Eisenbahnwesens '87*, Folge **38**, S. 40–44; Darmstadt: Hestra-Verlag.

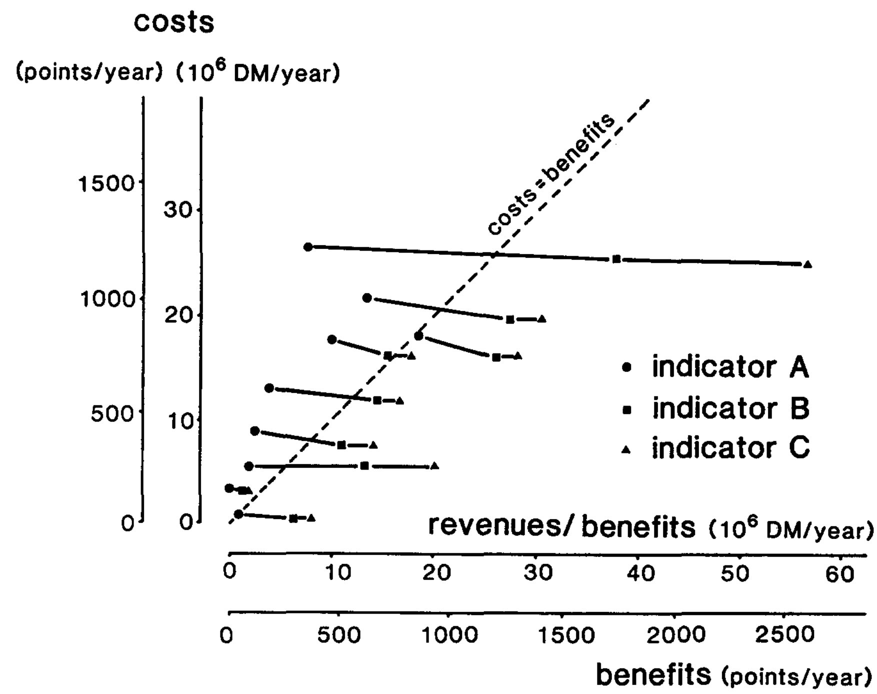

Figure 6. Examples of the standardized evaluation of costs and benefits for public transport projects in West Germany (Heimerl 1987).

France

The French approach to project appraisal

Following World War II, France underwent a period of some twenty years during which the rapid transit networks remained virtually unchanged.

Only during the 1970s were new projects implemented in the Greater Paris area and in the French provinces, this time on a large scale and in the form of lines running mostly underground.

The last 15 years have witnessed a complete turnaround in the matter of urban public transportation in France. Traffic on the public transit systems had dropped steadily since the 1950s, with a corresponding increase in financial difficulties. In the early 1970s, the public authorities adopted a new policy with regard to public transportation projects. This policy gave priority to public transportation and called for devoting the required amounts of resources for that purpose.

As a result, construction of a new network of mass rapid-transit systems was launched in the cities of Lyons (1,1 million inhabitants), Marseilles (0,9 million inhabitants) and Lille (1 million inhabitants). In the Greater Paris region (10 million inhabitants), existing metro subway lines were extended into the near suburbs and construction began on a genuine broad-gauge Regional Rapid Transit System (RER), serving the near and outer suburbs while crossing Paris from end to end. Meanwhile, a number of new extensions and services were introduced on the commuter railway system (see Table 12).

In France, the methods of appraising such projects, which had remained rudimentary until the war, did not reflect the changes that took place in English-speaking countries, where the method now known as cost–benefit analysis was developed.

Furthermore, in the Paris area the state is an active party, not only in bearing part of the capital costs but also in bearing a portion of the operating costs of the transit system. This situation does not apply to the French provinces outside Paris. In France, then, because of the special nature of the Paris area, two methods are used for appraising public transportation projects — one for the Paris area, and another for the provinces.

In the Greater Paris area, a codified cost–benefit type of approach is used. The feasibility studies for projects are conducted by the Transit Authorities (RATP[7] and SNCF[8], and then submitted to a joint state and Ile-de-France regional committee known as the Paris Transport Syndicate (STP[9]);

In contrast, an informal, multi-criteria type approach is used in the French provinces. In this case, the various studies for transit projects are submitted directly by the local political authorities to the state.

[7]Régie Autonome des Transports Parisiens.

[8]Société Nationale des Chemins de Fer Français.

[9]Syndicat des Transports Parisiens.

Each of these approaches is discussed below.

1. The Paris region approach

In the Paris region, the two-fold project appraisal involves:

(1) A strictly financial evaluation (see Table 13).

(2) A cost–benefit type of socioeconomic analysis (see Table 14).

The socioeconomic analysis lists the advantages and costs (or drawbacks) to the main parties involved in constructing the project. It takes into consideration the impacts of the project — insofar as these are measurable in the current state-of-the-art — from the standpoints of the users, transit authorities, state and local communities.

In this way, the socioeconomic evaluation includes both purely financial items that are computed in the financial balance sheet for the operation; and certain items that are not strictly financial, yet are evaluated in financial terms through specific parameters (e.g., value of time, value of human life).

After compensating for the economic agents, an annual balance sheet for the community is completed. This balance sheet covers the following items (see Table 14):

- Time saved by patrons.
- Savings to car users.
- Savings in parking expenses.
- Savings in improved safety.
- Savings in highway decongestion.
- Savings in highway maintenance.
- Variation in state tax revenues for gas.
- Additional operating costs of the public transportation system.

It is then possible to evaluate the profitability of the investment for the community by comparing the annual balance sheet with the capital cost of the project in the same manner practiced in the private sector.

In this way:

- The immediate profitability of the project for the initial year of operation is defined as the ratio of benefits to the community to the total amount of the outlay (infrastructures and rolling stock).
- The discounted benefit of the project is defined as the discounted sum of the annual expenses (outlay) and revenues (balance from the community balance sheet).
- The internal rate of return of the project is defined as the rate that brings the discounted benefit to a zero value.

Table 15 shows some typical figures for RER and metro projects completed in Paris. One interesting feature that must be noted is the great discrepancy in the results obtained. Among other things, this discrepancy shows

Table 12. Highlights of rapid transit projects constructed in France, 1978-87.

System	Opening date	Length (km)	Number of stations	Capital cost (millions of 1987 US $)
Lyons Métro				
Section 1:				
• Line A				
• Line B (to "Part Dieu")	1978	12	17	624
• Line C (to "Croix Rousse")				
Section 2:				
• Line B (to "Jean Macé")	1981	2.4	3	152
Marseilles Métro				
• Line 1	1977-1978	9	12	571
• Line 2	1984-1987	9	10	516
Lille Métro: line 1	1983-1984	13.3	18	614
Paris Métro extensions				
• Line 13 to "St-Denis"	1976	2.4	2	119
• Line 13 to "Châtillon"	1976	2.3	3	76
• Line 7 to "Aubervilliers"	1979	2.3	2	118
• Line 13 bis to "Asnières-Gennevilliers"	1980	3.2	2	165
• Line 10	1980-1981	2.4	2	125
Subtotal	1976-1981	12.6	11	603
Regional Rapid Transit System (RER)				
• Central sections	1977	8.8	2	911
• Marne-la-Vallée branch	1977	7.9	4	261
Computer railway system				
• New line to Cergy-Pontoise	1979	23	2 new stations 4 existing renewed stations	237
• Invalides-Orsay link	1979	0.85	2 existing renewed stations	247

1 US $ = 6 FF.

that, over and above the inevitable errors in forecasting, the decisions about whether or not to implement a particular facility are, fortunately, not made solely on the basis of socioeconomic profitability criteria.

Last, it must be stressed that the socioeconomic analysis does not analyze the environmental impact of the project, which is dealt with in a specific document (the "impact analysis") and, in a subsequent administrative phase, a public inquiry.

2. The approach of the provincial French cities

Owing to their entirely different social and political contexts, the other French cities have not followed the somewhat technocratic approach of the Paris area in their negotiations with the state as a potential donor of funds. Rather, their evaluations have always involved multiple and, generally speaking, disaggregated criteria. This means that, except for the quantified items required for dimensioning the projects and for estimating the capital outlay, the documents are usually submitted in the form of disaggregated inventories of criteria aimed at the specific decision-making levels concerned.

Table 16 illustrates this process for the city of Lyons, listing the criteria considered in the feasibility studies for the first and the second phases of the construction of its rapid transit system.

An operating budget forecast can be prepared from the items "Additional rapid transit operating costs", "Variation in operating costs of bus system", and "Anticipated new traffic revenues". Except for the operating budget forecast, the quality of service has been gauged by an assessment of the criteria listed in Table 17.

3. Current trends in appraisal methods

France has never been the preferred ground for cost–benefit types of appraisal methods. Indeed, where these methods are used (as in the case of the Greater Paris area), they appeal more to "tutelary" values set forth by the Public Bodies regardless of any behavioral reference (such as the British "willing to pay") with regard to parameters used in costing.

Moreover, the new framework laid by the 1982 law on decentralization and the guideline law pertaining to domestic transportation favors a far more macroeconomic approach involving disaggregated, multi-criteria analyses extended to include impacts related to social, energy, employment and international trade factors. However, the legislation does not specify in detail any method to be used; and this lack of direction continues to give rise locally to all sorts of interpretations. RATP, for example, has embarked on the development of a non-weighted multi-criteria method known as ELECTRA.

All in all, it is quite clear that, whatever the degree of sophistication of the methods to be used, no method can account for all of the long-term impacts of rapid transit projects.

In such a context, it can be said that the existing "French way" consists, in the long run, of giving the

Table 13. Paris Métro-Line 1 extension to "La Défense": Expected operating balance sheet variation for RATP in 1987, 1992 and 1997 (MFF–1981 value). Based on the June 1981 feasibility study for the project.

	1987	1992	1997
Revenues (subsidies excluded)			
• Direct revenues	+ 6.3	+ 7.1	+ 7.9
• Compensation for reduced fares	+ 4.2	+ 4.7	+ 5.3
Overall gross revenues	+10.5	+11.8	+13.2
• Taxes	– 0.8	– 0.9	– 1.0
NET REVENUES	+ 9.7	+10.9	+12.2
Operating costs			
• Running of trains	– 1.6	– 1.8	– 2.1
• Station services	– 3.0	– 3.1	– 3.3
• Energy	– 1.0	– 0.8	– 0.5
• Maintenance of the rolling-stock	– 0.8	– 0.8	– 0.8
• Maintenance of the infrastructures	– 1.8	– 1.8	– 1.8
Overall operating costs	– 8.2	– 8.3	– 8.5
OPERATING BALANCE (VAT excluded)	+1.5	+2.6	+3.7
Depreciation charges			
• Infrastructures	– 3.4	– 2.8	– 1.9
• Rolling stock	– 6.1	– 4.1	– 2.7
Total	– 9.5	– 6.9	– 4.6
Interest and bank charges			
• Infrastructures	– 9.6	– 7.3	– 4.4
• Rolling stock	– 9.3	– 5.5	– 2.6
Total	–18.9	–12.8	– 7.0
Overall investment expenses	–28.4	–19.7	–11.6
FINAL RESULT	–26.9	–17.1	– 7.9
Variation of subsidies (VAT excluded)	+26.9	+17.1	+7.9
Variation of subsidies (VAT included)	+28.8	+18.3	+8.5

Table 14. Typical cost–benefit analysis for the extension of Paris Métro-Line 7 northward. (Source: April 1975 feasibility study.)

Overall Balance Sheet for the Community

Below is a breakdown of the benefits accruing to the community in 1980:

Time saved by patrons	:	+ MF 57
Car users' savings	:	+ MF 5
Savings in parking expenses	:	+ MF 9.5
Savings on improved safety	:	+ MF 0.6
Savings in highway decongestion	:	+ MF 11.7
Savings in highway maintenance	:	+ MF 0.8
Variation in gas State tax	:	– MF 1.5
Additional operating costs of the public transit system	:	– MF 10.1
Altogether		+ MF 73

From the above, one can derive the immediate profitability of the project, which is the ratio of benefits for the community in 1980, the first year following start-up, to the total amount of outlay, namely 73/310 = 23.5%.

In addition, based on estimates for 1980 and 1985, the discounted benefit for the community has been evaluated, along with its fluctuations in keeping with the rate of discount, from which is derived the internal rate of return.

The discounted benefit amounts to MF 200 (in 1974 francs) for a discount rate of 10%, while the internal rate of return amounts to 16.5%.

last word to political decision-makers, who must overcome the non-objective and non-technical issues relating to mass rapid transit projects. Once a decision is made, the only concern is how to make the best of the so-called "external" power of such infrastructures.

Specific considerations in appraising underground public transportation projects

When comparing two equally possible projects — one aboveground and the other underground — that offer the same quality of service for passengers, the cost–benefit analysis as currently applied leads, in most cases, to a recommendation of the aboveground infrastructure. The reason is that, for identical evaluated advantages, the aboveground line requires lower capital costs and therefore appears to yield greater social profitability.

However, as noted above, the common tendency is to place metro lines in the subsurface. One possible factor in doing so is the opposition of certain pressure groups to aboveground lines. These comments are sufficient to demonstrate not that the pro-subsurface decisions are "technically inconsistent", but merely that designers and their techniques cannot always encompass and evaluate

Table 15. Internal rate of return for projects completed in Paris (RER and Métro).

Métro/RER project	Internal rate of return	Discounted benefit at 10% (MFF — 1982 value)
Line 7 to "Fort d'Aubervilliers"	18.2%	850
Line 13 to "Saint-Denis Basilique"	9.2%	- 74
Line 13 to "Châtillon-Montrouge"	15.5%	354
Line 13 to "Asnières-Gennevilliers"	13.4%	557
Line 10 to "Boulogne"	6.0%	- 156
RER — Central sections		
— Marne-la-Vallée branch	14.5%	5220

Table 16. Criteria considered in feasibility studies for the first and second phases of construction of the Lyons rapid transit system.

Criterion considered	Phase 1	Phase 2
Capital cost	X	X
Expected State investment subsidies	X	X
Local share for capital investment	X	X
Additional rapid transit operating costs	X	
Variation in operating costs of bus system		X
Anticipated new traffic revenues	X	X

Table 17. Criteria considered in assessing the quality of service for the Lyons rapid transit system.

Criterion	Phase 1	Phase 2
Average travel time within urban area		X
"Induced" traffic	X	X
Average generalized time savings within urban area for mass transit (MT) passengers	X	X
Average real time savings for MT passengers	X	X
Overall generalized time savings for MT passengers		X
Annual quantified time savings	X	X
Accessibility of the population to jobs		X
Average number of transit lines ridden by a patron		X
Percentage of patrons whose travel time has decreased (or increased) by at least 10%		X
Miscellaneous indicators characterizing the effects on long-distance trips		X
Immediate accessibility to the population and jobs, i.e. number of opportunities within 500 m from stations	X	X
Space distribution of average travel time saved		X
Rate of immediate profitability of outlay, calculated on basis of annual time saved by MT and highway users, variation in operating costs, and overall cost of outlay		X
Quality of comfort		X
Impact on quality of life (balance of number of trees before and after the project, etc.)		X

objectively all of the factors involved in making decisions about transit projects.

The above remarks underscore the fact that existing cost–benefit methods do not express the reality of urban transportation planning. Apart from the cases that it would be unthinkable to imagine as overground infrastructures (such as an RER within downtown), the compromises between the parties involved in favor of underground infrastructures clearly demonstrate a complementary value of the underground alternative that is not, at present, taken into account. Some of the less apparent values associated with the underground option are discussed below in terms of the decision-making process.

1. Difficulty in comparing projects offering "same quality of service"

Before continuing with the analysis of factors that constitute the basis for choosing between aboveground and underground projects, we must determine whether the aboveground alternative, as it is set forth, is a real one. In fact, most metro systems, including "Regional Metros" in dense urban areas, are underground. However, in France there are several exceptions to this general rule:

(1) During the last century, most urban railway lines (which often preceded the urbanization of suburban areas) were built aboveground, either at grade or on elevated structures.

(2) At the beginning of the century, important sections of Paris metro lines were built on elevated structures.

(3) Recent suburban extensions located in less dense urban areas have occasionally been built aboveground, at grade or on elevated structures. Two notable examples in the Paris area must be pointed out: the extension of metro line 8 to the suburban town of Creteil, which has been built right-of-way at grade in conjunction with an expressway, and the extension on elevated structures of the Regional Express Metro to the new town of Marne-la-Vallée, east of the metropolis, which, however, was built in a fairly dense zone of private housing.

Aside from these examples, aboveground realizations are now relatively rare. In some cases, it happens that existing infrastructures scheduled to be set in operation again become covered; this is the case for the Innerail Ring in Paris, for a section included in the project of a link between Invalides station and Vallée de Montmorency. It happens, too, that extensions of the main railway lines and lines of the Regional Metro in new urbanized areas are built in open-cut or cut-and-cover.

Quite often, also, some sections of metro line extensions that appear to be entirely suitable, in technical terms, for construction at grade or on elevated structures — as, for instance, river crossings and free areas along existing canals — become the subjects of legal and political disputes that obviously can jeopardize their realization.

Naturally, the exclusive right-of-way characteristic of metro and railway lines (as opposed to bus, light rail or tram lines) requires the total isolation of the infrastructure from every other traffic mode. In a dense environment, such isolation can be ensured only by using elevated structures or by building underground, except in a limited number of specific cases. Here, the difference in the investment cost is rarely sufficient to justify elevated construction, which would involve massive destruction and a high level of noise nuisance in the densest areas, and which would be completely incompatible with the organization of traffic interchanges that construction of a normal transit system requires.

For the dense downtown areas of large cities, consideration of the aboveground alternative takes place at the more general level of transport policy. In opposition to systems based on public transport lines running on a right-of-way (i.e., underground systems, in most cases) are systems based mostly on private transport or on public transport running on reserved lanes in the streets or in general traffic — the latter either by deliberate choice or from a lack of financial resources.

Finally, it appears that the effective scope of choice between aboveground and underground modes is very narrow. It is usually possible to consider the alternatives only in cases of suburban extensions of existing networks — especially in lightly dense areas and newly urbanized areas. The alternatives also may be considered in cases involving extensions through the densest areas; for specific sections, such as river crossings or crossings of free urban areas; and for sections that can be designed within existing aboveground railway right-of-way territory.

Thus, it should be kept in mind that the "aboveground versus underground problem" is relevant in only a relatively small number of cases in existing networks, although it applies to an increasing number of projects involving newly urbanized areas.

2. Comparing underground and aboveground infrastructures

In considering comparisons of underground with aboveground infrastructures it must be remembered, first, that such comparisons must be based on the assumption that both options offer the same quality of service; and, second, that the system under consideration provides a genuine aboveground/underground alternative in which the benefits derived from the cost–benefit analysis are identical with respect to quality of service offered, anticipated traffic and traffic diverted from other modes.

On this basis, a list may be drawn up of the differential factors characterizing the two modes of infrastructure. Some factors are fully included in the conventional cost–benefit appraisal; others, less so; and some, not at all.

The differential factors listed in the section, "Examples of Benefits: French Case Studies", below, may be grouped into three major categories: (1) the capital cost of the infrastructures; (2) the quality of the project; and (3) all of the environmental effects, after considering the measures taken to ameliorate or eliminate negative impacts. Each of these factors is discussed in detail below.

2.1. Capital costs of infrastructures. Undoubtedly the most visible item, the capital costs of the infrastructure has been the subject of a specific research study carried out by AFTES (Association Française des Travaux en Souterrain). In general, in calculating capital costs, the result is almost always unfavorable to the underground. It is characterized by an imprecision that grows in accordance with the costs. Such an imprecision should be given more consideration in the assessment of the project.

In certain specific cases, the aboveground/underground differential may be so important that it results in a rejection of the underground solution because its rate of return is lower than is required by official regulations. The alternative choice then shifts to "do nothing" or "build an aboveground structure". This may prove to be a false choice unless the social and political feasibility of the aboveground project is established.

2.2. Assessing the "quality" of the project. This item includes all of the things that may make the system attractive to potential passengers: access time, interchange time with other transit modes, physical and human comfort and convenience when travelling.

Although we can obtain good information concerning access and interchange time, thanks to methods for taking them directly into account when calculating time savings for passengers, we have only a vague idea of the comparative attractiveness of the aboveground versus the underground. Specific surveys should be conducted to enlighten us about this question, the importance of which should not be disregarded. Given the present state of knowledge, it would be very difficult to assess the complementary value obtained through comparing the attractiveness of aboveground versus underground systems. Although such a comparison most probably would favor the aboveground infrastructure, in the authors' opinion it would not be a decisive factor in choosing one type of system over the other.

Another factor that has been included in this item is implementation time. The time required to implement the system could influence the decision considerably — especially in residential areas where right-of-way public transport is not very developed or in cases where the importance of the problems may act in favor of quick decisions and implementation (e.g., at election time), as is frequently the case in developing countries. This criterion is easily quantifiable and, therefore, may be included in social profitability estimations. Delaying the investment is known to increase the cost of updating a project and, thereby, reduce its social profitability.

2.3. Effects on the environment.

2.3.1. Consequences for land use. This item includes nearly everything related to the consumption of urban space necessary to the realization of the project (right-of-way, interchange areas, auxiliary volumes and areas). In fact, such factors are integrated into the standard scope of assessment inasmuch as they are taken into account in the investment cost. It is clear, however, that the various factors are, in themselves, straightforward arguments favoring an underground mode, which is often easier to insert into the urban environment.

The same reasoning applies to the "civil defense" criterion, although no analysis to date has actually concluded that underground infrastructures may be used for civil defense purposes at a non-prohibitive cost.

Concerning the consumption of urban space, it is interesting to note that the Paris metro takes up only two percent of the overall Paris area — that is to say, about 10 times less space than the public highways.

2.3.2. Environmental impact. This factor often provides the main justification for choosing the underground alternative.

Among the eleven criteria listed in Table 18, only two appear unfavorable to an underground solution: the impact on hydrological and geological conditions, and the consequences of closing down an underground structure. One criterion, "impact on utility systems", may be considered either favorable to the underground solution (e.g., "reconditioning of utility systems in relation with a new project") or unfavorable ("relocation of recently built systems"), depending on the individual case. All of the other criteria are favorable to an underground solution, including those related to land use, as well as to road traffic and city living conditions.

According to French procedure, the various environmental impacts are analyzed in a special administrative study report, called the impact study. Although qualitative in most respects, the impact study may include a quantified assessment of the environmental impact. Therefore, it may result in rejection or modification of certain projects within the scope of a public inquiry.

2.3.3. Operating costs of transit

Table 18. Factors to be considered when comparing underground with aboveground infrastructures.

CAPITAL COST OF THE INFRASTRUCTURES

"QUALITY" OF THE PROJECT

- Accessibility to the transport system
- Interchange facilities with other transport modes
- Environmental conditions: climate, aesthetic, cultural
- Implementation time

EFFECTS/IMPACTS ON THE ENVIRONMENT

- Land-use consequences
  - Organization of interchanges with other transport modes
  - Convenient insertion in urban environment (feasibility, layout, longitudinal profile, crossings)
  - Surface land and underground space consumption
  - Civil defense
- **Environmental impacts**
  - Land purchase and expropriations
  - Impact on geological and hydrological conditions
  - Nuisances: noise, vibrations, atmospheric pollution
  - Visual and aesthetic considerations
  - Impact on plants and green spaces
  - Incidence on land values and economics of neighboring properties and neighboring activities
  - Impact on other traffic:
    - saving of space that would be necessary for another traffic mode
    - effects of disruptions
  - Impact on existing utility systems
  - Impact on projects concerning the city and the transport and utility systems
  - Impact when working on the project realization
  - Impact in the event of discontinuing the use of the infrastructure
- **Operating costs of transit system**
  - Personnel
  - Energy
  - Maintenance of rolling stock
  - Maintenance of the infrastructures and fittings

systems. In this category, one would logically expect to discover differences with respect to aboveground and underground projects that would be unfavorable to the latter. While this is, indeed, the case for the lighting and cleaning up of the stations and the associated maintenance, the underground system may provide savings on rolling stock.

Surprisingly, it seems that operators of public transport systems are only slightly interested in these various cost differences because their cost accounting methods are generally unsuitable for such analyses. With regard to working conditions, advantages for RATP employees are identical for the two modes, without taking into account the specific nature of their working environment.

Suitable studies should be able to provide a more refined appraisal of all of the above factors, which are directly related to cost–benefit analysis. Nonetheless, in the opinion of the authors, there are no factors classified under "operating costs" that could be a decisive criterion in choosing one type of system rather than the other.

2.4. Problems with the aboveground-underground choice. By now it should be clear that current cost–benefit analysis methods do not result in a direct choice between the aboveground and underground alternatives. Indeed, the long list of criteria reflects the complexity of the factors that must be considered, while permitting a better appreciation of the possible alternatives.

One way to improve cost–benefit analysis would be to extend it by estimating, in monetary terms, some of the criteria considered, especially those related to the environment. This approach is preferred by some researchers, who consider that it is sufficient to evaluate the unfavorable impacts of a project by determining the cost of eliminating them, or the amount of financial compensation that the affected populations would have to be paid to suffer them.

Those who would prefer to support decisions by multiple criteria studies might seek a method of aggregation that would synthesize the various criteria. The criteria then could be evaluated by fully independent means, using measurable scales that allow an ordinal classification of criteria.

Considering the specific nature of the relevant factors, the authors believe that neither of these two viewpoints is entirely correct. It is sufficient to point out that most environmental criteria follow from subjective estimations, varying according to time and space, and often depending on the person making the evaluation. Consequently, no general evaluation scale or aggregation method can be devised.

Furthermore, in analyzing concrete cases where a choice between the aboveground and underground has been made, the explanations of the choice appear to stem from considerations of whether certain thresholds that characterize the criteria are exceeded or not, rather than from a weighted aggregation of the criteria. Moreover, it would seem that even when these thresholds are exceeded, the choice can be affected by a number of complementary measures — not necessarily corrective ones — that become more costly in the aboveground projects because they involve environmental consequences.

What might these thresholds be? Possible factors include the following:

- The number and quality of persons or businesses expropriated.
- The number of people who have to suffer, and the degree of suffering caused as a result of increased amounts and levels of noise.
- The minimum distance from the public transport line, and the number of people involved.
- The balance of trees planted versus those pulled out.
- The relative increase in distances when walking; changes in traffic and parking capacities; and the importance of trading activities affected.
- The relative difference between costs and total amount of savings in the investment costs.
- Possible differences in implementation.
- The extent and nature of compensatory measures, if used.

A second comment relates to the criteria themselves. Unquestionably, the actual criteria considered in making the choice may be reduced from those listed herein. For some people, the aboveground/underground differential will never be so great that it will significantly influence the choice. To them, any effort to assess such differentials more closely would seem to be of only slight interest.

In the authors' opinion, the list of criteria used to determine the aboveground/underground differential could be reduced to the following:

- Investment cost of infrastructures.
- Implementation time.
- Land purchase and expropriations costs.
- Environmental nuisances: noise, vibrations, air pollution.
- Visual intrusion and aesthetic considerations.
- Impact on vegetation and green spaces.
- Impact on other traffic modes.

Not surprisingly, these criteria are identical to those used in France in cost–benefit evaluations and impact studies.

Ultimately, it is primarily through studying actual cases — taking into account the explicit framework, the considered thresholds and any compensatory measures taken — that it will be possible to understand the mechanisms involved in the aboveground/underground choice and to understand the preferences of the decision-makers. This approach obviously is totally different from the "scientific, technical and objective approach" implied in conventional cost–benefit methods.

Undoubtedly an objective and total evaluation of the costs and benefits of underground systems will remain beyond reach of the technicians for years to come. The underground solution, obvious for the most central and densest urban areas, today appears far less obvious when considered outside of such a context. On the other hand, progress in understanding the reasons for deciding against the aboveground choice — and, therefore, in favor of the underground — appears fully possible before too long.

Such research will have to be conducted with a view to defining the "acceptability thresholds" and the way some criteria combine with others and react upon others, rather than with a view to attempting to determine a scale for evaluating the various environmental factors, or methods of aggregating the criteria. At the same time, such research must aim at determining the nature and extent of possible compensatory measures that are, in fact, the price of acceptability for any transit system.

Example of benefits: French case studies

The benefits of urban underground transportation projects vary greatly in nature, and most of them are either entirely of a qualitative nature or are not directly quantifiable in monetary terms.

The benefits have been classified into benefits to the patrons of the new infrastructures, to non-users of public transit systems, to the local authorities, and to the community in general.

1. Benefits to patrons of new infrastructures

1.1. Trends in passenger traffic on public transit systems. The benefits of a new infrastructure may be measured indirectly from the registered traffic and such trends over time (see Table 19). The traffic may be broken down into previous traffic acquired by public transit but having changed its mode or itinerary; traffic diverted from individual transport modes (i.e., pedestrians, private cars, bicycles and motorcycle riders); and induced traffic, i.e., traffic generated solely through the presence of the new infrastructure.

With regard to the new infrastructure, the new traffic recorded is in all cases far greater than the traffic previously recorded on the transit systems (generally buses) that served the considered sectors. The most spectacular example is line A of the Lyons metro, which runs on former bus routes, for which the traffic nearly tripled. In Lille, too, the metro recorded 2.6 times the traffic carried by the previous bus routes located in its area. This change in traffic trends reflects the specific attractiveness of rapid transit systems.

The origin of the traffic on the new infrastructures is shown in Table 20. Note that these data reflect only the short-term effects of the implementation of the new infrastructures, because the surveys from which they have been abstracted were conducted less than one year after operation began.

The observed fluctuations naturally derive from differences in the nature of the projects. For instance, on the Lyons, Marseilles and Lille systems, which were only surface types of systems before the metros were completed, the new traffic carried on public transportation appears considerable (36–56% of the total). In the Greater Paris Region, however, far less new traffic was recorded, although the numbers were not insignificant in absolute value (30 600 trips per day on the RER alone).

An additional phenomenon worth emphasizing is the fact that traffic on the new infrastructures continues to increase over time; and that, moreover, the "boosting" effect with respect to transit is also evident on the surface modes (see Table 19).

This phenomenon is worth considering more closely. A survey conducted on the line 13 extension north of Paris five years after its opening, which supplemented an earlier inquiry performed in 1977 (shortly after the extension started operation), pointed out the following:

(1) The flow of daily entries in the two stations of the extension rose from

Table 19. Transit traffic trends in Lyons, Marseilles and Lille.

City	Year	Annual rapid transit traffic (millions)	Annual bus and trolley traffic (millions)	Annual trips on public transit system (millions)
LYONS	1967	–	177,5	177,5
	1977	–	132,7	132,7
	1979	42,1	132,9	175,0
	1980	47,7	140,6	188,3
	1981	55,3	147,7	203,0
	1982	60,4	145,3	205,7
	1983	62,4	143,3	205,7
	1984	65,3	141,9	207,2
	1985	67,0	139,8	206,8
MARSEILLES	1967	–	90,6	90,6
	1977	–	85,2	85,2
	1978	20,5	91,0	111,5
	1979	26,6	99,2	125,8
	1980	27,7	98,2	125,9
	1981	28,7	96,7	125,4
	1982	29,8	102,2	132,0
	1983	29,7	101,1	130,8
	1984	35,8	92,0	127,8
	1985	36,5	92,0	128,5
LILLE	1981	–	47,0	47,0
	1982	–	50,8	50,8
	1983	8,1	50,5	58,6
	1984	21,2	48,2	69,4
	1985	28,7	45,9	74,6

Table 20. Modal origin of patrons.

	Previously used mode %			
	Public transport	Private car	Other modes	Induced traffic
LYONS Métro	64	11 ,5	9	15 ,8
MARSEILLES Métro	63	15	13	9
LILLE Métro	41	11 ,5	2 ,5	45
PARIS Métro extensions				
— Line 13 to "St-Denis"	90	6	1	3
— Line 13 to "Châtillon"	83	11	1	5
— Line 7 to "Aubervilliers"	89	6	2	3
— Line 13 bis to "Asnières-Gennevilliers"	85	8	2	5
— Line 10 to "Boulogne"	83	11	2	4
Average	87	8	8	4
PARIS - RER				
— Central stations	95 ,5	3	–	1 ,5
— Marne-la-Vallée branch	80	12 ,5	5 ,5	2
Paris Commuter Railway System				
— New line to "Cergy"	81	9	4	6
— "Invalides-Orsay" link	81	2	4	13

16 500 persons in October 1976 (the line was opened to the public in May 1976) to 26 600 persons in February 1981 — i.e., a 58% increase, or a little over 10% a year. This increase occurred during a time when the overall increase on the metro network was only about 2% per year.

(2) Although the population of the town of Saint-Denis, which is directly concerned, dropped overall from 96 800 in 1976 to 91 300 in 1981, the pull exerted by Paris, to which it is linked by line 13, has been reinforced by the new accessibility made possible by the two newly opened stations;

(3) One-half of the new trips recorded in the two stations of the line 13 extension stemmed from changes in the population served (e.g., arrival of new inhabitants in Saint-Denis, attracted by the new infrastructure); one-quarter came from other transit modes delayed in time (at constant mobility); and one-quarter from an increase in mobility ("induced" traffic).

1.2. Advantages to patrons. The most tangible advantage, and the one on which the social profitability of projects is generally calculated, is the savings in travel time.

As a rule, the time savings are usually important, both on an individual and on a collective basis, and irrespective of any "psychological" time resulting from the use of a regular transit mode, as opposed to surface transit modes, for which it can often be shown that, failing specific protection against general traffic (such as own right of way, bus-only lanes, etc.), the headways between vehicles at any given point are absolutely random.

Thus, people living close to the terminal station "La Rose" in Marseilles are now 18 minutes from the city center, whereas the previous travel time by bus was 45 minutes. In Lyons, the average time saved by patrons of line A of the metro, compared with the previous situation by bus, is approximately 12 minutes, for the same itinerary. In Lille, the time savings to the city center are about 10 to 15 minutes.

As regards the Greater Paris area, patrons of the new facilities have benefited from substantial time savings in every single case, as shown in Table 21.

The above elements taken together show that the attractiveness of rapid transit is incomparably greater than that of surface modes, which are dependent on the other surface traffic. This fact, as we shall see, means that the advantages of the subsurface modes extend far beyond those specific to their own patrons.

Table 21. Time saved by Paris patrons.

	Average time saved per trip (minutes)		Annual time savings (hours)
	People walking to stations	Others	
Line 13 to "Saint-Denis"	10,6	3	1 240 000
Line 13 to "Châtillon"	13	4	1 800 000
Line 7 to "Aubervilliers"	9	5	2 400 000
Line 13 to "Asnières-Gennevilliers"	10	6	2 300 000
Line 10 to "Boulogne"	5,5	3	280 000
RER: — Central sections } — Marne-la-Vallée branch }	15		19 100 000

2. Benefits to non-users

Strange as it may seem, the implementation of rapid transit systems also benefits a great many persons not directly concerned with the transit systems.

Specifically, the modal transfers recorded lead to a short-term reduction in the automobile traffic flows along parallel roads. However, all of the surveys conducted agree that this phenomenon is entirely transient, and that the situation quickly returns to its previous level. Indeed, in the European countries, the gap between car ownership and the road network capacity is such that any drop in traffic quickly entails the arrival of new users.

In any case, there remains the fact that the possibility made available to new patrons to use the road network should be considered from the standpoint of additional means of mobility, and hence of a gain in this respect. It is, moreover, clear that improving a mass transit system reduces growth in car ownership trends. In this connection, it may be pointed out that Paris is the least motorized of French cities.

Among the other positive effects of implementing rapid transit facilities in cities, there is the fact that their very construction is often the impetus for the "reconquest" of space by the pedestrians, especially in the downtown areas of cities. This was the case in Lyons, when the streets of Victor Hugo and of La Republique were turned into pedestrian malls; in Marseilles, when four vast new squares totalling 7600 m^2 were built in the city center; and in Paris, with the planned construction of a pedestrian plaza, the largest in Europe, which will connect Les Halles with the Georges Pompidou Museum. These are just a few of the many examples demonstrating how mass transit is synonymous with space savings, which is a basic requirement in the heart of cities.

Concurrently, the environmental impact appears, broadly speaking, to be positive, primarily because of the underground nature of most of the rights of way. In addition, the new pedestrian zones created and the reduced bus traffic in the central areas result in an appreciable decrease in noise and pollution.

3. Benefits to local authorities

For the local authorities, the construction of rapid transit facilities offers numerous advantages.

Apart from the problems of financing the capital cost of such facilities, projects of this nature are, above all, efficient in terms of operating costs and revenues. Leaving aside the dry figures, it must be understood that, if such facilities are not provided, the operating cost of surface systems increases steadily while the commercial speed of the vehicles inevitably drops. In this connection, attention has already been drawn to the beneficial effects imparted by such projects on the transit system in general, the image of which they substantially improve. This improvement, in turn, leads to increased utilization and to improved acceptability, in particular for the implementation of exclusive rights of way for surface systems.

Concurrently, the construction of rapid transit facilities is a powerful factor in orienting urban growth. This has been the case for a long time in the Greater Paris area, as is evidenced by the example of line 13 and, perhaps even more, by the rapid growth of the town of Marne-la-Vallée, located east of the Paris conurbation and now entirely served by the RER.

The case of Lyons illustrates what urban dynamics may be generated by the construction of a metro system. Construction of the Lyons Métro has:

(1) Stimulated the implementation of a comprehensive traffic and parking management policy in the city center;

(2) Offered the local political authorities occasions to develop some spectacular projects such as:

- Pedestrian malls.
- Housing renewal.
- Elimination of unsanitary housing and concurrent construction of new municipal housing.
- Actions to enhance the image of certain districts.

(3) Permitted development of the arts (sculpture, painting, etc.) and open air cultural activities.

All in all, then, it is impossible to underestimate the economic impact of this type of operation. The creation of jobs is directly related to construction of the metro facilities; and there are the indirect effects of enlargement of the job market (due to increased accessibility of jobs) and increased productivity resulting from the shortened transit time.

Finally, it would be appropriate to estimate the capital outlay saved through such projects, especially in regard to traffic and parking facilities avoided by using the subsurface facilities.

4. Benefits to the community in general

In addition to the promotion of industry and the development of exportable technical know-how arising out of such operations, the community in general benefits from a great many other advantages, such as, typically:

(1) Energy savings resulting from both the modal transfers and the use of transportation that tends to consume energy of non-oil origin. A complete energy balance sheet drawn up for the city of Marseilles gives the following results:

- Energy expended in constructing the system amounted to 52 000 oet, i.e., only one-third of the annual oil consumption for the automobile traffic in Marseilles;
- The annual energy consumption of the metro amounts to 4500 oet, while the savings due to modal transfers from private cars alone amounts to 1400 oet;
- The overall energy consumption of the mass transit systems rose from 10 700 oet in 1976 to 15 600 oet in 1979. The additional energy consumption generated by the operation (construction plus operation) is, thus, very low compared with the energy that would have had to be spent in constructing an equivalent road infrastructure of equivalent carrying capacity to the metro, in addition to the energy generated by the additional trips resulting from the metro implementation (some 10 500 oet), if they had been done in private cars.

(2) The enhanced safety resulting from the transfer of trips from private cars to mass transit. In the case of the Paris line 7 extension only, this value was estimated in 1980 at FF 1.1 million.

(3) The leverage exerted by such an operation on the local urban policy and on the overall policy on land use.

Summary and Comparison[10]

Evaluating Costs and Benefits — Limits of the Traditional Approach

Public transport does not appear to be a conventional economic asset because it is not, in fact, directly exchanged on a market in which its "price" would result from the confrontation of supply and demand.

First, one is dealing with an intermediate (not a final) commodity, the "consumption" of which is necessary for satisfying the citizen's needs, whether "obligatory" (e.g., work, school, business) or not (e.g., shopping, leisure activity, personal matters).

Second, the so-called "external" effects of public transport are very important. These encompass the general economics and environment of the city, as well as the various impacts affecting more directly the areas served by the fixed guideway lines and systems such as commuter rail, rapid rail or light rail.

Thus, it must be clear that the traditional approach, which would consist of a financial profitability evaluation — i.e., balancing the revenues and costs linked to a fixed guideway public transport line — cannot encompass the overall costs and benefits of such an investment. This is all the more true given that, in the great majority of the cases, public transport is, because of the existence of these "externalities", operated partly through national or local subsidies.

A Wide Range of Impacts

The various impacts — whether "internal" or "external" — resulting from the implementation of a public transit line on exclusive right-of-way can be either quantitative or qualitative. Quantitative impacts may or may not be financial in nature. A few examples are (also see Table 22):

- *Financial impacts*: capital costs, operating cost, fare-box revenues, land values, foreign trade balance and macroeconomic impacts;
- *Quantitative impacts*: time savings, safety savings, some environmental impacts (noise, pollution, land acquisition);
- *Qualitative impacts*: most of the environmental and economic impacts. Urban development, social and industrial impacts in general.

It is usually rather easy to evaluate, within a reasonable margin of error, all the capital or operating costs relating to a project.

It is much more difficult to take into account, other than in a qualitative way, all of the anticipated benefits or non-financial costs.

The summary international comparison in Appendices 1–6 clearly illustrates this last point.

Evaluation Methods at Hand

The various evaluation methods described in Appendixes 1–6 show that

[10]Prepared by the French Tunnelling Association Working Group on "Cost and Benefits of Underground Public Transport".

Table 22. Underground public transport impacts.

IMPACTS / ENTITIES AND GROUPS INVOLVED	PUBLIC AUTHORITIES			"ENVIRONMENT"			
	Federal or State level	Local level	Public Transit Authorities (PTA)	Public Transit (PT) Riders	Car-users	Regional and local business	Neighborhoods
• Quality of service (PT)	(X)	X	X	X		X	X
— Catchment area							
— Frequency/amplitude							
— Travel times							
— Regularity							
— Comfort							
— Transfers							
— Capacity and flexibility							
• Fare level (PT	(X)	X	X	X			
• Operating cost and cost/ revenue balance (PT)	(X)	X	X				
• Capital cost (PT)	X	X	(X)				
• "Eluded" investments	X	X					
• PT patronage	(X)	X	X				
• New PT riders' costs	(X)	X		X			
• Road network congestion		X	X		X	X	
• Car ownership				X		X	X
• Accessibility to the City	(X)	X	X	X	X	X	X
• Mobility	(X)	X	X	X	X	X	X
• Safety	X	X	X	X			
• Environmental impacts	(X)	X	(X)			X	X
— Traffic and parking							
— Noise							
— Air quality							
— Aesthetics							
— Community disruptions							
— Land acquisitions							
— Recreation areas							
— Water quality							
— Historic properties							
— Landscape							
— Safety and security							
• Urban development impacts	(X)	X	(X)			X	X
— Land values							
— Ground space consumption							
— Development incentives							
• Economic impacts	X	X				X	
— Labour market							
— Foreign trade balance							
— Gross local product							
— Industrial incentives							
— Energy consumption							
• PTA impacts	(X)	X	X				
— Image/patronage							
— Technical, human and financial consequences							
• Social impacts	X	X					
— Equity							
— Quality of life							

there are many ways to deal with the wide range of impacts listed in Table 22.

In particular, it appears that there may be no aggregation at all (provincial cities in France); a partial aggregation (U.S.A., F.R.G.); or a complete aggregation (Belgium, Czechoslovakia, Paris).

Furthermore, it appears that, if the main impacts (capital cost, operating cost, time savings) are evaluated in every case, the methods vary widely in the way they deal with the other impacts. At the same time, these variations relate to whether or not some of them (e.g., user costs, eluded investments, new public transit riders) are taken into account, as well as to whether or not they are "monetarized" (e.g., energy savings, noise and pollution).

Conclusion

The country to country differences that appear in the underground public transport cost–benefit evaluation methods come as no real surprise, because they are directly related to the local political, administrative, technical and financial conditions.

Nevertheless, it might be very valuable to try to clarify, on the basis of an enlarged sample of cases, the following:

(1) The set of impacts and related criteria that should be taken into account.

(2) Some scaling procedures that could be used, whether or not they would lead to a "monetarization" of the criteria.

(3) The advantages and drawbacks of an aggregation of the criteria, be it partial or complete. □

Appendices 1–6

Appendix 1. The case of Belgium.

Decision Maker	
Evaluation method edicting body	Transport Ministry
Basics of the evaluation method	Aggregated method based on the computation of the Discounted Benefit and Internal Rate of Return of the investment
Criteria and evaluation scales and procedures	• Capital cost of the new facility • Operating cost of the public transit system • Time savings — Scaling method: value of time (per type of trip) • "Eluded" investments (road network and parking lots) • Other financial savings (safety, car operation, road network maintenance)
Aggregation procedure	Discounted Benefit = $\sum_{i=1}^{n} \frac{Bi - Ci}{(1 + j)^i}$ Bi = benefit year i Ci = cost year i j = discounting rate n = expected lifetime of the facility
Financing of the projects	State and operating company (rolling stock only)

Appendix 2. The case of Czechoslovakia.

Decision Maker	
Evaluation method edicting body	Federal Ministry for Technical and Investment Development (1982)
Basics of the evaluation method	Aggregated method based on the "Minimum Converted Cost per year" computed for the lifetime of the facility
Criteria and evaluation scales and procedures	• Capital Cost *CC* Scaling method : *CC* x *a* *a* = coefficient taking into account the duration of construction and the lifetime of the project; varies between 0,0275 and 0,076 • Operating Cost per year *OC* • Wages and Personnel Costs per year *PC* Scaling method : *PC* x *b* *b* = 0,6 • Energy Consumption per year *EC* Scaling method : *EC* x *c* *c* = 0,6 • Passengers Transportation Time per year *PTT* Scaling method : value of time • Accidents Impacts *AI* Scaling method : cost of accident • Environmental Impacts *EI* Scaling method : financial evaluation of noise and pollution reduction
Aggregation procedure	Simple addition of the different items $(CC \times a) + OC + (PC \times b) + (EC \times c) + PTT + AI + EI$
Financing of the projects	

Appendix 3. The case of West Germany.

Decision Maker	Federal/State/Local Authorities	
Evaluation method edicting body	Federal Government	
Basics of the evaluation method	Multicriteria analysis based on a set of indicators relating to the 3 groups involved: the PT users, the Transport Authorities and the Community as a whole.	
Criteria and evaluation scales and procedures	*Criterion*	*Scaling method*
	Capital cost	Financial
	Operating cost and cost/revenue balance	Financial
	Time savings	Value of time
	Accidents	Monetary value
	Pollution, noise	Monetary value
	Energy consumption	Non-monetarized
	Accessibility	Non-monetarized
	Ground-space requirements	Non-monetarized
	Level of service to Public Transit riders (frequences, capacity, comfort, seat availability, walking distances...)	Non-monetarized
	Landscape and water table impacts	Non-monetarized
	Economic and social impacts	Qualitative
	Other environmental impacts	Qualitative
Aggregation procedure		
Financing of the projects	Federal (≃ 60%), State (≃ 20%) and Local (≃ 20%) Authorities	

Appendix 4. The case of France.

Decision Maker	State/Regional Body in Paris, State/Local Authorities otherwise	
Evaluation method edicting body	State Agency in Paris, none otherwise	
Basics of the evaluation method	Aggregated in Paris (Discounted benefit), Multicriteria otherwise	
Criteria and evaluation scales and procedures	*Criterion*	*Scaling method*
	Capital cost	Financial
	Operating cost and cost/revenue balance	Financial
	Time savings	Value of time
	Accidents	Monetary value (Paris)
	"Eluded" investments (Parking lots, road space)	Monetary value (Paris)
	User costs (road congestion and maintenance, car usage costs)	Monetary value (Paris)
	Service to PT riders	Non-monetarized
	Patronage, new PT riders	Non-monetarized
	Accessibility to the city	Non-monetarized
	Some environmental impacts	Non-monetarized (specific report)
	Energy savings	Non-monetarized
	Economic and social impacts	Non-monetarized
	Urban development impacts	Qualitative
	Other environmental impacts	Qualitative (specific report)
Aggregation procedure	Discounted Benefit in Paris (see the Belgium case) none otherwise	
Financing of the projects	State (≃ 35%), Regional body (≃ 35%), Transit Authorities (≃ 30%) in Paris State (≃ 20 to 40%)/Local (60 to 80%) otherwise	

Appendix 5. The cases of Denmark, Finland, Norway, and Sweden (from "Metros in the Nordic Capitals —Costs and Benefits", Stig Nordquist, Prague, 1985).

Decision Maker	
Evaluation method edicting body	
Basics of the evaluation method	Rules of thumb (in the past) Multicriteria analysis (General case now) Discounted Benefit (recently in Stockolm)
Criteria and evaluation scales and procedures	Capital cost Operating cost User costs (travel times mainly) Urban development impacts (Stockolm)
Aggregation procedure	Discounted costs and benefits (see the Belgium case)
Financing of the projects	

Appendix 6. The case of the U.S.A. (from "Technical Guidelines for Major Capital Investment Policy", UMTA 1984).

Decision Maker	Federal/Local Authorities
Evaluation method edicting body	U.M.T.A. (Department of Transportation)
Basics of the evaluation method	Multicriteria analysis including the computation of 2 cost-effectiveness ratios
Criteria and evaluation scales and procedures	• Capital cost *CC* and its local share *LCC* • Operating cost of Public Transit *OC* • Patronage, pointing out New Public Transit Riders (*NPTR*) • Time Savings (*TS*) — Scaling method: value of time (according to the type of trip) • Environmental impacts (specific report) • Qualitative criteria referring to the mastering of public transit deficits and the local support towards the project
Aggregation procedure	Computation of 2 efficiency ratios: • *NPTR/CC* - Δ*OC* - *TS* • *NPTR/CC* - *LCC* - Δ*OC* - *TS*
Financing of the projects	Federal (≃ 80%), State and Local Authorities (≃ 20%). The Federal share is now being cut down drastically