Technical University of Denmark

# Note about socio-economic calculations

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*Publication date:*
2006

*Document Version*
Publisher's PDF, also known as Version of record

# Note about socio-economic calculations

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## Indholdsfortegnelse

# 1. Introduction

This note gives a short introduction of how to make socio-economic evaluations in connection with the teaching at the Centre for Traffic and Transport (CTT). It is not a manual for making socio-economic calculations in transport infrastructure projects – in this context we refer to the guidelines for socio-economic calculations within the transportation area (Ministry of Traffic, 2003). The note also explains the theory of socio-economic calculations – reference is here made to "Road Infrastructure Planning – a Decision-oriented approach" (Leleur, 2000).

Socio-economic evaluations of infrastructure projects are common and can be made at different levels of detail depending on the type of project and the decision making phase. A common feature of the different levels of detail of the socio-economic analysis is that the planned project(s) is compared with a basic; the basic alternative or a null alternative. In socio-economic evaluations it is intended to describe the effects in economic terms whenever possible ("+" is used when it is positive for the society, and "–" when it is negative for the society). However, not all the effects for the society can be described in economic terms, and instead these effects must be described qualitatively.

This note describes the socio-economic evaluation based on market prices and not factor prices which has been the tradition in Denmark till now. This is due to the recommendation from the Ministry of Transport to start using calculations based on market prices (Ministry of Transport, 2003). However, when following courses at CTT, it is recommended to use the factor price method which will be described in further details in a later chapter.

# 2. The basic alternative

The basic alternative is the scenario where the planned project(s) is not realized, often called a "what if"-scenario. It means that the basic alternative, like the planned project(s), can also include construction costs, operating costs and externalities. It could for instance be construction costs in connection with the creation of more capacity on existing roads and railways, e.g. in the form of more tracks or changed signals with the corresponding consequences for both the operating costs and the externalities.

# 3. Choice of year for the socio-economic calculation

There are many different ideas about which year the various costs and benefits should be calculated. Normally, it will be so that particularly the construction costs are available at the present level as the politicians who have to approve the budgets like estimates of costs based on already existing budget constraints. The most optimal year for an evaluation base calculation is in the project opening year, as most construction costs are usually realized at that time, why it is only the pure costs involved in the infrastructure and the benefits that have to be evaluated.

The chosen year of the socio-economic calculation does not necessarily mean that the socio-economic effects are calculated in the prices of the opening year of the infrastructure. The main calculation should be in the year that most (or the most important) unit prices are present, as a disocunting of these unit prices will increase the uncertainties with respect to these unit prices.

## 3.1. Discounting

The Danish Ministry of Finances have made a unit price catalog elaborating over the different impacts and their price settings. This catalog often dates back to one or two years prior the actual calculation year why a discounting is necessary to achieve consitens between impacts and their prices[1]. The discounting is made according to formula 3.1

**Formula 3.1** $K_0 = K_n(1 + i)^{\pm n}$

Where:

$K_0$ is the value in the calculation year
$K_n$ is the value in year n to be discounted
i is the (average) yearly inflation in %
n is the number of years to be discounted
+ if discounting forward in time
- if discounting backwards in time

In most cases, the discounting interest rate is the same as the (expected) inflation. Information about the inflation can for instance be found at Statistics Denmark's homepage (www.dst.dk). Statistics Denmark has information about the development of the prices over the years, and thereby information about the price development/inflation from one random year to another random year. Based on this information from Statistics Denmark formula 3.2 can be used:

**Formula 3.2** $K_0 = K_n \cdot f$

Where:

$K_0$ is the value in the calculation year
$K_n$ is the value in year n to be discounted
f is the factor used as discount factor

# 4. Construction and operation costs

The construction costs of the planned project alternative(s) can be used as a kind of standard of reference in the further socio-economic analysis. As previously mentioned it is here necessary to determine an opening year and a calculation year. The calculation year is the year in which the calculations are made, so that a comparable basis of costs and benefits is obtained. As the construction costs will generally be realized over a number of years, it is also necessary to know how these are divided. In this connection it is necessary to know a number of charges belonging to the market price method.

## 4.1. Charges

The reason why a number of charge calculations are necessary to carry out a cost-benefit analysis is that public investments are normally financed by means of taxes. But if tax incomes are used to finance a public project, it means that a number of other financial activities will be put on hold. This actually means that the social investment value of one crown is in reality bigger than one crown, which may seem rather odd to may people. If you e.g. have a person A that wants to carry out a piece of work for person B for 100 DKK, and person B is actually prepared to pay 110 DKK for this work, both person A and person B benefits from this piece of work. But if person A's work is taxed with 50%, it means that he will as a maximum receive 55 DKK of the 110 DKK that person B was willing to pay. With this new calculation, the work will not be carried out, and the so-called potential profit of 10 DKK will not be realized.

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[1] *Discounting can be seen as an expression that 1,000 DKK is worth more today (for the individual person and for the society) than within for instance 3 years. In the same way 1,000 DKK would be worth more if you go it 3 years ago, as you could have chosen to save the money or spent it on something more useful.*

It is exactly the 10 DKK that mean that both person A and B will obtain a bigger loss than the tax payments themselves, as person A could have demanded 110 DKK, whereas person B could have restricted himself to only paying 100 DKK. The Ministry of Finance has established that the loss by financing a project by means of taxes is 20 øre per DKK, or 20 %, which is called tax distortion.

Another and somewhat more down-to-earth factor is the so-called Net Taxation Factor (NTF) that converts factor prices into market prices. Market prices are as previously mentioned a kind of consumer prices, i.e. the prices a private company would use to calculate its profit or loss. When calculating the benefits and losses of the public sector by means of this factor it is possible to compare privately and publicly financed projects. The Ministry of Finance has fixed this factor at 17.1%.

## 4.2. Example of investment cost

If for instance the total construction costs amount to 1,400 million DKK in 2001 price level, but the project itself is not expected to be opened until 5 years later meaning that the last payment will take place in year -1. The payments are distributed evenly over the 5-year period, i.e. with 20 % per year, and it is therefore possible to make the following table.

| Year | 5 | 4 | 3 | 2 | 1 | Total |
|---|---|---|---|---|---|---|
| % distribution | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 1 |
| Construction factor prices | -280 | -280 | -280 | -280 | -280 | -1.4 |
| Investment incl. NTF | -327.88 | -327.88 | -327.88 | -327.88 | -327.88 | -1,639.40 |
| Investment incl. NTF & *d* | -438.78 | -413.94 | -390.51 | -368.41 | -347.55 | **-1,959.20** |

**Table 4.1 Example of investment cost calculation**

As it appears from table 4.1, it is not unimportant to include the Net Taxation Factor (NAF) and discounting (d) of the construction cost. Actually, the real difference between a total factor price and a total price calculated by means of the market price method is about 500 million DKK. However, the use of the factor price method is recommended in the following due to the many and difficult charge calculations mentioned above.

The other big item of expenditure is the operating costs of the new infrastructure. These costs arise as a result of the planned projects. In this case, the operating costs cover all the operating costs of the new infrastructure as well as the increased or reduced operating costs.

## 4.3. Operating incomes

The operating incomes, e.g. the fares, are not included in the socio-economic evaluation, as it is assumed that these incomes are just a redistribution of resources belonging to society.

Even though the operating incomes are not included in the socio-economic evaluation, it can however be interesting to assess/calculate the operating incomes, as operating incomes often play an important role when making the decision about the construction of a new infrastructure. If the infrastructure is profitable (without public subsidies), which is e.g. the case of the Great Belt connection (Storebæltsforbindelsen), it is easier to make a decision about the construction of the infrastructure.

The distribution of the operating incomes for public transportation can be a decisive factor for the investment in new infrastructures for public transportation. This is due to the fact that the transport companies/authorities that will not receive any of the increased operating incomes or that may even get a worse operating account will be against the project, even though the project as a whole is an advantage for the public transportation.

If the operating incomes are not sufficient to finance the new infrastructure, it is the socio-economic benefits that to a large degree are decisive for the realization of an infrastructure.

## 5. Time benefit

One of the main arguments in connection with most infrastructures is that is possible to save time, and the benefit of time saved on travelling is often one of the most important contributions in the socio-economic evaluation.

The socio-economic calculations of the time saved on travelling require that the travellers maximize their utility when choosing the route. The travellers' demand is determined by relevant supply variables for the transportation market such as travel time, fare etc. and the travellers' own characteristics such as e.g. income (Gissel, 2000).

Changed traveller benefits and subsequent changes in the number of trips in connection with e.g. changed travel times (induced traffic) and fares or comfort can be illustrated by means of a demand curve – cf. figure 5.1. In case of reduced travel costs (Cost) the change in utility (the time benefit) for the existing travellers is calculated as the rectangle that is bounded by the previous travel cost ($C_0$), the new travel cost ($C_1$) and the number of passengers at the starting point ($N_0$) – cf. figure 5.1 and formula **5.**1.

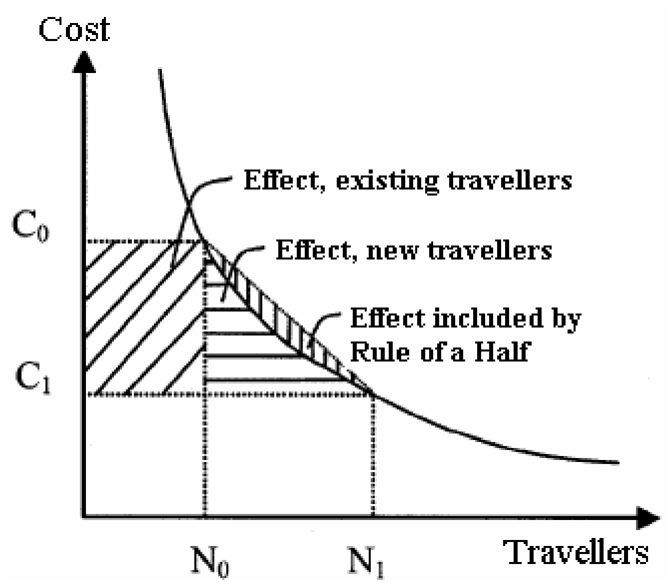


**Figure 5.1 Calculation of time benefit**

**Formula 5.1** The time benefit for existing travellers = $(C_0 – C_1) \cdot N_0$

More travellers due to transferred trips from other means of transportation or completely new travellers (induced traffic) mean that more time will be spent in the transportation system, which is not a disadvantage, as the travellers choose the transportation system because it offers them a benefit. Part of the increased time consumption is therefore a benefit, but not the entire new time consumption. This is because the first new traveller will benefit 100 % from spending the time in the new/changed transportation offer, whereas the the benefit of the following new traveller decreases until the last new traveller only obtains a very small benefit when using the new/changed transportation offer.

The benefit to the transferred and new travellers (the benefit of the induced traffic) can therefore be calculated as the area that is bounded by the demand curve in figure 5.1, the passenger growth ($N_1 – N_0$) and the difference in travel costs ($C_0 – C_1$). If the demand curve is linear the beneficial effect for the new travellers can be calculated as a right-angled triangle – cf. figure 5.1 and formula 5.2.

**Formula 5.2** The time benefit for new travellers = $½ \cdot (C_0 – C_1) \cdot (N_1 – N_0)$

However, it is only in a very few (idealized) cases that the demand curve is linear, but it is a generally used assumption that the demand curve is approximately linear, and that the area of the beneficial effect (the benefit) is therefore calculated as a right-angled triangle – this assumption is called Rule of a Half (Gissel, 2000). The difference between Rule of a Half and the real area depends on the shape of the demand curve, and it has been showed that that Rule of a Half can be approximately twice as big as the real beneficial effect (Salling, 2003).

The output from route choice models can be used as background material for the calculations of the socio-economic time benefit, as they normally contain a cost matrix and an OD-matrix. The time benefit should be calculated separately for all zone pairs for each category of travellers and each mode[2], after which the benefit can summed up.

Time is not just time – one should distinguish between different kinds of time. For public transportation the waiting times and transfer times are more inconvenient than the time spent in the mean of transportation itself, because of that the time value of waiting time and changing times should be higher. Different means of transportation have different comfort etc., and the travel time in a bus should therefore have a higher time value than the travel time in a train. If the same time and inconvenience value is used for both bus and train, it can result in the paradoxical situation that there is a negative socio-economic time benefit due to the investments, because some passengers change to a slower but more comfortable route, even though they can still use the same route as before. There are no general time values for different public means of transportation yet, but a Danish time value study is in progress, cf. (Ministry of Traffic 2003b).

## 5.1. The value of time

An essential parameter in the cost-benefit analysis is thus the travel time and the corresponding time saved on travelling. A traveller will probably be willing to pay for less time in the train or in the car, and thereby have more time for e.g. the family.

Based on this argument, it is not unreasonable to assign precisely time value, as this factor is limited in nature. In some projects this time factor actually accounts for 60-70% of the total benefits obtained. On the other hand, it is quite difficult to split up such a factor. Especially in Scandinavia a large number of time value studies have been carried out in which different travelling purposes and distributions of trips have been weighed and an attempt to estimate their value has been made. The problem is of course that time is weighed incredibly individually, depending on the purpose, e.g. occupation, home-work, leisure time etc.

If the same time value is used for all means of public transportation the paradoxical situation may arise that one obtain a negative time benefit in spite of improvements. Illustrated in Figure 5.2. If a traveller is going from A to B, the traveller can go by bus from A to B with transfer at C. If a new metro, light railway or suburban railway is built between A and D (without changes in the existing bus connections), some travellers will choose to go by railway from A to D and then change to the bus going to B.

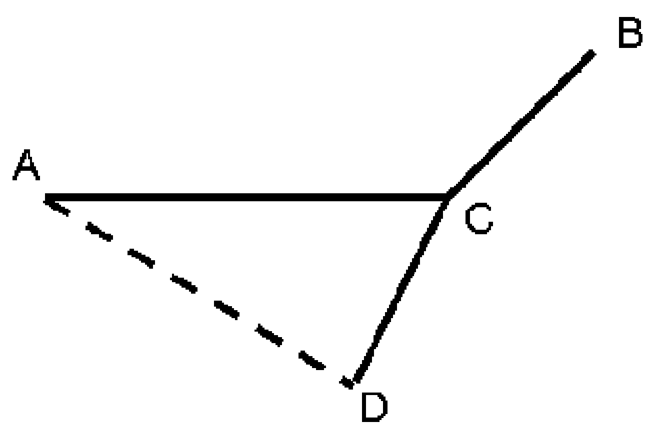

**Figure 5.2 Travel opportunities for trips between A and B**

The number of travellers from A to B via D depends on the time they save, but even though it maybe takes just as long or maybe even a little longer to travel via D, there is still people who will do that as it is more comfortable to go by train than by bus. If the socio-economic benefit of time saved on travelling is calculated based on a general value for public transportation, the route via D is considered a disadvantage since it takes longer time than before. There are however passengers that choose to travel via D and therefore there must be a benefit, but it only occurs if you take the actual values of inconvenience and time into consideration for each means of transportation.

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[2] *With respect to car traffic this applies to free time and congested time separately, whereas it with respect to public transportation applies to transfer time, waiting time, access/egress time, hidden waiting time (headway) and in vehicle time separately. However, depending on the chosen route choice model this can vary*

## 5.2. Saved congestion

When a stretch of road is so congested that the capacity of the road is about to be exceeded or it is already exceeded, problems with queues, reduced speed and delays arise. With respect to modelling, this is a rather special problem, as e.g. reduced speed on a road stretch changes the travellers' behaviour. This can e.g. result in a changed choice of route, another mean of transportation or a changed time for the commencement of the trip. These changed choices can later result in a "fictitious" increase of the speed on the road stretch and in this way result in further changes or new prerequisites for the travellers, and so can this cycle go on. In this way it can be necessary to run the congestion models several times to obtain a kind of equilibrium.

Studies have shown that there is an increased willingness to pay to avoid congestion and queues compared to the time value of normal driving. The primary reason is that congestion makes it difficult to foresee how long time a given trip will take, and that it therefore can be necessary to leave in good time or risk being late for an appointment or the like. The value of saved congestion is thus fixed at 150 % of the value of the normal travel time. This of course means that the saved congestion in some projects account for a very big part of the user effects.

The relatively many traffic models existing today more or less indirectly take this congestion factor into consideration. Unfortunately the congestion factors are calculated implicitly in the user effects and that often gives a misleading picture of the congestion. It is therefore recommended that there for each road stretch is found a saved congestion contribution, after which an actual socio-economic value is calculated by multiplying the 150% of the normal time value.

The biggest pitfall of such a calculation is the double calculation of the travellers' user benefits. Normally you have a traffic model that gives a total first-year effect for the travellers, indicated in number of saved hours. These values contain the saved congestion hours which thus are calculated for the normal "100%" time values.

# 6. Driving costs

Driving costs are only calculated for car traffic, as the driving costs of public transportation are included in the operating costs – cf. chapter 4. Construction and operation costs.

The driving costs for cars depend on the number of kilometres and can therefore be found based on the expected number of kilometres driven. The expected number of kilometres driven can often be estimated by means of a route choice model calculating the number of kilometres driven between each zone pair and then sum up.

Since different types of vehicles (passenger cars, vans and trucks) have different driving costs, and since the composition of types of vehicles varies from road to road, it is important to distinguish between the different types of vehicles as much as possible. Most route choice models contain data for the different types of vehicles at zone and/or road level.

If induced traffic is implemented, the benefit/disbenefit of driving costs (as opposed to the time benefit of chapter 5 Time benefit), is the entire difference between the total driving cost in the basis scenario and the scenario with induced traffic.

When calculating the benefit/disbenefit for driving costs, it is done without taxes and charges, as it is a redistribution of the socio-economic resources.

# 7. Externalities

The externalities are a project's impact on the surrounding society in the form of e.g. noise, pollution, congestion and accidents. These externalities can be calculated with different levels of detail, and here it is important to evaluate which externalities are the most important and carry out a more detailed/precise calculation of these instead of the less important externalities.

When calculating the externalities it is important to calculate them for all the relevant means of transportation[3], and not leave out externalities from one or several means of transportation that are implemented in the other calculations.

It is not always possible to calculate all the externalities, and in that case you can choose to make a qualitative description of the impact of the individual externalities. Based on the qualitative description(s) the socio-economic effect(s) might be assessed.

# 8. Writing-up the results to yearly level

Often part of the socio-economic effects are evaluated at working day level or even at peak hour level, but as the socio-economic analysis is based on a yearly level, it is necessary to write up the results. Generally, the results should be written up as little as possible to avoid uncertainties, and e.g. operating costs/savings for public transportation should therefore be calculated for both a working day, a Saturday and a Sunday, and then be added up to a yearly level.

It can be very time- and resource consuming to calculate certain results that it is not realistic to calculate them for an entire year, but only for a working day or a peak hour. These data have to be written up to a yearly level with the inherent uncertainties regarding changes in traffic composition, trip patterns etc. It is considerably easier to calculate car traffic than public transport, and car traffic should therefore be calculated for an entire working day, whereas it is enough to make the calculations for the morning peak hours in case of public transportation.

During the morning peak hours, public transportation operates a traffic volume equivalent to 20-25 % of a working day traffic. Under the assumption that the length and destination of the trips is more or less regularly distributed over the day, the morning peak hour can therefore be written up to working day traffic using a factor 4-5. It is normally assumed that a yearly traffic volume of public transportation is equivalent to 300-310 working days traffic volume for metropolitan traffic[4]. Under the same assumption that the length and destination of the trips are more or less regularly distributed over the entire year, the working day traffic can therefore be written up to yearly traffic using a factor 300-310.

Traffic is normally calculated as working day traffic (WDT), but it can be converted into annual average daily traffic (AADT) by means of formula 8.1.

**Formula 8.1** AADT = WDT / 1.1

Since a year consists of 365 days, the average annual daily traffic can simply be written up to yearly level by multiplying with 365.

Many socio-economic effects based on peak hour level and/or working day level can be calculated at this level, after which they can be written up as described for the traffic. However, in many cases the socio-economic effects should be calculated based on the annual average daily traffic and/or the total yearly traffic.

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*[3] In several of CTT's courses it can be difficult/impossible to calculate the externalities for all means of transportation, as the courses normally deal with either public transportation or individual traffic*

*[4] For long-distance traffic, e.g. the Danish IC-traffic, the large travel days are Friday and Sunday and the days in connection with vacations and holidays*

# 9. The socio-economic analysis

There are a number of different calculations that make up the socio-economic analysis. When comparing different projects, the different calculations can give a different ”ranging” of the projects. This note only deals with one method for socio-economic calculation: The cost-benefit analysis (CBA).

## 9.1. The cost-benefit analysis (CBA)

The cost-benefit analysis has gradually been broad recognized for evaluation of projects, in particular in the traffic and transportation sectors. In short, the CBA-method is a way to evaluate the ”goodness” of a public investment, in this connection often by ranging a number of project alternatives, i.e. the CBA consists of a counterbalance or comparison of the total costs of a given project with respect to the benefits that will arise during the project lifetime; all indicated in the same scale – monetary units.

In many ways, such an analysis is similar to a kind of welfare maximization which is normally carried out in private companies. A private company normally carries out a number of analyses of its business, before it decides to engage or dismiss. In this way, the future profit of the company can be maximized which, other things being equal, is the purpose of both private and public enterprises.

Obviously, the general difference between the two evaluation methods is that the private company looks at a given market, normally the selling price of the product that contributes to the total benefit as opposed to e.g. subcontractors and other production factors that will contribute to the mentioned costs of the company. In this way, the financial analysis is obtained in the form of market prices, where the benefits and costs are estimated based on what “we” experience. If you instead look at a public investment, in this note a traffic project, it is not that simple to estimate the benefits and costs based on a given market. By studying the social welfare instead of a factual benefit the analysis is complicated considerably. Just like the private enterprises, public enterprises want to maximize the welfare, but how is it measured?

### 9.1.1. Welfare theory

The general welfare theory and thereby the theoretical basis of a CBA has its origin in microeconomics. This concept is widely described in the literature, and this should therefore not be considered a thorough examination.

The fundamental assumption behind a cost-benefit analysis is that everybody in society thinks and acts rationally, *the rational consumer*. In this way it is assumed that the consumer will always choose a method that maximizes his own welfare/utility. This welfare maximization can thus be represented by a utility function, *u*. As a whole, society consists of a number of individuals, and a change in social welfare as a consequence of a given investment is therefore considered an aggregated value of the individual person’s welfare benefits or losses. A total social welfare benefit or loss *W* is therefore found by summing up all the *u*´es

$$W_N = u_1 + u_2 + .... u_n$$

where *N* is the number of individuals affected by the investment.

The starting point is therefore that all individuals are identical, and that all have the same value. In this way ”the winners” compensate ”the losers”, which is further described in the so-called *Kaldor-Hicks criterium*. If it for instance is assumed that Person A loses 90 DKK due to the new investment, whereas Person B wins 100 DKK, this project is considered an increase in welfare of 10 DKK (Gissel, 2002).

It is this traditional microeconomic approach that is the basis of a CBA, where each individual is assigned the same weight whether he is rich or poor.

## 9.2. Concepts in CBA

Referring to the previous comparison between private companies and the public sector or society, private companies will often only look at the costs and benefits directly adhering to the company. Unfortunately, this is not possible for society that has to include other effects, the so-called externalities.

This can be illustrated by means of an example, e.g. a company that expects to expand with a new factory. The financial manager performs a so-called CBA, in which the company obtains a clear benefit in the form of increased sales and productivity after an initial infrastructure investment. On the other hand it is the intention to place the factory in a densely built-up area, where noise, contamination and smell are very bothering for the neighbours to the factory. These factors will not be included in the CBA of the private company, but it is necessary to include them in a social CBA, which can actually mean that such a factory will not have a positive impact.

In this connection the market prices that the private company uses to calculate its CBA cannot apply to a socio-economic analysis because of e.g. taxes and charges. In this way it is necessary to deduce the effects behind the respective benefits or costs based on other methods. As previously mentioned a welfare maximization from individuals utility function. Based on this way of thinking, the value that an individual is willing to ”give up” to obtain a given benefit, e.g. time saved on travelling, less noise etc., has been used. In this way it is possible to use a monetary unit indicating how big a cost the individual person is willing to pay for a possible improvement, hence the two concepts, *willingness to accept (WTA)* and *willingness to pay (WTP)*.

Normally, these two concepts is not obtained by asking the individual person direct questions, we are simply too different to answer that. Instead of asking direct questions, e.g. how much you are willing to pay to save 10 minutes on travelling, which can be relatively difficult to answer, two preferences are laid down – also called *Stated Preferences SP*.

In this way a preference will, if any, reveal whether a person is willing to pay for an extra benefit, e.g. in the form of time saved on travelling.

When all benefits and costs have been assigned a monetary unit, it is possible to interpret or indicate possible changes for the utility functions of each individual. A number of evaluation criteria can be used for this:

## 9.3. First year rate of return (FYRR)

The first year rate of return is the simplest socio-economic analysis, as you only have to determine how many percent of the constructions costs that are “recovered” the first year of operation – cf. formula 9.1:

**Formula 9.1** $FYRR = B_0/C_0 \cdot 100$

Where:

$B_0$ is the total benefits in year 0
$C_0$ is the construction costs in year 0

The first year rate of return is a good (and fast) indicator whether a project seems to be socio-economically viable. Furthermore, the first year rate of return can be used to compare big and small projects as it is independent of the net present values and internal interests.

## 9.4. Net present value (NPV)

The net present value (NPV) can be used to determine whether a project is socio-economically viable – i.e. that the total benefits (discounted back) are bigger than the construction costs. The net present value is calculated according to Formula 9.2:

**Formula 9.2**

$$NPV = \sum_{t=0}^{T} B_t \cdot (1+r)^{-t} - C_0$$

Where:

$B_t$ is the total benefits (and disbenefits) in year t
$C_0$ is the construction costs in year 0
r is the calculation interest rate

## 9.5. Benefit-Cost ratio (B/C)

The benefit/cost ratio describes the ratio between benefits and costs in the project, and is calculated as appears from Formula 9.3:

**Formula 9.3**

$$B/C = \frac{\sum_{t=0}^{T} B_t \cdot (1+r)^{-t}}{C_0}$$

Where:

$B_t$ is the total benefits (and disbenefits) in year t
$C_0$ is the construction costs in year 0
r is the calculation interest rate

The benefit-cost ratio (B/C) must therefore be bigger than 1 before the project is socio-economically viable – i.e. before the benefits are bigger than the construction costs.

## 9.6. Internal interest rate (IRR)

The internal interest rate (IRR) indicates the yearly socio-economic yield of the project. The internal interest rate (IRR) is therefore the interest rate at which the net present value (NPV) is equivalent to 0 – cf. Formula 9.4:

**Formula 9.4**

$$NPV = \sum_{t=0}^{T} B_t \cdot (1+IRR)^{-t} - C_0 = 0$$

Where:

$B_t$ is the total benefits (and disbenefits) in year t
$C_0$ is the construction costs in year 0

When calculating the internal interest rate it should be noted that Formula 9.4 can result in several internal interests, of which however several can be disregarded.

## 9.7. Choice of parameters for socio-economic calculations

In socio-economic calculations a number of parameters such as calculation period and calculation interest rate have to be chosen. These parameters are not given in advance, and often require major considerations.

### 9.7.1. Calculation period and scrap value

The calculation period should ideally be equivalent to the project lifetime, but since transportation investments projects as such do not have a fixed lifetime (the railway Copenhagen-Roskilde was for instance opened in 1847 and will probably exist for many years to come), it is necessary to use shorter (and more relevant) calculation periods.

For large infrastructure projects, the Ministry of Traffic recommends a calculation period of 50 years (Ministry of Traffic, 2003), but for "ordinary" road projects a calculation period of 20 years is often used. For more operation related socio-economic calculations, e.g. investments in new rolling stock, the calculation period is more or less equivalent to the lifetime of the rolling stock.

When a calculation period is used that is shorter than the project lifetime, the project's scrap value should be calculated. The scrap value (or the residual value) is equivalent to the value in use that the project represents at the end of the calculation period, and this value must be included as a benefit in the socio-economic calculations for the year where the calculation period ends. If reinvestments and maintenance of the infrastructure are included in the calculation, the scrap value can (roughly) be set the same as the construction cost (except cable and pipe rearrangement) and investments in rolling stock, if any. This is due to the fact that the infrastructure is maintained and that new stock has been purchased for public traffic projects as a result of the reinvestment.

Cable and pipe rearrangement are often an important cost in connection with (particularly) public transportation projects. However, many cables and pipes in Denmark, e.g. sewers, are so old and worn that they need to be changed – or should have been changed already. When calculating cable and pipe rearrangement it should be taken into consideration that sooner or later it would in any case have been necessary to make the rearrangement. It is therefore only the additional cost in relation to the cable and pipe rearrangement as compared to the scrap value of the existing cables and pipes that should be included in the socio-economic calculation.

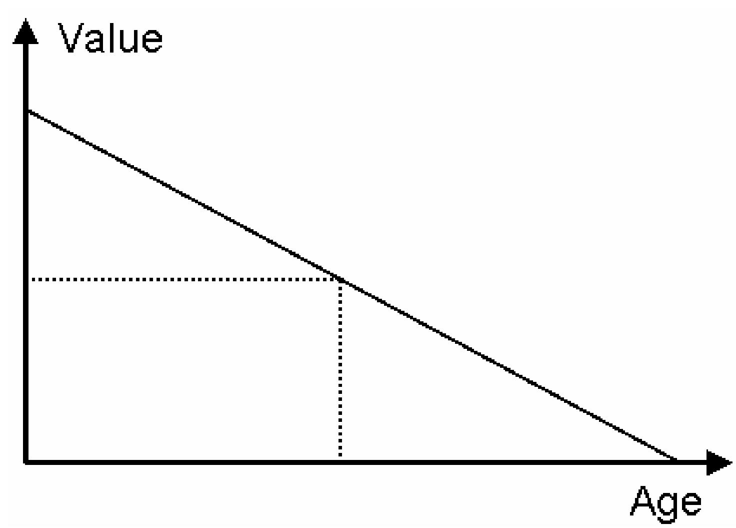


**Figure 9.1 Scrap value for cables and pipes**

A simple way to calculate the price for cable and pipe rearrangement with regard to the scrap value is to assume that the price for cable and pipe rearrangement is only half of the infrastructure investment. This is based on the assumption that the cables and pipes are written off in equal parts over their entire lifetime, and that the cables and pipes are renewed when their residual value is 0. It is furthermore a requirement that the age of the cables and pipes is evenly distributed. When this prerequisite is fulfilled, the age of the cables and pipes will on average be half of their lifetime, which means that the scrap value is half of their "replacement value" – cf. figure 9.1.

### 9.7.2. Calculation interest

The calculation interest is used to compare the benefits over time, and thereby make it possible to compare the present and future socio-economic effects. The calculation interest reflects (ideally) the interest that society could obtain by investing in other projects, but at the same time it expresses an ”impatience factor”, where you prefer to receive the benefits today rather than tomorrow and at the same time prefer to postpone the costs till tomorrow instead of defraying them today (Ministry of Traffic, 2003).

Economic theories do not offer one general calculation interest rate that can be used for all projects. Nonetheless, the Ministry of Finance establishes at regular intervals a socio-economic calculation interest rate for socio-economic consequence evaluations. The ”valid” socio-economic calculation interest rate for traffic analyses can be found in the latest catalogue of key figures for socio-economic analyses within the area of transportation which is published by the Ministry of Traffic. In the catalogue of key figure from June 2003 the calculation interest rate is fixed at 6 % (Ministry of Traffic, 2003a). However, a rule of thumb in factor price calculations is that the interest rate can be fixed at 7 % instead, but only in case of evaluation periods of more than 20 years.

## 9.8. Multicriteria analysis (MCA) and strategic effects

Not all effects can directly be quantified in economic terms, either because it can be difficult or impossible to estimate the price of effects such as urban environment, clearer timetables, etc. These effects cannot form part of a cost-benefit-analysis, but it is possible to use them in a so-called multicriteria analysis by means of weights or point distributions that make comparative analyses possible. For more information on multicriteria analyses, reference is made to (Leleur, 2000).

Furthermore, projects can have long-term effects such as changed location of homes and/or business, changed car ownership, etc. These long-term effects, which can have an important impact on future transportation, are called strategic effects. These effects are often so long-term that they (due to discounting) only to a small degree are included in ordinary socio-economic analyses. However, there are hedonic methods to estimate the price of some of the strategic effects – see e.g. (Rich, 2002).

# 10. Final comments

There are a number of circumstances that traditionally causes or may cause problems in socio-economic analyses. Some of these aspects are described in this chapter.

## 10.1. Uncertainty intervals as well as different interests and periods of time

Socio-economic evaluations can include many uncertainty factors, and it is therefore important not to state the results of the socio-economic effects with (too) many significant figures as this can give an impression of very precise calculations. Another way to allow for any uncertainties in the project, can be to indicate uncertainty intervals for the various socio-economic effects.

As described in chapter 9.7.1 Calculation period and scrap value and chapter 9.7.2 Calculation interest, it is not possible to determine an exact calculation period and one calculation interest. It can therefore be appropriate to show the effect of changed calculation periods and calculation interests in order to elucidate the uncertainties when choosing these two parameters.

## 10.2. Miscalculation of (particularly) public transport projects

As it appears from 10.1, the socio-economic effect of an infrastructure depends on the traffic load of the infrastructure. If the existing infrastructure is used in a socio-economically optimal way (A), an extension with unchanged traffic will obtain a higher socio-economic effect. The improved socio-economic effect appears as a consequence of improved regularity and the time saved on travelling, if any. The most optimal socio-economic effect as a result of new infrastructures (C) can occur by an increased traffic load, as it allows for e.g. more direct connections.

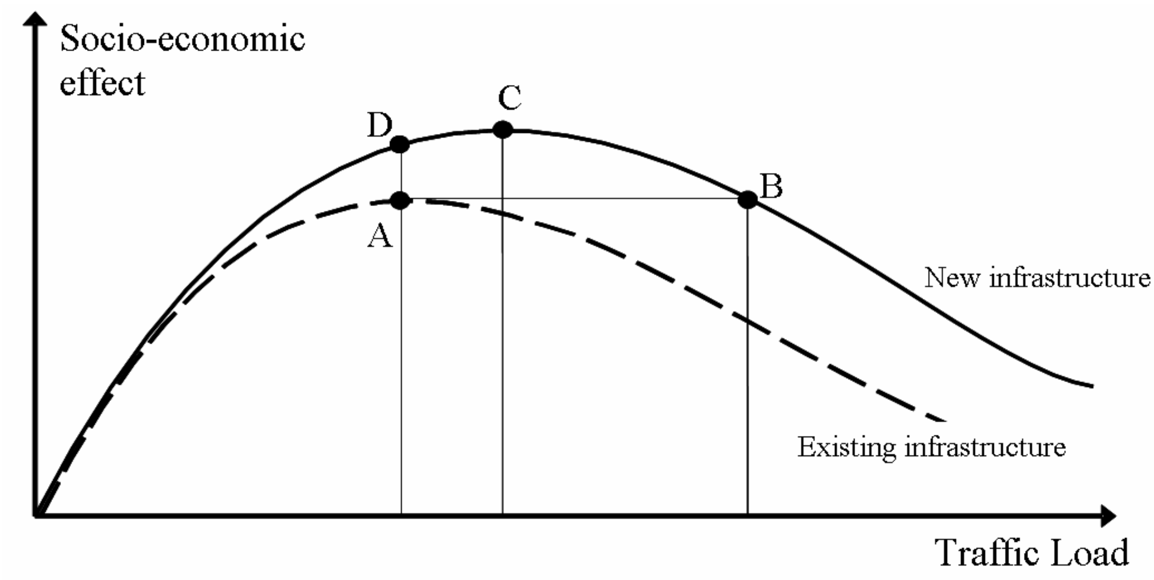


**Figure 10.1 Socio-economic effect of an infrastructure project depending on traffic load (Landex, 2003)**

If the traffic load of the new infrastructure is increased beyond the socio-economically optimal situation (C), the socio-economic effect will begin to decrease as a result of the investment in new infrastructures. If the traffic is increased so much that the socio-economic effect is just as big as the optimal socio-economic effect on the existing infrastructure (B), even a small increase in the number of trains will result in a negative socio-economic effect. Finding the socio-economic optimal traffic load of the infrastructure is an ”iterative” process that requires calculation of various plans of operation and timetable proposals for the new infrastructure. It is therefore not enough to carry out the calculation based on one timetable proposal, even though this is often the case.

The curve representing the socio-economic effect in Figure 10.1 is not static, as external influences can shift the socio-economic utility curve. The ways in which the utility curve can be shifted, with changed socio-economic optimum regarding the traffic load of the infrastructure, is by adding new lines to other destinations or to introduce road pricing. These changes are likely to resemble strategic effects and can lead to more passengers on the infrastructure whereby the utility curve in Figure 10.1 is shifted right upwards. It means that the socio-economic effect will be bigger, but that this effect can be further increased by introducing more departures.

The socio-economic utility curve of the new infrastructure shown in Figure 10.1 can also be changed/shifted as a result of follow-up investments – e.g. extended priority of signalling for a light railway or increased capacity on the existing infrastructure.

## 10.3. Extrapolation of the traffic (general traffic growth)

The socio-economic viability of a project can be influenced by changes in the traffic. Changes in the traffic can occur due to the road users’ changed choice of route as a result of infrastructure changes elsewhere on the network, but also as a result of changed locations of homes and work (perhaps as a result of the infrastructure project). Furthermore, a general traffic growth is seen due to general development within the transportation area.

Traffic growth can cause changed choices of route as a result of capacity problems on the infrastructure, and as a result of (new) capacity problems and/or new infrastructure investments, the modal split (choice of transportation mode) can also be changed. On this background it is not always easy to calculate the socio-economic consequences of an increase in the traffic[5] without proper modelling.

For public transportation it is usually sufficient to calculate the time benefit, as the other benefits/disbenefits are normally constant, since it generally is not necessary to change the traffic supply as a result of more passengers. This is based on the fact that there is normally a certain amount of free capacity in the public means of transportation. For car traffic however, the changes in the other socio-economic benefits/disbenefits must be calculated, as more/less cars have deviated effects on both driving costs and externalities.

A good approximation to evaluate the general traffic growth is however to assume that the time benefit (and other benefits/disbenefits, if any) shows the same increase expressed in percentage terms as the general traffic growth for public transportation and/or individual traffic, respectively. However, if you want to know the traffic growth for more than just the general traffic growth, you have to assess the influence of this traffic growth on the time benefit (and other benefits/disbenefits, if any).

Furthermore, it can be assumed that other effects such as noise, driving costs and particle pollution costs will change over the years, e.g. because of new technology. These effects can also be treated more or less like the traffic growth.

## 10.4. Typical errors and deficiencies

A number of errors and deficiencies are often seen in connection with socio-economic calculations. Below is listed a number of the most common errors and deficiencies made in socio-economic calculations in projects carried out at CTT.

The errors and deficiencies in the socio-economic calculations are often very serious (even though it is only a small error), as the results of the calculations are often used in the conclusion. Some times the conclusions regarding a project are downright wrong, as they are based on an insufficient and/or defective socio-economic evaluation. In this way, projects that are actually socio-economic viable, can be assessed as non-viable, reason why they should not be established.

### 10.4.1. Sign errors

In many cases, socio-economic calculations cannot be made until the end of the project as sufficient data to make the calculations are not available until then. That the socio-economic calculations can only be made late in the project, means that there is less time for quality assurance, and foot faults may occur due to the time pressure.

One of the typical (and often serious) errors in socio-economic calculations is to change the signs, so that benefits become disbenefits and vice versa. The error typically arises because the influence of e.g. air pollution has been calculated without regard to it being a benefit or a disbenefit. When the results of the individual socio-economic calculations are summarized, there is a risk that the influence that is in fact a disbenefit is considered as a benefit because of the missing sign. To avoid sign errors in socio-economic calculations you should therefore always use signs (at least in case of disbenefits). Here ”+” represents a benefit for society, whereas ”-” is a disbenefit for society.

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[5] *Here there is special focus on the general traffic increase*

### 10.4.2. Depreciations

When calculating the operation and maintenance costs it is possible to make the calculation with and without depreciations, respectively. If it is done without depreciations it is a prerequisite that investments in new stock and ”extraordinary” maintenance should be made on a regular basis and that the scrap value is regulated in proportion to the real scrap value of the project. In case of calculations with depreciations you do not have to calculate reinvestments in stock and ”extraordinary” maintenance such as new catenary systems. When calculating operation and maintenance with depreciations it can (roughly) be assumed that the scrap value of the project is the same as the investment in infrastructure and rolling stock, without ”one-off costs” such as cable and pipe rearrangement etc. – cf. chapter 9.7.1. Calculation period and scrap value.

### 10.4.3. Double calculation and omitted effects

Calculation of socio-economic effects should only be made once for each effect, as the effect would otherwise be calculated twice. It can however be difficult to avoid double calculation of socio-economic effects – particularly if unit prices from different sources are used, as some unit prices implicitly can include values/information about other effects. For instance, the valuation of the barrier effect and local urban environment be very correlated, as a good urban environment can include the ”easiness” of passing the infrastructure.

At times it can be difficult to calculate all the effects, and it can therefore be necessary to estimate some of the effects. However, if certain effects are completely omitted, it can distort the results of the socio-economic evaluation. For instance it will some times be possible to obtain a very big distortion, if the externality effects for bus service reduction are included without evaluating the operation savings.

Especially for public transportation there may be problems with “forgetting” means of transportation and routes, as it in reality corresponds to omitting effects. If for instance a bus route that runs in parallel with a new light rail on half of the route, is eliminated completely instead of being shortened, the passengers on the other half of the route will have to find alternative routes that take longer time. The longer time contributes negatively to the socio-economic analysis, and at worst it can convert a socio-economically good/positive project into a socio-economic bad/negative project.

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