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Swedish experiences from LCC-calculations for pavements

Abstract

There is a trend to work with the influence of roads on the whole society. The quality level, and the initial investment cost, for pavements and road superstructures, should therefore be grounded on Life Cycle Cost analysis (LCC). LCC or Whole Life Costing (WLC), is described in a PIARC document (ISBN: 2-84060-114-1), written by the author of this paper. LCC analyses are often grounded on an economic model, which is called the Net Present Cost (NPC).

This paper will prove that NPC is not either logical or mathematical correct. In spite of this, the NPC model is also more or less used in many countries (USA, Great Britain, Sweden, South Africa etc.)

Some consequences are:

- The use of the NPC model gives unnecessary high maintenance costs, and also an inferior society economy!
- High quality pavement, with good values on the surface characteristics, and small maintenance costs, like concrete pavements, are treated unfairly!
- Countries, with high interest rate (12-14%), have to build roads with a very low quality, which gives very high maintenance costs in the near future, which is very bad for their economy in a long view.

The paper also describes how Sweden works with LCC in the comparison between Asphalt and concrete pavements."

1 Background, the public sector

Income acquired from taxes should be used in the most effective way. Hence, cost/benefit analyses are performed in many countries to compare the advantages in the different ways of using this source of income. However, it is very difficult to measure the benefit in different parts of the public sector.

Although some activities are of major socio-economic benefit, it is difficult to determine the connection between those who are to pay for the benefits and the real cost of these activities. Hence, these activities are paid for with public funding.

A public authority, which is allocated public funds for its activities, is responsible for ensuring that these funds are used in a way that is of most benefit to society while providing the best economic return on investment. For a road manager, this means building roads where they are of most benefit to society, and also at a level of quality that ensures an optimal investment in road capital.

2 Financing and capital costs

2.1 Example, comparison between cost to society and pavement costs

A comparison between the impact on society and the cost of a pavement can be described by the following example. A specific road has the following conditions: an ADT of 17.000 vehicles, of which 2 000 are lorries. A car has an average speed of 100 km/h and a lorry 80 km/h. The average cost for a car is 0.3 Euro/km and the cost for a driver is 0.1 Euro/km. An average cost for a lorry is 100 Euro/hour. The cost of accidents and environmental impact can be estimated at 0.15 Euro/km. The annual cost of traffic on a pavement with a 20-metre cross-section (motorway standard in Sweden), is 200 Euro/m^2. Thus, a change of only 1% in traffic costs produces either a benefit or extra cost of 2 Euro/m^2. The average cost of a flexible pavement is 20 Euro/m^2. If this were to be paid for over a period of 20 years, the cost, including normal interest, is less than 2 Euro/m^2. This means an annual cost of the same magnitude as one percent of the cost of traffic. Improvements in the quality of the pavement produce better surface characteristics, such as better friction, less rutting, less roughness, better gradient and less noise emission etc, all of which have an impact on society. This means that improving the quality is also beneficial to society. A complete (100%) improvement of the pavement, for example o concrete pavement, could reduce socio-economic costs by 1-5%. Improvement also means a more durable surface that requires less maintenance, which reduces the cost to society of disruptive road works.

2.2 Examples of the socio-economic benefit of better road surface characteristics

Better road surface characteristics reduce socio-economic costs; e.g.,

Better skid resistance means a shorter braking distance and better road safety, even when the skid resistance is increased above a limit value, for example 0.5.

- Roughness and ruts reduce comfort and average speeds, jeopardise road safety and entail higher vehicle costs. Lower average speeds could result in better road safety, which might give the impression that roughness and ruts promote road safety. However, if a reduction in the average speed is necessary, a country ought to have better means at its disposal than road roughness and ruts, which at the same vehicle speed impairs road safety while increasing vehicle wear and fuel consumption.

- Gradient, surface damage and lightness, etc affect road safety, average speed, vehicle costs, etc.
- The micro, macro and megatexture of the road affect the noise emission caused by wheel/road contact.

One example is that improving skid resistance from 0.5 to 0.8 means decreasing the braking distance from 60 to 40 metres at 90 km/h. Needless to say, this improves road safety.

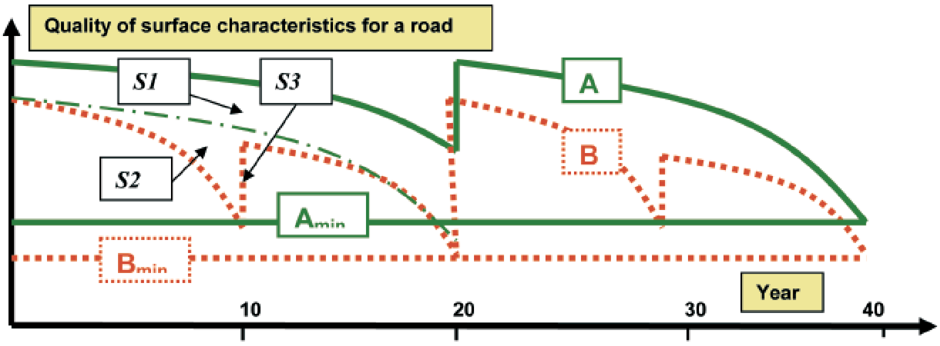
The following illustrates what people are willing to pay for comfort. If a normal car costs 14.000 Euros, and is paid for over a period of 10 years at 5% interest, the total cost of the car will be an average of 1.750 Euro/year during that period. A car lasts 15 years, and it covers a distance of 14 000 km/year on average. This means a cost of 5/60 Euro/ km. For 15 000 cars per day, this would be 23 Euro/m^2 and year. About half the population in Sweden drive more expensive cars than this, with a normal price being 28 000 Euros. This means that about half the population is willing to pay 23 Euro extra per m^2 road surface and year for this comfort and vehicle safety, which could be compared to a normal surfacing cost of 2 Euro/m^2 and year.

If the average vehicle speed could be increased by 2 km/h without affecting the other costs, the reduction in the cost to society is 2/100 km/h = 2 % for the time cost for cars and 2/80 km/h = 2.5 % for lorries. This makes 1.7 Euro/m^2, which is the same as a 0.85 % decrease in the cost to society, which is about the same as the cost of the investment in the pavement.

These examples indicate that road surface characteristics have a major impact on socio-economic costs, and that a change in the surface characteristics will also entail either a benefit or cost to society.

The surface characteristic values depend on the amount invested in quality and the age of the road and bound layers. (See Figure 1).

Figure 1: Relationship between the quality of the yearly deterioration of bound layers and surface characteristics



3 Measurable performance which affects socio-economic costs

Different surface characteristics have an effect on road safety, travel times for road users, vehicle wear and tear, environmental impact, etc. Positive characteristics from a road safety perspective can however, when followed up, indicate a negative repercussion on road safety through making higher speeds possible. It is important to separate these types of effect if road investments are to optimise safety. If the vehicle speed should be reduced for safety reasons, other more effective means than dangerous surface characteristics should be employed.

For more information about performance, function and valuation of the function, see ref. [4].

3.1 Roughness

Roughness should primarily be measured and recorded as a deviation from a straight line. Input data from these measurements can be analysed with regard to the length and amplitude of the wavelengths, speed limit etc.

An analysis of the longitudinal and transversal roughness, including these in combination, can be used to study how the road surface condition affects all vehicles in the vehicle fleet, and also how roughness affects road safety.

There is a relationship between longitudinal roughness and road user comfort, vehicle wear and tear, fuel consumption, vehicle speed and road safety.

3.2 Ruts

There are four main causes of rutting on asphalt pavements:

- Wear from studded tyres in the winter.
- Flow rutting in the asphalt layers due to the action of large wheel pressure (super single tyres), especially during hot summer days.
- Plastic deformations in the asphalt layers.
- Plastic deformations in the unbound materials.

For concrete pavements, the only cause for rutting is wear from studded tyres, and a concrete pavement is much more resistant against wear than the asphalt pavement.

There is a relationship between transversal roughness, mainly the ruts, and road user comfort, vehicle speed and the risk of aquaplaning (road safety).

3.3 Gradient

There is a relationship between the gradient of the road and rainwater run-off. The thickness of the film of water on the road surface is related to the risk of aquaplaning, and thus road safety.

A concrete pavement, with a surface of exposed aggregate, has good characteristics against aquaplaning.

3.4 Cracks and damages

Cracks have no greater impact on road users, road safety, etc.

There is a relationship between road surface damage and road user comfort, vehicle wear, fuel consumption, vehicle speed and road safety.

3.5 Friction (skid resistance)

There is a relationship between the friction on the road surface and road safety.

3.6 Micro, macro and megatexture (noise)

Macro and mega texture primarily have an effect on the noise from wheels generated in traffic, but also on the rolling resistance, and thus fuel consumption and pollution. The macrotexture also affects the drainage of water from the road surface. Good drainage improves the friction and thus road safety. Microtexture affects friction.

3.7 Lightness of the road surface

The colour of the road surface, especially the degree of lightness, affects the visibility conditions for drivers during hours of darkness. Hence, the lightness of the surface affects road safety.

A concrete pavement is normally much lighter than an asphalt pavement.

4 Economic models

It is important to recognise the different underlying premises when choosing economic models for various purposes. The model ultimately chosen should provide information on the costs and benefits for society, which can be used when comparing different alternatives. This comparison results in important decisions concerning the level of investment for pavements on new roads and also helps determine the maintenance strategy.

The optimisation of cost and benefit for a pavement ought to include how better quality, together with greater financial investment, should benefit society as differences in effect from better surface characteristics and less maintenance work. See reference [8].

4.1 Optimisation of road capital

The road manager knows that there are benefits related to a better pavement, but it is impossible to describe this relationship. In this situation, the best way to use funds could be through the optimisation of road capital and ignoring the cost/benefit for society. In order to do so, a level of investment should be found that results in the lowest investment and maintenance cost during the life span of the road. The difference in cost between two pavement alternatives is calculated, which produces different maintenance costs. No interest cost is included in the model due to insufficient knowledge about the relationship between revenue and expenditure that would pay for the interest and depreciation. This model was commonly used 20-30 years ago.

4.2 Optimisation of socio-economic result, investment calculation with the net present value model (NPV)

A calculation model that is often used internationally is the Net Present Value model (NPV), which provides the present-day value of all costs and benefits, instead of calculations including interest. To obtain present-day values, all future costs and benefits are reduced by the effect of the interest. In this model, all costs and benefits are multiplied by the factor $(1\text{-}r/100)^n$, where r is the interest rate and n is the number of years after the investment was made. This model enables a comparison between the present value of costs and benefits for different alternatives.

This model has some disadvantages. For instance, a human life is given different values depending on when an accident occurs. Another example is that finite resources also have different values depending on when they are used; i.e., according to the model, more than the total existing amount of resources can be used if this is relegated to the future.

4.3 The Net Present Cost model (NPC)

It is very difficult to measure small differences, like 1-5 % in the cost to society, a cost, which nonetheless is large, but cannot be estimated with any great degree of certainty. Due to the difficulties involved in estimating the magnitude of the benefits to society, such as better road safety, a better environment, lower user costs, better comfort, etc, these effects are neglected in many countries and a zero is assigned in the calculation. One reason for this is that it is not possible to measure a value outside the statistical variance. In spite of this, many road administrations still use the economic model with Net Present Value (NPV), but without benefits. It is then called the Net Present Cost (NPC) model. Their justification is that the funds could be used somewhere else, for example for new roads, where they provide a benefit to society in the terms listed above. This is highly questionable. One obvious question being, why it is possible to estimate the same benefits to society of new roads and not pavement quality? If all the revenue, or even parts of it, are disregarded, and if despite this the NPC model is used with an interest rate on the road manager costs only, the outcome is that a lower investment cost will be advised. (This is due to the fact that the interest rate reduces the maintenance costs in the model). This results in the choice of a lower level of quality, higher total costs for the road manager, and also higher costs for society. The strategy involving the use of NPC gives, quite naturally, higher maintenance costs in the future, which also could be a problem, due to the lack of funds for this.

4.4 Conclusions

- There is a clear relationship between the benefit to society and interest costs in an economic model. It is wrong to exclude only one of these costs or benefits in an economic model intended for cost/benefit analysis.
- A pavement on a new road provides benefits through the decreased cost of traffic for society, and improving the pavement provides extra benefits through a greater decrease in this cost.
- The NPC model ignores these last benefits, and provides the information that the saving in investment costs could be used for new roads where there would be benefits through a decreased cost of traffic for society, the same benefits that the model ignores for an improved pavement!
- This means a recommendation that the optimal investment level should be calculated using a socio-economic model only when it is possible to calculate all costs and benefits for society.

Other important conclusions:

- Unnecessarily high maintenance costs without better socio-economic results will be obtained if the NPC model is used. In almost every case, the opposite result will probably be obtained, including poorer socio-economic results.
- The most important conclusion is that it is wrong to conclude a zero decrease in cost to society when the quality and surface characteristics of a pavement are improved. If it is not possible to estimate the revenue, a NPV model that assumes both cost and benefit should not be used, and absolutely not a NPC model that shows a negative return on investment, both for the road manager and society.

4.7 Example

4.7.1 Optimal road capital

In order to get an optimal road capital, the calculation should include all real incomes and costs in the road administration or the company.

When a road administration gets money through a budget or borrowed money, the "administration" (or the company) gets a limited amount of money over a period of for example 20-50 years. If you shall optimise the road capital, all real costs for one project during this period ought to be minimised. Therefore it is possible to optimise the road capital for one project through a "Whole Life Costing" analyse and minimisation of all real costs for the project. It is also possible to optimise the quality level for rules and recommendations on a strategic level.

In order to optimise the road capital, the correct choice of economic model is:

- "Calculation of all costs (except interest rate)" when the administration is financed with help of a budget.
- "Calculation of all costs (inclusive interest rate) and loss of benefits"

when the road is financed with borrowed money" and income from road users.

See also ref. [3] for more information about similar examples.

4.7.2 Example, comparison between asphalt and concrete pavement

Two different pavements are chosen and only the client's costs are compared. The first alternative, A, is a concrete pavement, which have only small problems with high axle loads, "super single" tyres and wear from studded tyres on a road with high volume traffic. The second alternative of pavement, B, is an improved flexible pavement (compared with the Swedish code for roads) for a road with high volume traffic.

Alt A consists of a 200 mm thick concrete pavement, where 50 mm of this is a wear resistant concrete in the surface, and 150 mm cement bound layer, with an estimated cost of 38 Euro/m^2. This pavement is thicker than alt B, which gives a cost reduction of 3 Euro/m^2 for the need of extra unbound material in alt B. This gives a cost for comparison of (38-3) 35 Euro/m^2. For this type of pavement you perhaps have to exchange the performed rubber sealing for a cost of about 4 Euro/m^2. The pavement maintenance cost is 4x12,5/40=1,25 Euro per year and m if the road is 12,5 m broad.

Alt B consist of a 40 mm thick surface layer with wear resistant aggregate, 80 mm binding layer and 110 mm bitumen bound layers with an estimated cost of 27 Euro/m^2. For this type of pavement you have to make a new surface pavement every tenth year for a cost of 5 Euro/m^2. The pavement must be strengthened after 20 years for an extra cost of 5 Euro/m^2. The pavement maintenance cost is 20x12,5/40=6,25 Euro per year and m if the road is 12,5 m broad.

- Total cost over 40 years is 47 Euro/m^2 for alt. B and 39 Euro/m^2 for alt. A. In this case you should choose alt A, the concrete pavement.
- Total cost with borrow money for investment and repair with 5 % interest rate, gives a cost over 40 years of 79 Euro/m^2 for alt. B and 76 Euro/m^2 for alt. A. In this case you should also choose alt A, the concrete pavement.
- Total fictitious cost, with the NPC model, where you discount the cost for repair with 5 % interest rate over 40 years, is 35,0 Euro/m^2 for alt. B and 36,5 Euro/m^2 for alt. A. In this case you shall choose alt B, the asphalt pavement.

Now you can make the following prerequisites:

- Pavement cost is about 15 % of a total road project cost.
- From this follows that 30 % increase of pavement cost gives 4,5 % increase of the project cost.
- A country (Sweden) has 8.000 km trunk roads and construct 200 km new trunk road every year.
- Average total construction cost is 3.000 Euro per m road.
- Average maintenance cost for pavement (alt. B) is 6,25 Euro per m and year.
- 30 % increase of the pavement cost gives an average maintenance cost for concrete pavement (alt. A) of 1,25 Euro per m and year.

This gives, for alt. B, a construction cost of 200.000 x 3.000 = 600 million Euro per year and the pavement maintenance cost is 8.000.000 x 6,25 = 50 million Euro per year.

This gives, for alt A, an extra construction cost of 600 x 4,5 % = 27 million Euro per year and the pavement maintenance cost becomes reduced with 8.000.000 x (6,25-1,25) = 40 million Euro per year.

The result of these different strategies, in the continuous business of a road administration, is that the choice of alt. A, a concrete pavement, gives a yearly saving of 40 - 27 = 13 million Euro every year in comparison with alt. B, the asphalt pavement.

5. Whole life costing

Roads exist for the benefit of society, and are primarily financed by taxes. This makes it relevant to calculate all the socio-economic costs when calculating the total cost of a road during its lifetime.

"Whole Life Costing" (WLC) (or Life Cycle Cost analysis (LCC)) is such a system and is used to compare different design and construction alternatives for different parts of a road construction.

A WLC system can be used as a tool for choosing the most economical solution for investment, repair and rehabilitation work or maintenance strategy. It can also be used to put a value on the benefit derived from using in-house design proposals, new materials, new techniques and the recommended quality standard specified in tender documents and on a road handed over by a contractor.

WLC for pavements is a calculation model that can be used to compare the cost for the owner, the user, the society and the environment (see also references [1] and [2]) of different designs for pavement structures and surfacing over the entire life of the road. The WLC model should build on functional characteristics of the road surface, and sound economic models, which are described in chapter 3 and 4.

A Whole Life Costing system consists of a computer model with a program for optimisation and presentation of the total amount of different costs, and several different modules for calculating the different costs in the model. The modules consist of many components, which can be parameters (values) and less extensive calculation models. Any component can be used in several modules. The period of analysis must be sufficiently long, meaning at least 35-40 years, perhaps even 50 years.

If the intention is only to compare different pavement structures and surfacing, it is not necessary to perform a calculation with all these costs and other circumstances. In a WLC model, costs and other circumstances that are different for various pavement structures and surfacing should be used.

The input data in a WLC model could consist of (ref [1]):

- General data like road geometry and all different unit costs etc.
- Traffic.
- Prediction of future surface characteristics or a reliable deterioration model..
- Maintenance strategy.
- Road management costs like investment costs, maintenance costs and rehabilitation costs etc.
- Road users cost like travel time, comfort, fuel consumption and vehicle wear.
- Road accidents costs.
- Environmental costs.

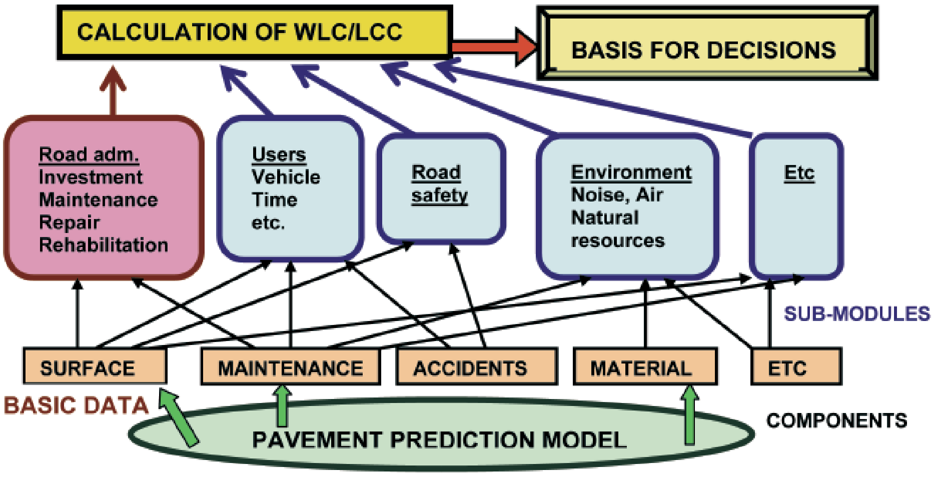


Figure 2: System for calculation of "Whole Life Costing" (WLC)

6. Comparison between concrete an asphalt pavements in Sweden

6.1 Comparison in tender documents for road construction projects

Since eight to ten years about twenty motorway projects (ca. 400 km) have been chosen as suitable for concrete pavements in Sweden. For about ten of these projects, the decision has been done in connection to the choice of contractor during the procurement process. For these projects, the contractors have given two different prices in the tenders, one price for asphalt pavement and one price for concrete pavement. A concrete pavement is more durable and need less maintenance then an asphalt pavement. A concrete pavement is also favourable from view of the society costs. Therefore the permissible difference between asphalt and concrete pavements were decided in advance for these projects. In order to calculate the differential costs, a special model for comparison is used, which is described in reference [5].

6.2 The Swedish model for comparison of pavements

During 1997, SRA issued a memorandum that contained changes in the socioeconomic factors, which are dependent of the pavement.

In this memorandum, the following recommendations are given:

- The same appraisal and valuation grounds should be used in all regions.
- When planning the operations, space should be allowed for the concrete road alternative. One of the valuation models described in the report should be used as an aid.
- In the valuation of different pavement alternatives, consideration should also be given to cost types other than the investment cost.
- The pavement designs that are compared should be of technically comparable design.

- The choice of payment type should be guided by factors such as the traffic loading, length of the object and road type. In addition, the intervals between maintenance and the choice of maintenance measures are important parameters. If any lane in the object is in traffic class 5 - 7, both flexible and rigid pavement designs should be checked and considered.
- When different pavement types are compared, the technical useful life should be the same for both designs. As an alternative, the design with the shorter useful life should be produced so that it will achieve the longer useful life.
- No routines are currently available for carrying out residual value appraisals. Such routines should be developed by the Finance Department. In addition, there are no valuation models for valuing the comfort impairment to which the road user is exposed when the road structure is degraded.
- The way in which valuation of the environmental impact is to be carried out should be developed, e.g. the possibility of reusing bonded material, how the environment is affected by factors such as noise caused by the pavement, etc.

The model is described in the following way in [5]:

6.2.1 General

The National Road Administration Publication 1991:053 “Model for present valuation calculation of the life cycle cost of a road”, reference [6], includes a model (MNV) for comparison between concrete and asphalt. The MNV is presented in the publication as an Excel file. The model is described in detail below.

6.2.2 Model description

The MNV calculates the building cost, maintenance cost, operating cost, road-user cost, vehicle cost, accident cost and environmental cost for flexible and rigid pavements for a road object. The costs and present values are presented.

The MNV has been modified, since it originally contained wear and abrasion relationships that were not validated. All such relationships and calculations have now been removed from the file.

6.2.3 Input data

6.2.3.1 General

The input data block is divided into two parts, i.e. the data that is common to both pavement types, and the input data that is unique to each pavement type.

6.2.3.2 Common input data

Brief description of the project name, heading and date.

Road data related to the length, surfaced width, speeds, etc. of the stage. The price level and opening year can be entered as information for those who read the results.

The traffic data with particulars of AADT_{tot} for the opening year, proportion of winter traffic/studded tyres (only as information for those who will later be reading the calculation results), traffic mix, i.e. distribution onto passenger cars, heavy traffic, proportion of traffic in the right-hand lane, and traffic development.

6.2.3.3 Building costs

Two different building costs can be calculated by means of the MNV, i.e. a standardized building cost based on per-item prices for the component building parts, and a detailed building cost based on the structures being described exactly and then priced.

6.2.3.4 Maintenance cost

The maintenance measures that are expected to be used during the useful life of the road object shall be given here. The model then calculates the maintenance cost for the pavement types.

These costs are highly dependent on the maintenance intervals, prices of materials, capacities of the machines, etc. A relatively small change in capacities may have very great consequences on the costs, since the road-user costs and accident costs are directly linked to the length of time during which work on the road is in progress. This can be compared with the change in speed past the road works area.

The road works being done when the traffic loading is low, such as at night, can be credited in the model by a somewhat excessively high capacity being specified for the work. The capacity increase must be proportionate to the reduced number of road-users affected. The problem is related to the fact that the AADT dimension describes the number of vehicles per 24 hours and not how the vehicles are distributed over the 24-hour period. In the Netherlands, problems are caused by queues forming at road works during the night.

6.2.3.5 Operating costs

Per-item prices are specified here for work such as snow clearance, anti-skid measures, washing of road signs, minor joint repairs, sealing, etc.

The differences in the operating costs between asphalt and concrete wearing courses must be validated if different factors are to be used.

6.2.3.6 Road-user costs

The time cost that the road-user "pays" when using the road is entered here. The road-user cost consists of two parts, one of which applies to normal use and the other to the use during road works. This is basically a journey time calculation. The input data for this section is taken from [5] or [6]. The journey time for a passenger car and truck has been increased in the report by a cost of capital of 4% from the 1993 level to the 1996 level.

6.2.3.7 Vehicle cost

Vehicle costs arising when the road is used. The breakdown into partial costs can be obtained from [7].

These costs take into account how the road causes wear of the vehicle. The costs are affected by the number of vehicles that pass the road section every day. At the present time, no differences in vehicle wear can be shown between vehicles that use rigid pavements and those that use flexible pavements.

6.2.3.8 Accident costs

Accident ratio during normal use, when road works are in progress, and a per-accident price for each accident are specified.

The accident cost is calculated by "accident ratios" that describe the number of accidents per million vehicle-kilometres. Publication 1991:053 refers to a British study, according to which the risk of an accident in a road works area is 1.5 times the normal.

6.2.3.9 Environmental cost

The environmental costs related to noise and exhaust gases are calculated by means of an estimated number of persons affected and a per-time price for each of them.

These do not change with changes in the general input data. This is because the model takes into account the number of persons who are affected by the road. The environmental costs must therefore be adjusted directly in the environmental cost part of the relevant surfacing. At the present time, the environmental cost parts are very difficult to value since there is no unambiguous model for this purpose.

6.2.4 Comments on MNV

At the present time, the MNV serves as an aid for calculating the direct costs and the present value costs of different pavement alternatives. The model is simple to use and quickly gives particulars of the order of magnitude of the components costs.

In certain parts, the MNV is very inflexible, and these parts should therefore be developed further. The environmental costs are a typical areas in which there are shortcomings.

The MNV requires the user to input manually factors such as accident frequencies, capacity data, etc. This demands that the input data should be up-to-date and relevant.

The order of magnitude of the calculation results when the MNV is used is around SEK 5 billion and above. This is because the MNV calculates the "total road rent" for the object, i.e. also "normal use" of the road. This generally means that the differences between the alternatives are not regarded as something significant. However, this can be remedied by calculating the differences between the various cost types.

6.2.5 Not included values in MNV

The knowledge available today concerning the various cost types calculated in the model described in "Model for present value calculation of the life cycle cost of a road" enables the following conclusions to be drawn:

- No differences between flexible and rigid pavement as regards vehicle wear, increased risk of accidents, and greater environmental impact can be given today, and their costs are therefore assumed to be the same
- Differences between different pavement types arise only in maintenance work.

In reality, this is not true. We know that there is less rutting on a concrete pavement. The concrete pavement is also lighter, which improves the traffic safety, especially during the nights. This means that a concrete pavement gives a better socioeconomic benefit than an asphalt pavement during the lifetime. A very small difference in these costs, for example only one percent, is of the same magnitude as the investment cost for the pavement.

6.3 Results from the procurement

In the competition for about ten different motorway projects, two were chosen with concrete pavement and the rest with asphalt pavement. Some reasons for this are probably:

- The contractors have not enough with knowledge about the concrete pavement technique.
- The contractors have asphalt pavement plants and equipment for paving asphalt pavement.
- The equipment for paving concrete has to be borrowed fro abroad.

7 Summary and conclusions

The road network in a country takes an essential part of the public funding. It is therefore important to choose the most optimal investment level, in order to minimise those costs for a government in a country.

The roads also have a large influence on the benefits and costs for the society for all transports in a country. It is even more important to choose an optimal investment level in order to minimise all costs for the society.

For the pavements of the roads, it is therefore important to choose the most optimal quality level on investments, reinvestments and maintenance.

Here comes some advises, with the earlier text as a background:

- There is a clear relationship between the benefit to society and interest costs in an economic model. It is wrong to exclude only one of these costs or benefits in an economic model intended for cost/benefit analysis.
- A pavement on a new road provides benefits through the decreased cost of traffic for society, and improving the pavement provides extra benefits through a greater decrease in this cost.
- The NPC model ignores these last benefits, and provides the information that the saving in investment costs could be used for new roads where there would be benefits through a decreased cost of traffic for society, the same benefits that the model ignores for an improved pavement!
- This means a recommendation that the optimal investment level should be calculated using a socio-economic model only when it is possible to calculate all costs and benefits for society.
- Unnecessarily high maintenance costs without better socio-economic results will be obtained if the NPC model is used. In almost every case, the opposite result will probably be obtained, including poorer socio-economic results.
- Developing countries are dependent on loans from the World Bank and other institutions. With the very high interest rates (12-14%) involved, this means that these countries have to build roads of very low quality, thus entailing very high maintenance costs in the immediate future. This is not good for their economy or the development of the road network.
- The most important conclusion is that it is wrong to conclude a zero decrease in cost to society when the quality and surface characteristics of a pavement are improved. If it is not possible to estimate the revenue, a NPV model that assumes both cost and benefit should not be used, and absolutely not a NPC model that shows a negative return on investment, both for the road manager and society.

Experiences from Sweden reveal that it is possible to take all LCC costs into consideration during the procurement process for new projects. In order have a fair competition between the different alternatives, the Swedish MNV model ought to be improved.

8 References

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