Norwegian Road Network Strategic Assessment:
Re-examining the Estimation of Costs and Benefits of Investments in Road Transport in Norway

Final Report

Prepared for

Norwegian Road Federation

Prepared by

Cambridge Systematics, Inc.

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Date

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Glossary

AAA	American Automobile Association
AIS	Accident Injury Severity
AMCB	Analysis of Monetised Costs and Benefits
ADT	Average Daily Traffic
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CPI	Consumer Price Index
DECC	UK Department for Energy and Climate Change
DfT	UK Department for Transport
EPA	US Environmental Protection Agency
ETS	Emissions Trading Scheme
GBP	Great Britain Pound
GDP	Gross Domestic Product
IRR	Internal Rate of Return
KPH	Kilometres per Hour
NOK	Norwegian Kroner
NPV	Net Present Value
NPRA	Norwegian Public Roads Administration
NTP	National Transport Plan
PMC	Pavement Maintenance Cost
SCC	Social Cost of Carbon
SPI	Noise annoyance index used in the UK
TGB	UK Treasury Green Book
VOT	Value of Time
VOC	Vehicle Operating Costs
VTTS	Value of Travel Time Savings
VSL	Value of Life Statistical
VKT	Vehicle Kilometres Travelled
VHT	Vehicle Hours Travelled
WTP	Willingness to Pay

1.0 Introduction

1.1 Study Objectives

There is a view among Norwegian business and industry and in some segments of the road sector in Norway that there have been years of underinvestment and a lack of prioritization in maintaining, upgrading, and expanding the Norwegian road network. This has resulted in a road network that is not adequate for meeting the current and future road transport needs of the Norwegian economy and society – the capacity of the road network is limited and the poor quality of this network results in low travel speeds on Norwegian roads. In considering their investment decisions, the relevant Norwegian authorities carry out cost-benefit analysis of investment projects. However, the adequacy of the models used to estimate the various costs and benefits of these investment projects is increasingly being called into question.

The Norwegian Road Federation commissioned Cambridge Systematics to conduct a high level analysis of the costs and benefits associated with investing in the road network in a more focused and prioritized manner.

Thus, this study has two strategic objectives:

1. Explore the case for making additional investments in priority corridors to maintain and expand the capacity and quality of the road network in Norway
2. Critically review the current approaches and methods used for estimating costs and benefits and propose alternatives, reflecting the current state-of-art, for estimating the long-term indirect economic effects of investments in road infrastructure.

To achieve these objectives, the work undertaken for this study included a comparative literature review of benefit cost analysis in Norway and other countries and applying the state of the art approach to estimate the costs and benefits of various roadway investment scenarios. For this study, four scenarios representing a "do nothing" plan, a "business as usual" plan, a "change the mix" plan and "invest in future" plan were developed. Traffic projections were developed under each scenario, allowing for the estimation of user benefits. The user benefits are then used to estimate a benefit cost ratio for each investment plan.

In reading this report, the reader should bear in mind that this study is a high level study and the analysis represents a high level, or sketch planning analysis that utilizes trend forecasting and generalization of traffic from representative corridors to the system as a whole. Thus, the analysis presented in this report cannot, and is not intended to, substitute for detailed project level analysis required for final decision-making about individual projects. The analysis in this study was carried out to demonstrate the potential benefits that could accrue to Norway if alternative approaches were applied to the estimation of costs and benefits on which investment decisions are based, and by using a different set of priorities than what are currently used. Thus, the analysis in this study is focused on the two strategic objectives described above and not on the detailed estimation of costs and benefits of individual investment scenarios.

1.2 REPORT ORGANIZATION

The remainder of the report is organized as follows:

- Chapter 2 provides a summary of the review of the literature on benefit cost methodology that informed the methodology used to carry out the analysis described in this report.
- Chapter 3 details the four investment scenarios, describes the traffic forecast methodology and presents the findings for each scenario in terms of vehicle kilometres travelled, vehicle hours travelled and delay.
- Chapter 4 presents the benefit cost methodology, including all key assumptions and data sources and details the benefit cost results for each scenario.
- Chapter 5 discusses the conclusions that can be drawn from the work that has been presented as part of this report for conducting and using Cost Benefit Analysis.

2.0 Review of Guidelines for Cost Benefit Analysis

This section reviews guidelines for conducting cost benefit analysis (CBA) for transportation projects in Norway, United Kingdom, and the United States. The purpose of the review is to compare Norway's CBA methodology with that of the other selected countries in order to identify the strengths and weaknesses of the Norway's CBA methodology. This review will also provide insights for improving upon the current methodology with an eye to capturing the wider economic benefits resulting from investments to improve transport.

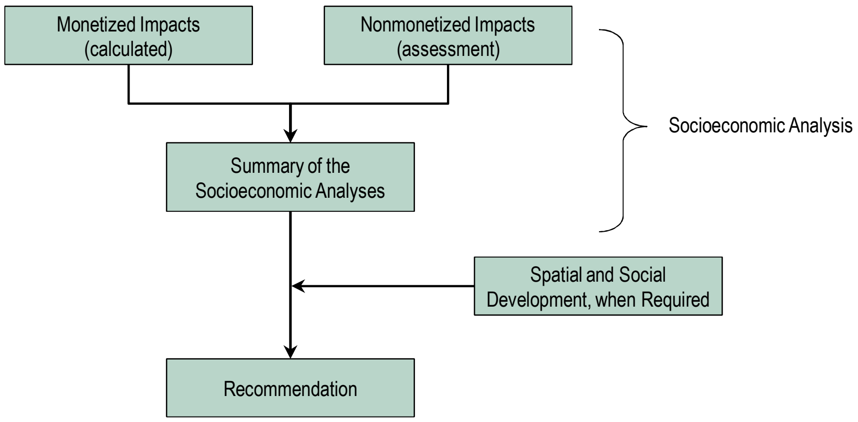
Relevant sections of the various national CBA guidelines are summarized and discussed below. The discussion primarily focuses on the quantification of economic benefits and associated costs.

2.1 NORWAY[1]

The Norwegian Public Road Administration's (NPRA) Handbook 140 provides the CBA guideline for transportation improvement. The Handbook is provided only in Norwegian; therefore a web translator was employed to translate relevant portions into English for analysis. Figure 2.1 shows a graphical overview of Norway's impact assessment for transportation improvements.

1 Norwegian Public Roads Administration, Impact Assessment of Road Transportation Projects.

Figure 2.1 Norway's Impact Assessment Process



Source: NPRA Handbook 140.

According to NPRA Handbook guide, monetized impacts are estimated using in-house software developed by the NPRA. Although the economic theory underlying the software is not outlined in the NPRA's Handbook 140, it does provide some details on the methodology employed. The NPRA Handbook indicates that estimation of monetary benefits is based on changes in monetary values of costs and benefits (cost benefit analysis) attributable to four main groups of stakeholders[2]:

- Transport users;
- Operators;
- Government; and
- Third parties (Externalities).

Transportation User Benefit

The guideline defines transportation users as both travellers and buyers of freight transportation services. Transport users are divided into five travel groups: driver, passenger, public transport user, cyclist, and pedestrian and three trip purposes: business, commute, and leisure. Transportation user benefits include changes in:

- Time dependent costs;
- Distance-related vehicle costs;

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[2] The monetized impacts are estimated as gross costs (market price, including taxes and duties).

- Other transport user costs; and
- Inconvenience cost in ferry connections.

Time-Dependent Costs

Travel time cost is a function of travel time and value of time for auto, ferry, and freight trips. For auto, value of time varies by trip purpose as follows:

- Business trips: The average salary for the employee plus overhead;
- Personal trips. Personal trips comprise leisure trips and commute. For each of these, the value of time is based on survey. The surveys reveal road-users willingness-to-pay (WTP) to save travel time. Results of survey conducted by (Ramjerdi et al., 1997) and updated by (Killi 1999) are currently utilized. Table 2.1 shows, updated value of times from the aforementioned surveys.
- Value of time for ferry trips by trip purpose are the same for auto trips.
- For freight (truck movements), value of time for heavy vehicles include, wage costs for the crew, idling cost, and a share of capital. Table 2.2 shows value of time for trucks.

Table 2.1 Value of Time for Auto and Bus Trips
NOK 2005

Trip Purpose	Auto	Buses
Business	263	109
Commute	187	70
Leisure	131	68

Source: English Translation of NPRA Handbook 140.

Table 2.2 Value of Time for Heavy Vehicles
NOK 2005

Vehicle Type	Socioeconomic Cost (kr/hour)	Private Economic Cost (kr/hour)
Heavy Vehicles	462	464
Buses	318	321

Source: English Translation of NPRA Handbook 140.

Travel time reliability for public transport and auto trips are currently excluded from cost benefit analysis. According to the guide, if travel time variability becomes a concern for road-users, it would be captured in the travel survey and its effect on travel patterns will be estimated utilizing transport models. The current 2006 transport models do not have the capability to estimate the extent of unforeseen delays.

Unlike other modes, unreliability in ferry services in included in the cost benefit analysis. Unreliability in ferry service stems from excess waiting-time. Excess waiting-time is defined as additional waiting-time beyond the scheduled departure of the ferry. Surveys are employed to estimate travellers' willingness to pay to avoid these excess waiting-times. In areas where ferry provides the only travel option, the estimated willingness-to-pay is adjusted by a factor of 1.5. Unreliability in ferry services is captured in the estimation of travel time in the new transport model (TRAFIKANTEN).

Distance-Related Vehicle Costs

According to the guide, distance-dependent vehicle costs include costs for fuel, oil, tires, repairs and maintenance as well as depreciation. These costs vary by vehicle type. Table 2.3 shows average operating costs for light and heavy vehicles. Vehicle with total gross weight in excess of 3.5 tons are defined as heavy and those less than 3.5 tons are regarded as light vehicles. Taxes make up the difference between the social and the private economic costs. Although taxes are costs to users, they serve as revenue to government.

Fuel consumption by vehicle type is estimated as a function of driving speed, road curvature, and gradient conditions. While fuel consumption estimation for heavy vehicles based on diesel, that for light vehicles is based on distribution between diesel and gasoline vehicles. This approach is applied to forecast future fuel consumption and related emissions. Detailed methodology for estimating these costs is further described in the user guide for transportation model (POWER/EFFEKT).

Table 2.3 Vehicle Operating Costs
NOK 2005/km

	Light Vehicle		Heavy Vehicle	
Cost Component	**Social Cost**	**Private Cost**	**Social Cost**	**Private Cost**
Fuel	0.27	0.69	1.37	2.55
Oil/Tires	0.13	0.15	0.59	0.59
Repairs	0.58	0.70	1.28	1.28
Capital Cost	0.32	0.54	0.49	0.53
Total	1.30	2.08	3.73	4.95

Source: English Translation of NPRA Handbook 140.

Other Transport User Costs

Tolls and Road Pricing. Motorists pay tolls when they pass specific points the road network (cordon toll). Tolls are based on dynamic pricing; they vary by time of day and vehicle type. Therefore, estimation of toll revenue is dependent on the number of collection points, road usage, investment recovery period, and toll structure.

Parking Fees. This relates to the cost of parking, either on public street or private parking.

Transit. Transit costs are determined by the face-value of the transit tickets.

Government Budget Effect

The impact assessment guide defines government budget effect as the sum of all disbursements and payments over all public authority budgets. This includes the state appropriations required by the project and the tax income it generates. For single road projects this represents the investment costs and changes in the operation and maintenance cost over the NPRA's budget as well as changes in the revenue from transport fees. For packages of project initiatives which include rail and public transport systems, the budget effects also include the infrastructure owner's budget and the state and the county purchase of the transport services.

Accidents Costs

Accident cost includes the real cost to society (medical treatment expenses, loss of work, material damages, administrative costs) and loss in quality of life for the injured, family and friends. The methodology for estimating the accident costs are as follows:

- Estimation of number of accidents in the current road network for all years in the analysis period;
- Categorization of accidents types by severity; and
- Estimation of accident costs as product of number accidents, severity, and unit costs.

Registered accidents and injury cases for major road networks (since 1977) are provided by the Accident Register of the National Road Data. For intersections and local roads where accident data may not be available, accident rate is assessed based on empirical data, road standards, and travel speed.

The total economic cost of a traffic accident comprises real economic costs, and victims and family's welfare loss due the reduced quality of life and loss of health or life years. Pricing of this welfare loss is based on people's willingness-to-pay (WTP) to achieve a year of life without loss of health. Based on previous studies, the WTP for risk reduction to avoid death in traffic is estimated to be NOK 18.3 million (price level 2005). Family's welfare loss arising from death in traffic accident is estimated to be 12.5 percent of victims WTP. Table 2.4 shows the total cost (economic and welfare loss) of prevent various degrees of traffic accidents.

Table 2.4 Accident Costs (*NOK 2005)*

Degree of Injury	Cost (kroner per case)
Death	26,500,000
Very severe damage	18,100,000
Severe damage	6,000,000
Light damage	800,000
Material damage	49,000

Source: English translation of NPRA Norwegian Handbook 140.

Production loss is the value of lost production due to deaths and injuries. This can either be permanent (in the case of death and permanent occupational disability) or temporary as in minor personal injury. The value of production loss is calculated using labour income, gender and age plus value of time for home care. For temporary production loss, official accident costs are adjusted for under-reporting.

Noise and Air Pollution

The guide allows monetization of indoor noise and local, regional, and global air pollution. Noise has an adverse effect on health and well-being and may lead to changes in the use of areas.

Monetization of noise and air pollution impacts is based on Ministry of Environment guidelines for planning and Building Act (T-1442: Norwegian Pollution Control Authority). According to the guideline, estimation of noise and air pollution comprises the following:

- The number of housing units and institutional buildings in the (55-65dB) and (>65dB) noise zones;
- Number of people exposed to long-term indoor noise level greater than 30dB and more than 55dB outdoor noise level;
- Noise annoyance index (SPI);
- Number of people exposed to NO_2 and PM_{10} of national targets;
- Emissions of NO_x and CO_2-equivalent in tons; and
- Health impacts of particulate matter in the form of premature death.

The unit price for noise is related to nuisance and it is established to be NOK 12,400 (NOK 2005), based on a study conducted by ECON (2001). Total noise cost is estimated as the product of the unit cost and the number of people affected by the noise nuisance as follows:

- Appropriate noise levels in the opening year is calculated;

- Number of people who are very bothered calculated; and
- Number of very troubled people multiplied by the corresponding unit price

Air Pollution

There is no planning guideline for air pollutants for new roads. National recommended targets set in 2006 are used. The following two approaches have been adopted for estimating air pollution:

- Specific investment measures with limited influence: and
- Measures that provide a general change in the pollution in a wider area.

Local Air Pollution. The most frequently used tools are VSTØY/VLUFT and AirQUIS. AirQUIS (transport models).

Air pollution costs are calculated based on the number of people exposed to different levels of PM_{10} and NO_2 and the level of nuisance. This valuation is based on willingness to pay surveys (Sælensminde and Hammer, 1994). Health costs of air pollution may probably included a small degree of these costs. Detailed approach is outline in the VSTØY/VLUFT user guide.

Alternative approach to estimating air pollution comprises:

- Current pollution levels of NO_2 (hourly average) and PM_{10} (daily mean) in opening year;
- Number of people affected by air pollution;
- Percentage change in pollution levels and unit price basis of change in pollution level
- The change in pollution levels is multiplied by the current unit price the number of sufferers in study region.

Regional Air Pollution. Sulphur emissions are excluded from costs benefit analysis because of the marginal contribution of road traffic. Emission of NOx is estimated in VSTØY/VLUFT and EFFECT and multiplied by the unit price of emission per kilogram to attain the emission cost. Unit cost is based on the cost of achieving the target objectives of the Gothenburg protocol.

Global Air Pollution. Estimate of global greenhouse gas emissions costs is based on the following steps:

- Emissions are calculated both in VSTØY/VLUFT and POWER (transport models).
- N_2O emissions are converted to CO_2 equivalents and added to CO_2 emissions;
- Unit prices of global emissions. Unit price for CO_2 is based on a review of various studies of implicit valuation (SFT 2005).

Residual Value

NPRA Handbook 140 defines the physical life of an infrastructure asset 40 years. However, appraisal period consists of 25 years of the project's lifetime, thus leaving a residual value of the asset there over the remaining 15 years. The residual value is accounted for as a net benefit (positive value)

Discount Rate

The discount rate is 4.5 percent (established in 2006) by The Ministry of Transport and Communications for all projects within the transport sector.

Economic Evaluation

The Net Present Value (NPV) represents the net contribution to society. It is estimated as the present value of project benefits minus the present value of all investment and operating costs. If the NPV is negative, the project is not profitable to the society, because the interest on the investment is lower than the discount rate.

Government's fiscal constraints does not allow for all projects with a positive NPV to be implemented. Therefore, the benefit-cost ratio is utilized to rank projects. Also, the IRR is used only as a supplement to the net benefit-cost ratio.

The NPV and BCR expressions are presented below:

Net Present Value (NPV) = $-I_o + \sum_{t=1}^{n} \frac{b_t - k_t}{(1+r)^n}$

I_o = Present value of construction costs;

b_t = Annual benefit in year *t;*

k_t = Annual costs in year *t;*

r = Discount rate;

n = Appraisal period

Net benefit cost ratio (BCR) = $\frac{(B+P-F+E)}{F}$

B= Transport user benefits;

P = Operator benefits;

F = Effect on government's budget

E = Third party benefits

Non-Monetized Impacts

Non-monetized impacts comprise various impacts affecting various aspects of the environment, namely:

- Landscape, cityscape;
- Community life and outdoor recreation;
- Natural environment;
- Cultural heritage;
- Natural resources.

Unlike, monetized benefits, non-monetized benefits are not discounted to reflect opportunity cost. Value, magnitude, and significance are the basis for evaluation of non-monetary benefits, as discussed below:

- Value: Evaluate how value or importance of an area relative to its environment;
- Magnitude: Evaluate the extent of future changes in these areas and the degree of change caused by the project; and
- Significance: This means a balanced evaluation of the advantages and disadvantages of the project compared to the base case (do-nothing).

2.2 UNITED KINGDOM[3]

This section discusses CBA guideline produced by the Transport Analysis Guide (TAG) Unit of the Department for Transport, U.K. This guideline is prepared in harmony with the provisions of the Treasury Green Book – "The Green Book – Appraisal and Evaluation of Central Government published in January 2003. The guideline includes:

- The CBA methodology to be employed in transport studies;
- Key elements of the framework for calculation of measures of economic worth, including guidance on the appraisal period; and
- Ways of comparing costs and benefits and measures of economic worth.

Cost Benefit Analysis

The Treasury definition of 'cost benefit analysis' is: "Analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value." The summary below, presents all the main impacts of a proposed improvement, including both qualitative and quantitative information (with the latter expressed in either money terms or in other units).

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[3] Department for Transport, Cost Benefit Analysis and Transport Appraisal and The Treasury Green Book -Transport Analysis Guide (TAG Units 3.5.4 and 2.7.1).

The categories of user benefits included in CBA are:

- Transport user benefit;
- Private transport operator benefits;
- Changes in accident costs;
- Changes in environment costs

Presently, monetized cost benefit analysis includes:

- Changes in business and non-business travellers' journey time, vehicle operating costs, fares and other changes;
- Impacts on private sector providers' revenues and costs;
- Changes in the numbers of accidents, but **excludes** impacts on personal and freight security;
- Effects of better transport interchange on traveller journey times but **excludes** other transport interchange quality factors;
- Impacts of noise
- Impacts on greenhouse gases
- Accessibility impacts to the extent that the cost benefit analysis takes account of all significant behavioural responses;

Presently, the guidelines for BCA exclude:

- Journey ambience impacts, although factors such as rail overcrowding, station facilities and rolling stock quality may be included in some studies, and the journey ambience impacts of walking and cycling can also be reported;
- Option values, although these may be included for some rail studies;
- Impacts on local air quality, although the Department expects to publish money values for this challenge in the near future;
- Reliability impacts in the Analysis of Monetised Costs and Benefits (AMCB), as the method for calculating these is still undergoing further study. However, reliability impacts can be included in the summary; and
- Impacts on landscape, townscape, heritage of historic resources, biodiversity, and water environment, as no money values for these have yet been established by the Department.

Transport User Benefits

Transport user benefits comprises

- Travel time savings;
- Changes in vehicle operating costs;

- Changes in accident costs; and
- Changes in environment cost.

Travel Time Savings

This section discusses the value of time for working and nonworking travellers recommended by the Department for Transport (DfT) for use in economic appraisal of transportation projects.

Value of Time for Work Related Trips. Working time values, apply only to journeys made in the course of work (business trips). This excludes commuting journeys. The perceived value of working time is the value as perceived by the employer. The value of time is calculated as being equal to the gross wage rate plus non-wage labour costs such as national insurance, pensions, and other costs which vary with worker hours. A 21.2 percent mark-up for non-wage labour costs used.

Value of Time for Non-Work Related Trips. The values for non-working time apply to all non-work journey purposes, including travel to and from work, by all modes. Commuting is travelling to and from the normal place of work. Other travel is travel for other non-work purposes, for example leisure trips. There is no differentiation between value of time for commuting and leisure travels by mode. The values for non-working time (commute and leisure) spent waiting for public transport is two and a half times the commute and leisure trip values.

Travel Time Reliability. The recommended reliability ratio associated with delay for auto, train, and bus/tram/metro for all trip purposes are 0.8, 1.4, and 1.4 respectively. A central lateness factor of three is recommended for trains. Also for total lateness factor caused by cancelled schedules, multiply 1.5 by service interval.

Growth Rates of Value of Time. The value of non-working time is assumed to increase with income, with an elasticity of 0.8. Working values of time are assumed to grow in line with income, with an elasticity of 1. The measure of income used is GDP per head. In accordance with HM Treasury's Green Book, VOT growth rates for a given year should be modified account for any difference in the discount rate for that year the rate for the current year as follows:

$$VOT_{growth\_modifiedy\ year} = VOT_{growth\_original\ year}\ x\ \frac{rm}{rc}$$

$$rm = discount\ rate\ for\ year\ in\ which\ VOT\ is\ to\ be\ modified$$

$$rc = discount\ rate\ for\ current\ year$$

Vehicle Operating Costs

Vehicle operating costs (VOC) comprise fuel and non-fuel costs. DfT's recommended VOC are discussed below:

Fuel Cost. Fuel cost (pence per kilometre) is estimated as a product of resource cost pence per litre (expressed in 2002 GBP) and fuel consumption. Fuel consumption is estimated based on the function below:

$$L = \frac{(a + b.v + c.v^2 + d.v^3)}{V}$$

Where:

L=consumption, expressed in litres per kilometre

V=average speed in kilometres per hour; and

a,b,c,d are parameters defined for each category of vehicle.

The resource cost of fuel VOCs is net of indirect taxation. The market price is gross of indirect taxation and is equivalent to:

$$Marketprice = (resource\cos t + fuel\ duty)x(1 + VAT)$$

For work related or business trips, the cost of fuel VOC perceived by businesses excludes VAT, since they are able to reclaim the VAT. Consequently, the perceived cost to business include is the cost of resource plus fuel duty. However, perceived cost related to non-work trips is the cost occurred by individual consumer, which is the market price.

Changes in resource cost of petrol and diesel are based on oil price projections published by the Department of Energy and Climate Change (DECC). The changes in each year for the average car reflect changes in resource cost, the forecast increase in proportion of diesel cars, and that the resource cost of diesel is forecast to remain above resource cost of petrol.

Non-Fuel Cost. Non-fuel operating cost comprises oil, tyres, maintenance, depreciation, and vehicle capital saving (only for vehicles in working time). Nonfuel is estimated by the expression below:

$$C = a_1 + \frac{b_1}{V}$$

Where:

C= cost in pence per kilometre travelled;

V=average link speed in kilometres per hour

a_1 is a parameter for distance related costs defined for each vehicle category and b_1 is a parameter for vehicle capital saving defined for each vehicle category (this parameter is only relevant to working vehicles).

Accidents Costs

The impact of casualties differs according to the severity of the injuries sustained. Three groups are usually differentiated; these are defined in the following way:

- Fatality: any death that occurs within 30 days from causes arising out of the accident;
- Serious injury: records casualties who require hospital treatment and have lasting injuries, but who do not die within the recording period for a fatality; and
- Slight injury: where casualties have injuries that do not require hospital treatment, or, if they do, the effects of the injuries quickly subside.

Changes in accident costs arising from transportation investment is estimated using the COBA, a project appraisal tool. Overall accident costs are determined using details of the average accident severity split (that is, the number of fatal, serious, and slight casualties per accident) and the proportion of fatal/serious/ slight accidents.

The value of preventing accidents in future years can be estimated in 2002 prices by expressing the current value of accident prevention in 2002 values and apply a growth rate equivalent to the expected long-term GDP per capita. This is on the assumption that the real cost of each element of accident costs (such as the cost of medical treatment) rises in line with increases in output.

Environment Costs

Noise. The assessment involves two steps. The first, based on the concept of noise annoyance. This measures the change in estimated population who would be annoyed by noise due to the improvement. The second is based on the effect of noise on house prices and involves estimating the present value of households' willingness to pay to avoid transport related noise over the whole appraisal period. Noise below 45dBLAeq is valued at zero. Standard appraisal values based on UK average household income ranges between 45dB and 81dB. The values are expressed in 2002 prices and are assumed to grow in line with real GDP per household. They should be used with a positive sign to value the benefit of noise reductions and with a negative sign to value the dis-benefit of noise increases.

Greenhouse Gas Emission. Valuation of green house emission is based on the Valuation of Energy Usage and Greenhouse Gas Emissions for Appraisal" published by the Department of Energy and Climate Change in June 2010. This publication provides guidance based on the estimated abatement costs per tonne of carbon dioxide equivalent to achieve the government's emissions targets. The value placed on carbon emissions depends on the sector in which they are emitted. The 'traded sector' values are used for all relevant emissions from those sectors that are included within the Emissions Trading System (ETS) (primarily emissions associated with electricity generation and energy-intensive Industry. For emissions in the non-traded sectors (i.e., all other sectors that are not in the ETS). These are estimated by the target-consistent marginal abatement costs consistent with the Government's commitments on greenhouse gas emissions.

Appraisal Period

The appraisal period is the period over which streams of costs and benefits should be estimated, discounted back to a base year (usually the Department's standard base year-2002). Appraisal period can be affected by the project life, as discussed below:

- **Projects with indefinite lives.** For these projects, the appraisal period should end 60 years after the scheme opening year. Extending the appraisal period to 60 years after opening takes account of the new, lower, discount rates introduced in the Treasury Green Book.
- **Projects with finite lives.** For some projects, the project life may be determined from the limited life of its component assets. In these cases, analysts should set out the evidence, and select an appropriate end year for the appraisal, subject to a maximum of 60 years. In addition, where there are special circumstances such as franchise or other arrangements or the transport problem being addressed by the scheme has a short time horizon, the appraisal period should correctly mirror those circumstances.

Residual Value

The Treasury Green Book states "even where an appraisal covers the full expected period of use of an asset, the asset may still have some residual value, in an alternative use within an organization, in a second hand market, or as scrap. These values should be included." The residual value should be estimated as follows:

- Resale or scrap value of the assets in the future should be used as a proxy for the residual value.
- Clean up costs should be subtracted from the final residual amount. In some cases these costs may already be factored into the resale or scrap value. The Department encourages these costs to be highlighted separately in the appraisal results.
- Derivation of the residual value at the beginning of appraisal should take account of the residual value risk' (the uncertainty to what the residual value will prove to be in the future), and adjustments made accordingly.

Discount Rate

Guidance on discount rate is provided by the U.K. Treasury. The most recent Treasury Green Book (TGB) **'The Green Book – Appraisal and Evaluation in Central Government'** was published in January 2003, and the prevailing discount rates over time are shown in Table 2.5

Table 2.5 Time Dependent Discount Rates

Years from Current Year	Discount Rate
0-30	3.5%
31-75	3.0%
76-125	2.5%
126-200	2.0%
201-300	1.5%
301 and above	1.0%

Source: Department for Transport.

Economic Evaluation

The overall economic worth of an option or alternative could be summarized using one or more of the following measures:

- The Net Present Value (NPV) The Benefit/Cost Ratio (BCR) The Net Present Value/Cost Ratio (NPV/C);
- The Net Present Value/Cost to Funding Agency (NPV/K); and
- The Forecast Year Benefit/Cost Ratio (FYBC).

2.3 UNITED STATES

This section discusses summary of guidance provided by U.S. Department of Transportation on cost-benefit analysis for transportation improvements. The guidance covers categories of user benefits and costs. The user benefits include:

- Travel time savings;
- Change in vehicle operating costs;
- Changes in safety costs; and
- Changes in emission costs.

Value Time Savings

Value of travel time savings is a function of value of time and changes in travel time. Also, value of travel time varies by trip purpose. Below is the summary of guidance on valuation of time for auto trips and truck trips:

Business travel. According to the U.S. DOT guidance, employers perceive their employees' gross wages (including payroll taxes and fringe benefits) as the value of the productivity sacrificed to travel. In general practice, value of time for business-related travel is not estimated empirically but is defined by the gross wage, the sum of the median hourly wage and an estimate of hourly benefits. The median wages are obtained from the Bureau of Labour Statistics. Median benefits are not available from this source and are approximated by deriving the ratio of average fringe benefits to average wages in the Employer Costs for Employee Compensation and applying it to median wages

Truck drivers' wages are estimated as the weighted average of heavy and light truck drivers from the National Occupational Employment and Wage Estimates.

Personal travel. The principal distinction in trip purpose is that between "on-the-clock" business travel time, for which a market wage is paid, and personal and leisure time allocated according to the traveller's preferences. In some cases, commute is treated as a separate category, intermediate between personal and business, but more frequently it is included in personal travel. For local personal travel, value of travel time savings (VTTS) is estimated at 50 percent of hourly median household income. The nationwide median annual household income is divided by 2,080 to yield the hourly value of time.

Value of Travel time growth. In using hourly income as a scaling factor to transfer VTTS estimates to new times and locations it has been common to assume an income elasticity of 1.0 (a one percent increase in VTTS per one percent increase in income), implying a constant proportional relationship.

Freight. The value of time in freight transportation is thus considerably more complex than is the case in passenger travel. Although, the U.S. DOT does not provide any guidance on the value of time for freight transportation, it indicates that research is underway to gather additional information to permit recommendation in the future.

Travel Time Reliability. The U.S. DOT does not provide guidance on travel time reliability. However, the guide makes provision for adding a mark-up to VTTS to account for reliability improvements on single routes.

Safety Benefits

The 1993 guidance memorandum "Treatment of Value of Life and Injuries in Preparing Economic Evaluations" established recommended values to be used in regulatory and investment analyses by all administrations within the U.S. Department of Transportation. The guidance has been revised and the value of life statistical (VSL) established in 2011 is $6.2 million. The fractions shown in Table 2.6 should be multiplied by the current VSL to obtain the values of preventing injuries of the types affected by the government action being analyzed.

Table 2.6 Value of Accident by Severity

AIS Level	Severity	Fraction of VSL
AIS 1	Minor	0.003
AIS 2	Moderate	0.047
AIS 3	Serious	0.105
AIS 4	Severe	0.266
AIS 5	Critical	0.593
AIS 6	Un-survivable	1.000

Source: U.S. DOT Guidance Memorandum, Published February 5, 2008.

The guide recommends use of the Congressional Budget Office's estimate of the long-term annual growth rate of labour productivity, 1.6 percent, to project future real income levels. Analysts should augment the base-year VSL by 0.877 percent per year to estimate VSL of any future year in base-year dollars before discounting to present value.

This growth rate should be used as a single value, although it, too, can be estimated only approximately. While EPA uses a slightly different elasticity estimate as the central value and has assumed high and low figures for development of alternative projections, that procedure is unduly cumbersome for our purposes. Instead, we will adopt a single measure of variation to reflect uncertainty in the benefit of reducing present and future risks of fatalities and injuries.

Vehicle Operating Costs

The U.S. DOT cost benefit analysis guide does not provide any guidance on estimation of vehicle operating costs. However, it refers to the American Automobile Association (AAA) annual data on per-mile driving cost that incorporates costs for fuel, maintenance, tires, insurance, fees (license and registration), and taxes, depreciation, and financing.

Emissions

Total emission cost is the sum of the individual emission costs, namely carbon dioxide (CO_2), volatile organic compounds (VOC), nitrogen oxides (NO_x), particulate matter (PM), and sulphur oxides (SO_x). The guide recommends the emission cost values shown in Tables 2.7. The social cost of carbon (SCC) shown in Table 2.8 is an estimate of monetized damages (at 3 percent discount rate) associated with an incremental increase in carbon emissions in a given year. The guide adopts emission cost of carbon from the Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, while costs for the remaining emissions are adopted from the Corporate Average Fuel Economy for MY2012-MY2016 Passenger Cars and Light Trucks (March 2010).

Table 2.7 Social Emission Costs

Emission Type	Dollars per Long Ton (2007)[4]	Dollars per Metric Ton (2007)
Carbon Dioxide (CO_2)	Varies*	Varies*
Volatile Organic Compounds (VOC)	$1,300	$1,280
Nitrogen Oxides (NOx)	$5,300	$5,217
Particulate Matter (PM)	$290,000	$285,469
Sulphur Oxide (SOx)	$31,000	$30,516

Source: TIGER Cost Benefit Analysis Resource Guide.

Table 2.8 Social Cost of CO_2, 2010-2050
2007 Dollars

Discount Year	Value
2010	21.4
2015	23.8
2020	26.3
2025	29.6
2030	32.8
2035	36.0
2040	39.2
2045	42.1
2050	44.9

Source: Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866.

Economic Evaluation

The investment is evaluation based on Net Present Value (NPV) or Benefit-Cost Ratio (BCR), as follows:

- Net Present Value (NPV) = Present Value of Benefits – Present value of Costs
- Benefit/Cost Ratio (BCR) = Present Value of Benefits/Present value of Costs

[4] A metric ton is 2,205 lbs, and a long ton is 2,240 lbs – resulting in a difference of about 1.6 percent between the monetized values per metric versus long ton.

2.4 SUMMARY OF COMPARISON CBA PROCEDURE

The comparison of cost benefit analysis procedures used in Norway, United States, and United Kingdom, indicate that these countries include the traditional benefits associated with transportation improvement in a cost benefit analysis, although computation of benefits varies across country.

These traditional benefits include:

- Travel time savings;
- Changes in vehicle operating costs;
- Changes in accident costs
- Changes in environmental costs; and
- Changes in private transport operator benefits (where applicable).

The major difference between Norway's CBA procedure compared to the U.S. and U.K. is that, unlike Norway, the US and UK include travel time reliability benefits, wider economic impacts, growth of user benefits, and application of the economic evaluation tool, specifically the benefit cost ratio (BCR) in their CBA procedures.

Travel Time Reliability

In addition to road congestion from high traffic volumes, unexpected incidents including accidents, inclement weather etc., cause further delay on roads, and increase travel time on roads. Increasing the capacity and/or quality of roads reduces the likelihood of incidents/accidents and consequently reduces travel times. Travel time reliability, however, has another, larger benefit. When travel times are unreliable, people and companies tend to "pad" their estimates of the time needed to travel from A to B. This extra time, if not used, is lost. For businesses, the costs of the extra time built into the schedules to compensate for unreliable travel times, can be considerable. Increased travel time reliability can result in tangible and large benefits to road users and thus needs to be incorporated into a CBA of road projects.

The Norwegian CBA methodology does not include any benefits related to improved travel time reliability, Norway only recognizes reliability for travel by ferry, and thus underestimates benefits associated with road corridor improvements. . The U.S. and U.K. methodologies, in one way or another, do account for travel time reliability. Although neither the U.K. and U.S. have official guidance on estimation of travel time reliability, both these countries have reliability ratios and other indices (buffer index, planning time index) to aid the estimation of reliability benefits. Currently, there is significant research activity at universities to improve our understanding of travel time reliability and to improve the methods used to estimate the benefits of improved travel time reliability. Also, many countries are looking at ways in which the benefits of travel time reliability could be better incorporated in CBA and decision making about investments in transport infrastructure.

Wider Economic Impacts

Investments in improving the accessibility and connectivity of a region by increasing the capacity and quality of the road network works, simply put, to make the region more attractive to both businesses and people as a location for commerce and living. This leads to a virtuous spiral that accumulates all sorts of economic benefits for the region, benefits that are often hard to directly link to a given project or investment, but almost certainly would not have been realised if the project or investment had not materialised. The difficulty of estimating the wider economic benefits of a road project or investment have worked to planners leaving out these benefits in considering the feasibility and attractiveness of road projects and investments. However, increasingly there is recognition, at least among the decision and policy makers that although difficult to estimate, these wider economic benefits properly belong in a CBA as they are very real and can be quite large. Investment in the development of road corridors, together with land-use planning, can open new lands for economic development and/or provide accessibility/connectivity to, or clustering with other firms as well as potential employees. This can lead to agglomeration benefits and accessibility to a larger labour pool, thus improving productivity and business output. These wider economic impacts, in addition to the usual travel efficiency gains, are increasingly influencing corridor development and investment decisions in the United States and the United Kingdom.

The Norwegian CBA methodology does not include a process for estimating and including the wider economic impacts of an investment in road projects. This means that the attractiveness of an investment in transport infrastructure project is more or less proportional to the potential travel time savings, and this in turn, is proportional to the volume of current and forecast traffic. Thus, one unintended consequence of omitting wider economic impacts from a CBA is that only projects where current and forecast traffic volumes are already high are likely to be found attractive enough for funding according to the CBA. The wider economic impacts are longer term impacts that take decades to develop and become visible, but eventually they do. Thus, leaving out the wider economic benefits from a CBA means that projects with a longer term payback period have a lesser chance of being found attractive enough to get a green light.

Growth in Value of User Benefits Over Time

Unlike the CBA Handbooks used in the U.S. and U.K., the Norwegian NPRA Handbook 140 does not provide any guidance on estimation of user benefits over a forecast period. For example, value of time for freight transportation and business-related trips are driven by economic performance. Therefore, the value of time over a forecast period will grow in tandem with macroeconomic forecast. Ignoring the increase in user benefits over time means that the total value of user benefits over the entire forecast period can be significantly lower than what the real benefits are.

Economic Evaluation Tool

The U.S. and the U.K. use the ratio of discounted benefits to discounted costs in comparing the attractiveness of alternatives for to decide which alternative is the most attractive for purposes of investment. Norway, however, uses the net benefit cost ratio for the same purpose. The net benefit cost ratio is the ratio of net discounted benefits to net present value of investment costs. The net benefits are the discounted benefits minus the discounted costs (everything except the investment costs) of a project. While the net benefit cost ratio used in Norway is an excellent tool for measuring the efficiency with which resources are being utilised by a project, using this as the sole or primary criteria for choosing which investments should be made from among the possible alternatives can result in a bias against projects requiring large (relative to benefits) up-front investment. Of course, one can ask the question of why a society should invest in projects where the investment costs are large relative to the benefits. The answer is that large strategic projects usually require large up-front investments, but these projects change the structure of costs and benefits and their distribution, and have benefits (and costs) that are very difficult to properly estimate and forecast. Thus, the use of net benefit cost ratio should be done keeping the nature and size of the project in mind, and when necessary additional criteria should be used to supplement the net benefit cost ratio in helping decision makers decide on which alternatives to invest in.

3.0 Traffic and Cost Analysis Methodology

3.1 METHODOLOGY OVERVIEW AND SCENARIOS

The following section details the methodology and assumptions applied to estimate traffic performance measures for the various investment/policy scenarios developed for the study. The traffic performance measures generated in this analysis primarily included Vehicle Kilometres of Travel (VKT) and Vehicle Hours of Travel (VHT). In this analysis, rough cost estimates were also generated related to several corridor-level investments. These traffic performance and cost data were then provided as inputs to the Benefit/Cost assessment in order to estimate and monetize the benefits of the scenarios.

Scenarios Analyzed

There are two important points that need to be made about the scenarios that we have developed. First, the results of any one scenario by itself are not meaningful; the results of the four scenarios taken together constitute the proper use of the analysis in these scenarios. More specifically, the differences between the four scenarios represent the effects of the different priorities reflected in the four scenarios. And second, this set of four scenarios does not represent the "only" or "best" set of scenarios in any way. This set of scenarios was assembled in order to shed light on the primary questions that this study addresses.

The scenarios that were developed included a reference scenario (every analysis that uses scenarios needs to have a realistic point of reference), and three investment scenarios representing different investment priorities. The Reference Scenario in this case represents what would happen on the Norwegian road Network if nothing is done. The National Transport Plan (NTP) scenario represents current policy and investment choices to 2019. The System of Expressways represents an unconstrained investment on six of the major road corridors in Norway. The Constrained Expressways scenarios shows what would happen if the funds available in the NTP were to be reallocated to the six major corridors instead of being spent according to the priorities in the NTP.

The four investment/policy scenarios are described in more detail below:

1. **Reference** scenario represents existing network improvements carried out in 2008, without the additional investments and improvements included in the NTP. This scenario represents the baseline or no-build alternative to which all other scenarios are compared.

2. **National Transport Plan** scenario represents investments in infrastructure, operations, and maintenance that are included in the NTP. This scenario represents the current investment priorities and plans through the year 2019, and this can also be described as the business as usual scenario.
3. **System of Expressways** scenario represents greatly increased investment levels to upgrade six road corridors connecting the major cities (both population centres and locations for business and industry) in Norway to In this scenario, investment is focused on these six specific corridors and is unconstrained by current funding levels.
4. **Constrained Expressways** scenario represents a reallocating of funds from the National Transport Plan to invest in a subset of the "System of Expressway" corridors. There are two key points to note about this scenario. First, it changes the priorities implicit in the NTP by reallocating funds away from maintenance activities to upgrading existing corridors. And second, the level of funding in this scenario is identical to the NTP. Thus, this scenario provides insights into the potential effects resulting from changing how the available money is spent, without changing the amount of money that is available.

For each scenario, performance measures were estimated for two points in time in the future; 2012 and 2036. Performance during interim years was interpolated in the Benefit/Cost assessment.

Corridors Analyzed

Within the "System of Expressways" and "Constrained Expressways" scenarios, several National roadway corridors were submitted to additional focused analysis. Figure 3.1 shows the National roadway corridors included in the NTP.

In the System of Expressway scenario five corridors were included in the analysis. These five corridors were chosen based on the magnitude of current traffic flows, population, and economic importance and a consideration of how this are expected to change in the future, in particular the development of the coastal regions and the population migration to the southern parts of Norway. Thus, the selected corridors included links between the four largest population centres; Oslo, Trondheim, Kristiansand, and Stavanger.

Focused performance and cost estimates were generated for these five corridors within the NTP, including (numbers in parentheses relate to the corridor numbers presented in Figure 2.1):

1. E6 Oslo to Trondheim (6A);
2. E16 Oslo to Bergen (5C);
3. E18/E39 Kristiansand to Stavanger (3);
4. Sections of E8, Troms (8B); and
5. Sections of E18, Østfold (2A).

The corridors included in the Constrained Expressways scenario were chosen based on total traffic volumes. We realize and fully understand that a prioritization process would normally include multiple criteria. However, given the constraints of time and budget, we have chosen to simplify the prioritization process and used only the traffic volume as a prioritization Once the corridors are prioritized, the cost of upgrading these corridors to expressway standards are estimated. Finally, the Constrained Expressways scenario selects corridors for upgrading to expressway standards, based on priority, until the available funds are depleted. Thus the total funding for transportation at the current NTP levels is adequate for funding improvements in only two corridors, #1 (E6 Oslo to Trondheim), and #2 (E16 Oslo to Bergen) . The performance measures and costs for the different representative segments were estimated for each scenario and forecast year for input directly into the benefit/cost assessment.

Figure 3.1 National Roadway Corridors

Source: Norway National Transport Plan, 2011.

Estimation of VKT

The VKT data for the "Reference" and "National Transport Plan" scenarios was obtained from Statistics Norway, representing travel on National Roads in 2011. This figure was used to estimate VKT for 2012 and 2036 based on growth in VKT from 2005 to 2011[5] representing an annual increase of 1.95 percent. The

[5] Statistics Norway, 2012.

differences in investments and improvements between the "Reference" and "National Transport Plan" scenarios may be expected to result in different levels of VKT for these two scenarios. The impacts of the investments included in the National Transport Plan are, however, difficult to estimate without detailed traffic modelling (which was not done) could– modest realignment changes could reduce VKT levels, while improved traffic conditions could promote induced travel leading to increases in VKT. Given the short time available for this study, no detailed traffic modelling was possible to assess these potential affects. Thus, VKT was assumed to be the same in both scenarios.

For the "System of Expressways" and "Constrained Expressways" scenarios, VKT was estimated by multiplying individual corridor lengths with estimated traffic volumes on each corridor. The individual corridor lengths were estimated using the Google Maps application. The 2011 traffic volumes for each corridor were available from the National Road Data Bank.[6] These traffic volumes, expressed as Average Daily Traffic (ADT) for all vehicle types, were used to multiply with the corridor length to estimate daily VKT for each corridor. For the corridors with relatively little variation in the traffic volumes along the length of the entire corridor, an average traffic volume number was used in the estimation of VKT. For corridors with more variation in the traffic volumes along the length of the corridor, the corridor was broken down into sub-segments and averages traffic volume for the sub-segment was calculated and used to estimate VKT (as applied to proportional estimates of the sub-segment's length). The resulting VKT estimate represented VKT on the corridors in 2011. This estimate was used to estimate VKT in 2012 and 2036 based on growth in VKT from 2005 to 2011,[7] representing an annual increase of 1.95 percent. This resulted in a total daily VKT, for all five corridors, of 16,052,781 in 2012 and 26,034,510 in 2036.

The above estimates of VKT represented all vehicle types. We further divided the total VKT (for all vehicle types) into automobile and truck VKT. To estimate the automobile and truck VKTs, we used the current proportion of automobiles and trucks in the traffic – 77% of the current traffic is made up of automobiles and the remaining 23% are trucks.[8] We assumed that the proportion of automobiles and trucks on these corridors would remain unchanged between 2012 and 2036.

For the "System of Expressways" and "Constrained Expressways" scenarios, roadways are expected to be re-routed to provide much more direct access between origins and destinations. Given the widely varying geography of

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[6] http://www.vegvesen.no/en/Professional/Roads+and+transport/National+Road+Data+Bank+NRDB.

[7] Statistics Norway, 2012.

[8] Statistics Norway, 2012.

Norway, straight line routes are not always going to be feasible; however, given the exploratory nature of this assessment and the lack of detailed engineering studies with more precise possible alignments for the corridors, we assumed that it would be possible to reduce the total corridor length by 20% by changing the existing alignment. This 20% number is obviously a rough estimate of the reduction in the corridor length; it could be more or less. This 20% number represents a significantly smaller reduction in the corridor length compared to the reduction in corridor length that would be realized using straight line distances. This 20% number can obviously be debated. However, what is not open to debate is that reducing corridor lengths will result in increased benefits resulting from reduced travel times and lower maintenance costs (from the shorter corridor lengths). Thus, we have assumed the 20% number and although we believe it represents a realistic possible reduction in the length of existing corridors, the number is intended to show how reduced corridor lengths increase benefits. Table 3.1 shows the estimated corridor lengths for the baseline (existing) versus the straight line and new alignments representing a 20% reduction in the corridor length. In the remainder of this analysis we have shown the results for both the straight line alignment and the 20% shorter alignments for each of the five corridors (see Table 3.1).

Table 3.1 Estimated Corridor Lengths
Baseline (Existing) versus New Alignment

Corridor	Baseline (KM)	Straight line(KM)	20% Shorter	Difference Straight line (KM)	Difference 20% shorter (KM)
E6 Oslo to Trondheim (6A)	538	392	430	146	108
E16 Oslo to Bergen (5C)	519	290	415	229	104
E18/E39 Kristiansand to Stavanger (3)	226	161	181	65	45
Sections of E8, Troms (8B)	75	54	60	21	15
Sections of E18, Østfold (2A)	100	85	80	15	20

The estimated average traffic volume in 2011 was multiplied by the estimated corridor length to calculate VKT. This 2011 VKT estimate was used to estimate the VKT for 2012 and 2036 based on VKT growth from 2005 to 2011, representing an annual escalation of 1.95 percent.[9]

Table 3.2 shows the resulting daily VKT, for each corridor, for the existing) and the new alignments in 2012. Table 3.3 shows the same for 2036.

[9] Statistics Norway, 2012.

Table 3.2 Estimated 2012 Daily Corridor VKT
Thousands, Baseline (Existing) versus New Alignment

Corridor	Baseline (KMT)	Straight line (KMT)	Difference (Percent)	20% shorter	Difference (percent)
E6 Oslo to Trondheim (6A)	8,282	6,035	-2,247 (-27%)	6,626	-1,656 (-20%)
E16 Oslo to Bergen (5C)	1,878	1,048	-830 (-44%)	1,503	-375 (-20%)
E18/E39 Kristiansand to Stavanger (3)	1,658	1,181	-477 (-28%)	1,327	-331 (-20%)
Sections of E8, Troms (8B)	401	292	-109 (-27%)	321	-80 (-20%)
Sections of E18, Østfold (2A)	739	628	-111 (-15%)	591	-178 (-20%

Table 3.3 Estimated 2036 Daily Corridor VKT
Thousands, Baseline (Existing) versus New Alignment

Corridor	Baseline (KMT)	Straight line (KMT)	Difference (Percent)	20% shorter	Difference (percent)
E6 Oslo to Trondheim (6A)	13,432	9,600	-3,832 (-29%)	10,540	-2,992 (-20%)
E16 Oslo to Bergen (5C)	3,046	1,667	-1,379 (-45%)	2,390	-656 (-20%)
E18/E39 Kristiansand to Stavanger (3)	2,690	1,879	-811 (-30%)	2,111	-579 (-20%)
Sections of E8, Troms (8B)	651	465	-186 (-29%)	511	-140 (-20%)
Sections of E18, Østfold (2A)	1,198	999	-199 (-16%)	941	-257 (-20%)

Once the change in VKT between the current and new alignment was estimated for each individual corridor, the resulting change was summed for all corridors for the "System of Expressways" scenario and for corridors #1 and #2 for the "Constrained Expressway" scenario and subtracted from the VKT for all National roadways identified in the Reference scenario to identify the overall VKT level and change for each scenario. Table 3.4 shows the estimated VKT associated with each of the various scenarios for 2012 and 2036.

Table 3.4 Estimated 2012 and 2036 VKT (National) by Analysis Scenario

	Straight Line		20% shorter	
Scenario	**2012**	**2036**	**2012**	**2036**
Reference	16,052,781	26,034,510	16,052,781	26,034,510
National Transport Plan	16,052,781	26,034,510	16,052,781	26,034,510
System of Expressways	14,246,764	22,968,961	14,812,581	23,869,028
Constrained Expressways	14,580,273	23,541,100	15,080,476	24,336,792

Estimation of VHT

VHT were estimated by applying average travel speeds to the estimated VKT. Unlike the traffic volumes, there was no data available on average speeds on the corridors, or the sub-segments on these corridors. Given the unavailability of this data, we used an average of travel speeds across National Roads to estimate VHT.

For the Reference scenario, an average speed of 69.2 Kilometres per Hour (KPH) based on average overall speeds reported for National Roads (2008)[10] was applied to VKT estimated in the previous step to estimate total baseline VHT. It should be noted that there is no reason to expect an increase in average speeds since 2008. In fact, to the contrary, there is reason to expect a reduction in average speeds as the volume of traffic has increased. We have, however, not made this assumption in order to avoid any possible criticism that the benefits of investments in the road are too optimistic.[11]

For the National Transport Plan scenario, the average baseline speed was increased to 78.9 KPH (a 14 percent increase). This adjustment was made based on speed elasticity's relating investments to performance, in this case average travel speeds. [12] We used these elasticity's to estimate the increase in average travel speeds and applied these new, higher, average travel speeds to VKT for 2012 and 2036 to estimate the VHT. ,

For the "System of Expressways" and "Constrained Expressways" scenarios, the VHT were individually estimated for each corridor included in the scenario. For the baseline measurement, we started by assuming an initial assumed average

[10]Statistics Norway, 2012.

[11] If the average travel speeds are low, the VHT will be large. Any investment which increases average travel speeds, and thus reduces VHT will therefore have a larger benefit than if the average travel speed which is used for comparison was higher.

[12]Michigan (U.S.A.) Department of Transportation, *Development of a Performance Curve for Transportation Investments*, Cambridge Systematics, 2010.

travel speed of 69.2 KPH and applied this to the length of each corridor to estimate VHT. In parallel, we also used Google Maps to get the expected travel time for each individual corridor. We compared the estimates of travel times from the two approaches.[13] For the corridors where the difference between the two estimates of travel times was larger than 15 percent, we reassessed the baseline average travel speed on the corridor and adjusted it. These adjusted baseline average travel speeds, for each individual corridor, were applied to the current corridor lengths and multiplied by the traffic volumes to estimate the baseline VHT.

To estimate the VHT for the individual corridors with the new alignments, assumed average travel speeds were adjusted upward to reflect the upgrading of the corridor roadways to expressway standards. For most corridor alignments, average travel speeds were increased to a minimum of 90 KPH. For selected corridors exhibiting faster than average speeds in the baseline scenario, speeds in the new alignment scenario were increased to 100 KPH, as shown in Table 3.5.

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[13] For those corridors requiring maritime passage in the baseline scenario, travel times include an estimate of travel time on the ferry(ies). This travel time estimate does not include a "wait-time" measure for accessing the ferry, or an assessment of the impact this access time may have on travel time reliability.

Table 3.5 Estimated Average Corridor Speeds
Baseline (Existing) versus New Alignments

Corridor	Baseline (KPH)	New Alignment (KPH)	Difference (Percent)
E6 Oslo to Trondheim (6A)	78	100	22 (28%)
E16 Oslo to Bergen (5C)	74	100	26 (35%)
E18/E39 Kristiansand to Stavanger (3)	69	90	21 (30%)
Sections of E8, Troms (8B)	69.2	90	21 (30%)
Sections of E18, Østfold (2A)	69.2	90	21 (30%)

The estimated speeds in Table 3.5 were then applied, for each corridor, to the corridor lengths and VKT for the existing and new alignments to estimate the difference in VHT for each corridor. Table 3.6 shows the estimated VHT for each corridor in 2012. Table 3.7 shows the same information for 2036.

Table 3.6 Estimated 2012 Daily Corridor VHT
Baseline (Existing) versus New Alignment

Corridor	Baseline (VHT)	Straight Line (VHT)	Difference (Percent)	20% shorter (VHT)	Difference (percent)
E6 Oslo to Trondheim (6A)	106,185	60,348	-45,837 (-43%)	66,260	-39,925 (-38%)
E16 Oslo to Bergen (5C)	25,384	10,485	-14,899 (-58%)	15,027	-10,357 (-40%)
E18/E39 Kristiansand to Stavanger (3)	23,974	13,126	-10,484 (-45%)	14,746	-9,228 (-38%)
Sections of E8, Troms (8B)	5,801	3,254	-2,547 (-44%)	3,568	-2,233 (-38%)
Sections of E18, Østfold (2A)	10,681	6,981	-3,700 (-35%)	6,570	-4,111 (38%)

Table 3.7 Estimated 2036 Daily Corridor VHT
Thousands, Baseline (Existing) versus New Alignment

Corridor	Baseline (VHT)	Straight line (VHT)	Difference (Percent)	20% shorter (VHT)	Difference (percent)
E6 Oslo to Trondheim (6A)	172,212	95,988	-76,224 (-44%)	105,402	-66,810 (-39%)
E16 Oslo to Bergen (5C)	41,168	16,678	-24,490 (-59%)	23,905	-17,263 (-42%)
E18/E39 Kristiansand to Stavanger (3)	38,881	20,880	-18,001 (-46%)	23,458	-16,999 (-43%)
Sections of E8, Troms (8B)	9,408	5,177	-4,231 (-45%)	5,676	-3,732 (-39%)
Sections of E18, Østfold (2A)	17,323	11,105	-6,218 (-36%)	10,452	-6,871 (-39%)

Once the change in VHT between the baseline and the new alignment was estimated for the individual corridors, the resulting changes were summed for all corridors for the "System of Expressways" scenario and for corridors #1 and #2 for the "Constrained Expressway" scenario and subtracted from the estimated VHT for all National roadways identified in the Reference scenario to identify the overall VHT level and change for each scenario. Table 3.8 presents the VHT estimated for each analysis scenario.

Table 3.8 Estimated Daily 2012 and 2036 VHT (National) by Analysis Scenario

	Straight Line		20% shorter	
Scenario	**2012**	**2036**	**2012**	**2036**
Reference	373,331	605,471	373,331	605,471
National Transport Plan	358,812	581,924	358,812	581,924
System of Expressways	313,400	506,021	322,624	520,693
Constrained Expressways	326,523	527,928	334,613	540,734

VHT estimates for each scenario were segmented by automobile and truck travel, based on the estimated VKT for each mode, prior to being used in the Benefit/Cost analysis.

Estimation of Costs

The construction costs for the new (shorter) alignments of the corridors included in the "System of Expressways" and "Constrained Corridors" scenarios were estimated using an average cost of construction for a 4-lane expressway roadway, with an estimated length of each corridor. We are fully aware that this average figure is not going to represent the actual construction costs of each new alignment. However, as we have stated earlier, this study is a high level intended to shed light on the possible impacts of alternative set of priorities for investing in the road network in Norway. Given this objective, it is our view that using an average figure for construction costs/kilometre is adequate. The length of each corridor was initially based on the straight-line route alignments used in calculating VKT for the corridors and presented in Table 3.9. The length of new construction needed for each corridor was reduced by a factor to reflect the reuse of existing corridor alignments and facilities. This factor varied slightly from corridor to corridor to reflect current alignments and standards of existing roadways (and potential to reuse current alignments).

Once the length of new corridor construction was estimated for each corridor, a constant cost of construction of 213,910,000 NOK per kilometre was applied to the resulting corridor lengths.[14] Tables 3.9 and 3.10 present the assumed percentage of reuse for each corridor, the length of estimated new construction, and the resulting cost for each corridor for the straight line and 20% shorter alignments, respectively.

Table 3.9 Straight Line Alignment - Estimated Percentage of Reuse, Length of Estimated New Construction, and Cost by Corridor

Corridor	Estimated Percent of Existing Corridor Reuse	Estimated Length of New Construction (KM)	Estimated Corridor Cost
E6 Oslo to Trondheim (6A)	30%	274	58,696,904,000
E16 Oslo to Bergen (5C)	30%	203	43,376,185,000
E18/E39 Kristiansand to Stavanger (3)	20%	129	27,540,434,846
Sections of E8, Troms (8B)	10%	31	6,545,646,000
Sections of E18, Østfold (2A)	10%	77	16,364,115,000

[14] Construction cost provided by Norwegian Road Federation.

Table 3.10 20% Shorter Line Alignment - Estimated Percentage of Reuse, Length of Estimated New Construction, and Cost by Corridor

Corridor	Estimated Percent of Existing Corridor Reuse	Estimated Length of New Construction (KM)	Estimated Corridor Cost
E6 Oslo to Trondheim (6A)	30%	301	64,446,804,800
E16 Oslo to Bergen (5C)	30%	290	62,170,802,400
E18/E39 Kristiansand to Stavanger (3)	20%	144	30,939,942,400
Sections of E8, Troms (8B)	10%	34	7,177,531,862
Sections of E18, Østfold (2A)	10%	72	15,401,520,000

3.2 KEY FINDINGS

The key findings of the analysis we have presented in this chapter to estimate the effect of changing investment priorities on VKT and VHT clearly show that:

- The National Transport Plan, which represents the business-as-usual scenario, yields vehicle kilometres of travel (VKT) consistent with the Reference Scenario and a 5 percent reduction in national travel times (vehicle hours of travel (VHT)) compared with the Reference Scenario.
- The System of Expressways which represents the Invest in the Future scenario yields an estimated 28 percent reduction in VKT and a 44 percent reduction in VHT in 2036 on the improved corridors. This represents nearly 135,000 hours saved every day.
- At the National network level, the System of Expressways scenario results in a 12 percent reduction in VKT and a 17 percent reduction in VHT.
- Under the Focused Expressway investment plan which represents the change the mix scenario, travel on the improved corridors experienced a 30 percent reduction in vehicle km travelled and a 46 percent reduction in reduction in vehicle hours of travel –representing nearly 100,000 hours saved per day in 2036.
- At the National network level, the Focused Expressway scenario translates to a 10 percent reduction in vehicle kilometres travelled and a 13 percent reduction in vehicle hours of travel.
- Redistributing the funds in the National Transport Plan (NTP) to focused investments in two key expressways results in a nearly tripling of travel time savings over the NTP or 40,000 vehicle hours saved per day, a 33 percent reduction in VKT in the two motorways and 5 percent reduction in VKT nationwide.

4.0 Cost Benefit Analysis of Proposed Investments

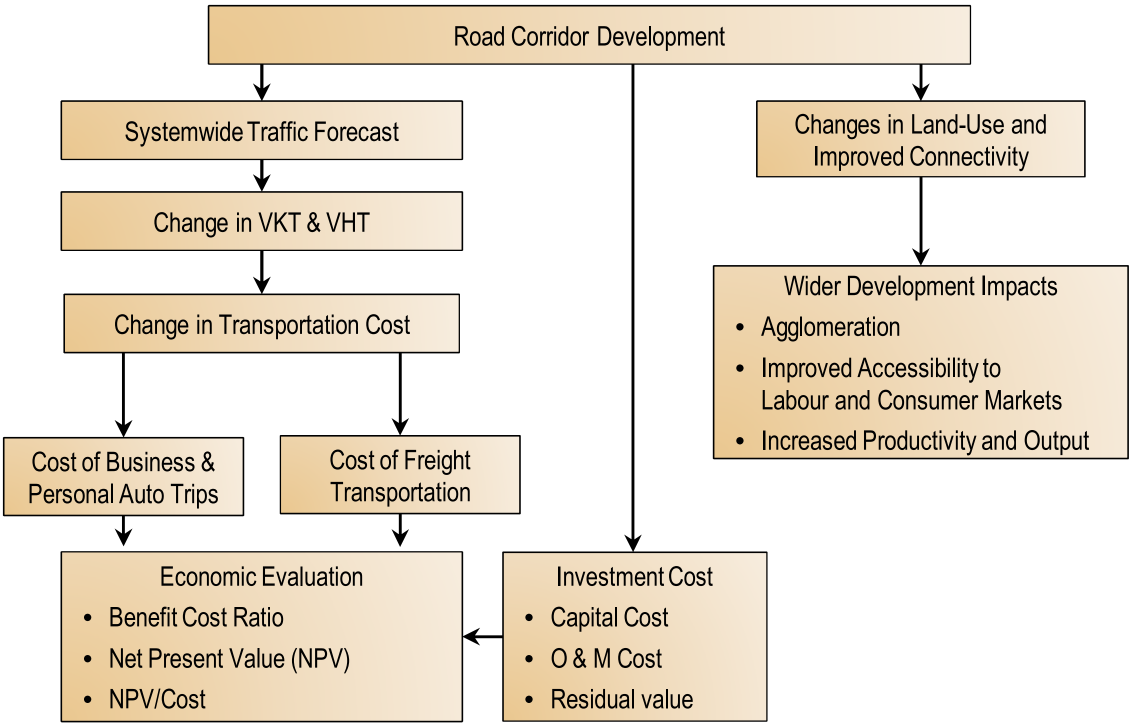
This section discusses the Cost Benefit Analysis (CBA) of proposed investments in the road corridors in Norway. This analysis incorporates insights gained from reviewing the procedures for carrying out CBA in the U.S. and U.K. in addition to the evaluation process in Norway. The three proposed investment alternatives discussed in the previous chapter are considered for analysis.

4.1 Analytical Framework for Cost Benefit Analysis

Figure 4.1 presents the analytical framework for a CBA of the investments in road corridors in Norway. The process involves estimating gains in travel efficiency gains associated with each of the proposed investments in the national road network relative to the national road network without the National Transportation Plan.

The travel efficiency gains are estimated using the output from a system wide traffic forecast expressed in daily VKT and VHT. These VKT and VHT are generated for automobiles (passenger) and trucks (freight) for the Reference and the other three investment scenarios for the years 2012 and 2036.

Figure 4.1 Analytical Framework for Benefit-Cost Analysis for Proposed Corridor Investments



Source: Cambridge Systematics, Inc.

The changes in VKT and VHT, resulting from the investment in the corridors included in the three scenarios, are estimated, annualized and monetized to determine the gains in travel efficiency, safety/accident costs, vehicle operating costs and emission costs. The monetized benefits in each of the three investment scenarios are compared to the monetized benefits in the Reference scenario to determine the net benefits from the investments. . A discount rate of 4.5 percent is used to discount the stream of benefits and costs to present values (2012). The costs include capital, operation and maintenance costs. The attractiveness of the investment is evaluated based on the benefit-cost ratio (BCR) or net present value (NPV).

4.2 Assumptions

The assumptions made in order to carry out the analysis as part of the CBA are listed below.

- Annual traffic growth is assumed to be linear. This assumption is used to estimate the traffic volumes in the years between 2012 and 2036.;

- Real per capita Gross Domestic Product (GDP) grows at 0.3 percent annually[15];
- Consumer Price Index (CPI) grows at 0.3 percent annually[16];
- Value of time grows at the same rate as real GDP per capita;
- Discount rate is 4.5%
- Safety, vehicle operating, and environment costs grow at the same rate as CPI; and
- Business-related automobile trips are assumed to 6 percent of total auto trips (this assumption has implications for the value of time as business and non-business trips have a different value of time)

4.3 SYSTEMWIDE TRAFFIC FORECAST

The system wide traffic analysis provided the travel demand forecast for personal vehicles (automobiles) and commercial vehicles (trucks) and for the Reference and the three investment scenarios for the years: 2012 and 2036. The traffic forecasts for the intermittent years are interpolated (based on Equation 1) to generate traffic data for the intermittent years. Equation 1 estimate f daily VKT for any referenced year 't'. Replacing VKT with VHT in Equation 1 provides daily VHT data for a reference year 't', where 't' is any year between 2012 and 2036.

$$VKT_t = VKT_{2012} + \frac{(VKT_{2036} - VKT_{2012})*(t-2012)}{(2036-2012)} \qquad (1)$$

Where VKT_{2012} and VKT_{2036} represent the VKT in 2012 and 2036, respectively.

Daily Changes in VKT

Following from above, daily changes in VKT (ΔVKT) between Reference

and investment scenarios are computed as follows:

$$\Delta VKT_t = VKT_t^{Reference} - VKT_t^{Investment} \quad 2012 \le t \le 2036 \qquad (2)$$

Daily Changes in VHT

Similarly, daily changes in VHT (ΔVHT) for the intermittent years (2012 ≤ t ≤ 2036) is expressed in Equation 3

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[15] Estimated from Statistics Norway

[16] Estimated from Statistics Norway

$$\Delta VHT_t = VHT_t^{Reference} - VHT_t^{Investment} \quad 2012 \le t \le 2036 \qquad (3)$$

4.4 ESTIMATION OF USER BENEFITS

Travel Time

The value of travel time has two components: resource cost and disutility cost. Resource or opportunity cost is equivalent to the value to the road-user of an alternative use of time. The disutility cost is associated with the additional problems and stress experienced by the road-user because of road congestion or other problems encountered while using roads. Consequently, travel time savings during peak periods, which are mostly congested, will be valued more than travel time savings during off-peak periods. However, data on the value of disutility cost is very limited so we have not included this component in the valuation of travel time savings. We have deliberately done this so as to avoid any possible criticism that we are unfairly inflating the value of travel time savings.

Opportunity cost is a function of trip purpose, wage rate, and amount of time saved. Table 4.1, shows the value of time utilized for the different types of trips that were used in this study. These represent the value of time reported in the NPRA Handbook 140 (2005), compounded annually at 0.3 percent.

Table 4.1 Value of Time by Trip Purpose

Mode	Value of Time NOK/hr
Auto	
Business Trips	269
Commute	191
Leisure	134
Commercial	
Truck	474

Source: NPRA Handbook 140 (update from 2005).

Travel Time and Reliability – Freight Transportation (Truck)

Freight transport is no longer about just moving some freight from point A to be point B. Increasingly, freight transport is a precision business that requires very precise times of departure and arrival. Deviating from these schedules means additional costs incurred by shippers and freight forwarders. Thus, in this age of global competition and footloose industry, predictable and reliable travel times are very important for business and industry.

The cost to businesses of transporting freight includes the cost of crew, vehicle idle time and holding cost of freight. Congested and poor quality roads means low driving speeds, and unpredictable travel times, both of which add to costs of moving freight. Also, these costs are a function of travel time, therefore travel time reduction (saving) from more, and better roads mans higher speeds and less congestion, leading to ultimately a reduction in the crew and freight costs. Reduction in daily freight transportation cost is measured as the product of freight transportation cost per hour and the daily change in travel time or delay resulting from increased capacity and quality. A transportation cost of NOK 474 per hour is used for this study. The reduced freight transportation cost (travel time benefit) is annualized by multiplying by 365 days, as expressed in Equation 6, below.

$$\Delta V_t^{Truck} = W_t^{Truck} \; x \; \Delta VHT^{Truck}{}_t \; x \; 365 \qquad (4)$$

In addition to improved travel time, reduction in travel time variability leads to greater reliability in freight delivery. A reliability ratio of 0.8 reported by the Department for Transport, U.K., for auto is assumed for freight and utilized in this study. According to a study commissioned by the U.S. DOT, "Guide to Quantifying Economic Impacts of Federal Investment in Large-Scale Freight Transportation Project," the reduction in logistics cost is equivalent to 25 percent of the value of travel time savings.

Travel Time and Reliability – Personal Travel (Auto)

Travel time savings are usually measured as the product of hourly value of time and changes in VHT. The value of time indicated in the NPRA Handbook 140 is updated to present value and used in this analysis. The detailed approach to the valuation is discussed below. A reliability ratio of 0.8[17], reported by the Department for Transport, U.K. is employed to account for improved reliability for business- and commute-related trips.

Step 1 – Valuation of Business Travel

For business-related automobile travels, the annual value of travel time savings is equivalent to value of daily travel time saving annualized over 230 working days (Equation 5). Daily value of travel time savings is estimated as the product of traveller's hourly wage and daily travel time savings. Average hourly wage of NOK 269 (Table 3.1) is utilized for this analysis.

$$\Delta V_t^{Bu\sin ess} = W_t^{Bu\sin ess} \; x \; \Delta VHT^{Bu\sin ess}{}_t \; x \; 230 \qquad (5)$$

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[17] This is the ratio of the standard deviation of the trip time of a journey to the average trip time. This ratio multiplied by the Value of Time and the average number of trips before and after a policy intervention to increase reliability provides the estimated benefit from increased reliability

Where,

ΔVHT_t = Change in daily travel time

$W_t^{Buisness}$ = Value of time for business-related auto trips (updated NOK2005/hr to NOK 2012/hr).

$\Delta V_t^{Bu\sin ess}$ = Annual monetized value of business-related travel time savings

Step 2 – Valuation of Commuters and Non-Work-Related Personal Travel

For commuters, the value of travel time savings is computed similar to the method used for estimating benefits for business travellers (as discussed above). The only difference between computations of value of travel time saving associated with business- and commute-related travels stems from application of wage rate. For commuters, value of time reported in the NPRA Handbook 140 (2005) is updated and utilized in the analysis (Equation 6).

$$\Delta V_t^{Commute} = W_t^{Commute} \ x \ \Delta VHT^{Commute}{}_t \ x \ 230 \qquad (8)$$

Where,

$\Delta V_t^{Commute}$ = Monetized value of commute-related travel time savings

$W_t^{Commute}$ = Value of time for commute-related auto trips (updated NOK2005/hr to NOK 2012/hr).

$\Delta VHT^{Commute}{}_t$ = Daily change in commute-related vehicle-hours travelled

Safety Cost

Two factors, namely frequency of accidents and cost of accidents, are considered when estimating the cost of accidents, or the value of safety. Accident frequency rate by severity is estimated from the accident types and annual vehicle mileage reported by Statistics Norway. Also, the cost of an accident used (Table 4.2) for this analysis is reported in the NPRA Handbook 140.

Table 4.2 Cost of Accident and Accident Rates

Accident Severity	NOK	Accident per Million km
Death	26,500,000	0.00592552
Injury[18]	8,300,000	0.252543326
Material damage	50,038	0.179531628

Source: NPRA Handbook 140, Statistics Norway, Cambridge Systematics Analysis.

[18] Average of very severe damage, severe damage, and light damage.

Safety Cost – Freight Transportation (Truck)

Changes in safety costs between an alternative scenario and the base scenario are calculated using the estimated changes in VKT, accident rates and cost of accidents. The cost and frequency of accidents reported in Table 3.2 are used for this analysis.

Changes in average daily safety costs are annualized by multiplying by 365 days using Equation 7.

$$\Delta SC_t^{Truck} = \Delta VKT_t^{Truck} \times AC \times AR \times 365 \qquad (7)$$

Where,

ΔSC_t^{truck} = Changes in the value of safety costs for freight transportation;

ΔVMT_t^{Truck} =Change in vehicle-kilometres travelled between the build and no-build travelled; and

AC = Cost of Accident
AR = Accident rates

Safety Cost – Personal Travel (Auto)

Estimation of the value of the benefit from improved safety for personal travel is similar to that used for freight transportation (see Equation (7)). For personal vehicles, the annualized benefits vary by trip purpose: business- and commute-related personal travels are annualized over 230 working days, while non-work trips are annualized over 365 days.

Vehicle Operating Costs

Vehicle operating costs include fuel and non-fuel operating costs. Non-fuel cost includes the cost of changing tires and general vehicle maintenance. For this study, change in vehicle operating cost is estimated as a product of fixed cost per mile and changes in vehicle-miles travelled. Change in vehicle operating cost is estimated separately for fuel and non-fuel and added together as shown in Equations 8, 9, and 10.

Non-fuel VOC comprises the wear-and-tear of expendable items on the vehicle. Due to evolving technological advancement, the wear-and-tear rate is expected to vary over the economic life of a vehicle. For now, a constant wear-out rate is a reasonable assumption given data limitations and the uncertainty about the future evolution of technology. In view of this, a per mile cost on non-fuel operating costs for both truck and personal vehicle from NPRA Handbook 140 are used for this analysis (Table 4.3).

Table 4.3 Vehicle Operating Costs

	NOK/km	
Vehicle Type	**Fuel Cost**	**Non-fuel Cost**
Auto	0.7	1.4
Truck	2.6	2.5

Source: NPRA Handbook 140 (updated from 2005).

Vehicle Operating Costs – Freight Transportation (Truck)

Fuel Cost

The change in the fuel component of vehicle-operating cost is expressed in Equation 8.

$$\Delta VOC_t^{fuel} = FC^{Truck} \ x \ \Delta VKT^{Truck}{}_t \ x \ 365 \quad (8)$$

Where:

$\Delta VOC^{fuel}{}_t$ = Change in annual fuel cost component of vehicle-operating costs

FC = Fuel cost per kilometre

ΔVKT_t = Daily change in vehicle-kilometres travelled

Non-Fuel Cost

Annual change in non-fuel costs of freight transportation is estimated as:

$$\Delta VOC_t^{Non-fuel} = NFC \ x \ \Delta VKT_t^{Truck} \ x \ 365 \quad (9)$$

Where NFC = non-fuel cost per kilometre for trucks

Total Operating Cost

Total change in vehicle-operating costs for freight transportation (ΔVOC_t^{TR}) can be expressed as:

$$\Delta VOC_t^{TR} = \Delta VOC_t^{Fuel} + \Delta VOC_t^{Non-fuel} \quad (10)$$

Vehicle Operating Costs – Personal Travel (Auto)

Using Equations 8, and assuming 230 working days a year, fuel and non-fuel vehicle-operating costs for yearly passenger travel (auto) can be expressed as follows:

Fuel Cost

$$\Delta VOC_t^{fuel} = FC \ x \ FE \ x \ \Delta VKT^{Auto}{}_t \ x \ 260 \quad (11)$$

Non-Fuel Cost

$$\Delta VOC_t^{Non-fuel} = NFC \; x \; \Delta VKT_t^{Auto} \; x \; 260 \qquad (12)$$

Total Operating Cost

Hence, annual changes in vehicle-operating costs were expressed as follows:

$$\Delta VOC_t^{Auto} = \Delta VOC_t^{fuel} + \Delta VOC_t^{Non-fuel} \; (13)$$

Equation 13 accounts for both business travellers and commuters.

Costs of Emissions

Vehicle emissions include carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC), particulate matters (PM), and oxides of Sulphur (SO_x). These emissions react with other pollutants in the atmosphere, especially NO_x and VOC, to form Ozone. VOC, SO_x, and NO_x, also react to form particulates. These pollutants cause damage to human health, including cancer, asthma, and heart attacks. Motor vehicles are also the most significant source of ultra-fine particles, which have been linked to increases in mortality and morbidity. Exhausts from fuel combustion are mainly carbon dioxide. Carbon dioxide traps heat and increases the concentration of greenhouse gas emission within the earth's atmosphere. This leads to changes in the earth's climate that could potentially impose costs on society through flooding, crop loss, and vegetation damages. The cost of these pollutants provided by the U.S. DOT are converted to Norwegian kroner and shown in Table 4.4

Table 4.4 Cost of Emissions

Emission Type	$/metric tonne	NOK/metric tonne
Volatile Organic Compounds	1,280**	7,552
Nitrogen Oxides		27*
Particulate Matter	285,469**	1,684,267
Sulphur Oxides	30,516**	180,044
Carbon Dioxide		214*

* NPRA Handbook 140 (updated to 2012).

** U.S. Department of Transportation.

Note: Exchange Rate 1USD = NOK 5.9 (Wall Street Journal – Foreign Currency Exchange Rates).

Costs of Emissions – Freight Transportation (Truck)

Change in costs of emissions is estimated as the product of the costs of emission per kilometre and the change in vehicle-kilometres travelled (Equation 14). The costs of emissions per mile are the sum of the per-kilometre cost of individual pollutants. The per-kilometre cost of individual pollutants is estimated as the cost per emission type multiplied by the emissions per kilometre. The costs of emissions are computed separately for freight and passenger personal travel and then added together to get the total costs of emissions from transport. Equation (14) represents this calculation for the five pollutants included in this analysis:

$$\Delta EC_t = \Delta VMT_t^{TR} \ x \sum_{i=1}^{n} (EC_i \ x \ EP_i) \ x \ 365 \qquad (14)$$

Where

ΔEC_t = Annual change in cost of emissions per kilometre

ΔVMT_t^{TR} = Change in vehicle-kilometres between build and no-build scenarios

EC = Cost of Emissions by emission type

EP = Emission per kilometre

Costs of Emissions – Personal Travel (Auto)

For auto trips, cost of emissions is estimated for commute and business trips and non-work trips as follows:

$$\Delta EC_t = \Delta VMT_t^{Auto} \ x \sum_{i=1}^{n} (EC_i \ x \ EP_i) \ x \ D \qquad (15)$$

Where,

ΔVMT_t^{Auto} = Change in vehicle-miles between build and no-build scenarios

D= number of working days: commute and business trips (230 days) and non-work trips (365 days)

Pavement Maintenance Cost Savings

The Federal Highway Administration's Highway Cost Allocation Study estimates a pavement maintenance price of NOK 0.08 per automobile VKT, and NOK 3.78 per truck VKT.[19]

$$\Delta PMC_t = \Delta VKT_t \ x \ PMC \ x \ D \qquad (16)$$

ΔPMC = Annual change in pavement maintenance cost;

ΔVMT = Annual change in vehicle-miles travelled for truck or auto;

PMC = Pavement maintenance cost per mile for truck or auto; and

D = Number of days in a year by trip purpose: truck (365 days); personal vehicle (commute – 230 days, nonwork-365 days, business – 230 days)

[19] http://www.fhwa.dot.gov/policy/otps/costallocation.htm.

4.5 INVESTMENT COSTS

Investment costs include capital, operation, and maintenance costs. The relevant costs for this study are construction costs and the incremental operation and maintenance costs. In accordance with NPRA Handbook 140, all projects are assumed to have a 40-year life-span, therefore there will be residual value of the assets by 2036 (end of forecast period), Table 4.5.

Table 4.5 Straight Line Alignment - Capital and Operation and Maintenance Cost by Projects

Costs (NOK Billion)	NTP	Constrained Expressway	Expressway System
Capital	104.00	102.07	188.89
O & M	8.40	0.86	8.40
Residual Value	39.00	38.28	70.83
Total	73.40	64.65	126.45

Source: Cambridge Systematics Analysis.

Table 4.6 20% Shorter Alignment - Capital and Operation and Maintenance Cost by Projects

Costs (NOK Billion)	NTP	Constrained Expressway	Expressway System
Capital	104.00	126.61	180.14
O & M	8.40	1.06	8.25
Residual Value	39.00	47.48	67.55
Total	73.40	80.19	120.84

Source: Cambridge Systematics Analysis.

4.6 ECONOMIC EVALUATION

From Tables 4.7 and 4.8, the constrained expressway and the expressway system are viable investment to be considered by the NPRA. However, given the fiscal constraint experienced by the NPRA, the constrained expressway alternative, which represents prioritized investments, is the best alternative for investment. The constrained expressway alternative posts the highest NPV and BCR, indicating the highest economic return

Table 4.7 Straight Line Alignment - Results of Cost Benefit Analysis by Alternative

Benefits (NOK Billion)	NTP	Constrained Expressway	Expressway System
Travel time	26.12	86.50	111.95
Reliability Improvement	3.87	80.35	103.84
Safety Improvement		22.35	27.45
Vehicle Operating Costs		36.36	45.02
Pavement Maintenance Savings		1.22	1.76
Air Pollution		12.93	13.66
Total Benefits	29.99	239.71	303.68
Costs (NOK Billion)			
Capital	104.00	102.07	188.89
O & M	8.40	0.86	8.40
Residual Value	39.00	38.28	70.83
Total Cost	73.40	64.65	126.45
NPV	(43.41)	175.06	177.22
BCR	0.41	3.71	2.40
NPV/Cost	-0.59	2.71	1.40

Source: Cambridge Systematics Analysis.

Table 4.8 20% Shorter Alignment - Results of Cost Benefit Analysis by Alternative

Benefits (NOK Billion)	NTP	Constrained Expressway	Expressway System
Travel time	26.12	71.93	100.91
Reliability Improvement	3.87	66.81	92.85
Safety Improvement		15.03	20.51
Vehicle Operating Costs		25.14	33.90
Pavement Maintenance Savings		0.82	1.40
Air Pollution		8.66	9.50
Total Benefits	29.99	188.4	259.06
Costs (NOK Billion)			
Capital	104.00	126.62	180.14
O & M	8.40	1.06	8.25
Residual Value	39.00	47.48	67.55
Total Cost	73.40	80.20	120.84
NPV	(43.41)	108.2	138.23
BCR	0.41	2.35	2.14
NPV/Cost	-0.59	1.35	1.14

Source: Cambridge Systematics Analysis.

4.7 KEY FINDINGS

We are well aware of the limitations of the analysis that we have carried out and have are presenting in this report. Thus, we hasten to add that these results cannot be generalised without incurring significant risks. This being said, the results clearly suggest that there may be some merit in reconsidering the current approach for conducting BCA in Norway.

The analysis shows that:

- The benefits of reliability to the Norwegian economy are almost as large as the travel time savings. Thus, clearly there is a benefit that is not being considered in the current Norwegian approach to BCA. Modifying the current approach to include the reliability benefit is clearly necessary.
- The set of investment priorities reflected in the NTP are a very inefficient. By changing the investment priorities in the NTP and, for example, by investing in improving two key road corridors increase the benefits by a factor of 6 (20% shorter alignment) and by a factor of 9 (straight line alignment).
- The NPV of the NTP itself is negative, and the BCR is less than 1, and the ratio of NPV/cost is negative. This suggests that, from a road transportation

perspective, the NTP is very bad policy. Clearly, the NTP does not seem to be justified on the grounds that it is improving the road sector.

- Investments in roads can yield significant return if properly prioritised. Both the Constrained Expressway scenario and the Expressway System scenario have a large, positive NPV, positive BCRs, and positive ratio of NPV to costs.
- The operational and maintenance costs in the Constrained Expressway and Expressway System scenarios are actually lower than in the NTP. While the difference is not large, this is interesting because the length of expressways in the Constrained and Expressway scenarios is longer than in the NTP. The benefits in these two scenarios are also significantly higher than in the NTP. The benefits in the two scenarios are large because the volume of current and forecast traffic on these routes is significant, in fact it represents the bulk of the traffic in Norway. What this suggests is that the operational and maintenance costs are being incurred on roads that do not have much traffic and consequently do not have much benefit for the country of Norway.

5.0 Conclusions

This study had two primary objectives: To explore the case for additional investments in road corridors, and two critically review the BCA approach and methodology used in Norway to support decisions regarding investments in roads. Chapter 2 reviewed the use of BCA to support decision/policy making for making investments in roads in Norway, U.S., and the U.K. Chapter 3 examined the effects of two investment scenarios representing significantly different investment priorities than the NTP. Chapter 4 carried out a BCA of the two investment options and the NTP. We briefly recapitulate our findings before proceeding to make a few key recommendations.

With regards to the BCA methodology used in Norway, it is a traditional methodology that includes most of the direct benefits accruing from investments in transport projects. What it does not include is the reliability benefit. Given that the reliability benefit is almost as large as the travel time savings, and is particularly important for business, it is important to estimate and include this benefit in a BCA.

Second, the wider economic benefits resulting from investments in transport projects are also not included in the BCA in Norway. The literature, however, is less conclusive about the desirability of including the wider economic benefits than it is about including reliability in the BCA. Nevertheless, what the literature does say quite clearly is that BCA should not be the wider economic benefits should be considered for large projects. Interestingly, the literature also seems to suggest that the BCA should not by itself be the sole criteria for making decisions about investments in large projects. Good examples of this are the U.K. and France, both countries make extensive use of BCA, but do not rely only on BCA when large projects and investments are involved.

Investments in road transport infrastructure typically have a life of 40 years. The analysis that we carry out to support decision making about these investments has to look 40 years into the future, and a lot can change in 40 years. One of the criteria that are critical to any CBA of a transport project is the value of time. The larger the value of time, the larger the value of potential travel time savings, and this increases the attractiveness of the project. In a CBA, however, the value of time figure that is used to calculate the value of the travel time savings does not increase over time, it stays constant for the entire period of the analysis. To judge the reasonableness of this assumption, one just needs to consider the value of time 40 years ago and today, the value of time today is significantly higher than what it was 40 years ago. Thus, it would make sense when considering investments with long time horizons, to increase the value of time figure used in the analysis in some systematic and defensible manner. This is currently not the case and it would clearly be an improvement if this were to be the case.

Finally, we turn to the criteria used for making investments decisions, in Norway the ratio of NPV to costs is one of the most important criteria for assessing the attractiveness of a project for investment. One problem with using this criterion is that it heavily favours projects with a short-term payback period, projects where the benefits come later on in time are unlikely to look attractive using this criterion. Again, several countries have moved to using the BCR instead of the NPV or IRR as the decision making criteria.

Given the above, our first concrete recommendation would be for the BCA approach to be thoroughly reviewed and revised based on international best practices and the latest theory and evidence.

Linked to the first recommendation is our second recommendation, namely the processes and institutions in which the BCA is embedded and by which it is applied to transport projects should also be part of the review we mentioned as part of our first recommendation. Currently, the Ministry of Finance sets the guidelines for the BCA, we believe that for transport infrastructure projects, this should be done by the Norwegian Ministry of Transport. And second, at the National level, the BCA presented for a project is checked for the compliance with the guidelines for doing a BCA, but there is no check of the fit with "National" priorities. Thus, it would be worthwhile to think of ways to link the BCA to a process by which national priorities are determined.

Our third recommendation is that when dealing with large investments and projects, projects that can change the economic and spatial geography of a region, the BCA should not be the basis for considering the attractiveness of the project. Thus, there needs to be some thinking done to develop a formal process for making decisions about large investment projects.

With regards to the investment priorities, what is clear is that there are large gains to be had by changing the investment priorities to be more focused on improving the capacity and quality of links between Norway's population and economic centres. The question that we asked is why are the investment priorities in the NTP what they are? The only reasonable conclusion that could come to is that these investment priorities result from some priority setting process. While we did not look too deeply into the processes and mechanisms for determining priorities, we can say that whatever the process and mechanisms, the resulting priorities as reflected in the NTP are far from being optimal.

Thus, our fourth recommendation is to revisit the process by which investment national, regional and city level priorities are deliberated and decided. We see two potential issues that should be addressed; the link between national and regional priorities should be made clearer and more transparent (national priorities are not explicitly considered in the current process), and how non-quantitative factors are included and considered in the decision making should be made more rigorous and transparent that what it is currently.

With regards to making the case for focused investments to improve the capacity and quality of the road network linking Norway's large population and economic centres, we showed that the benefits of investing in improving capacity and quality of road transport links can be quite large. The benefits from such focused investment in two corridors were higher by a factor of six than the benefits in the NTP, and the benefits from investing in a system of five corridors were higher by a factor of nine. Thus, while the exact magnitude of the benefits can be debated, it seems quite clear that the benefits can be large, and in any case larger than the benefits from the NTP.

Thus, our fifth and final recommendation is to carefully examine the case for increasing total investments to improve the capacity and quality of road transport in Norway. Supporting this case are the significant benefits that come from shorter alignments that are possible to link the major population and economic centres of Norway.