SUNDABRAUT SOCIOECONOMIC ANALYSIS

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CONTENTS

APPENDICES

GLOSSARY

Term	Explanation
CO_2	Carbon-dioxide
DT	Delivery Trucks
HGV	Heavy Goods Vehicle
IRR	Internal Rate of Return
ISK	Icelandic Króna
NO_x	Nitrous-oxides
NPV	Net Present Value
Pkm	Person km
$PM_{2.5}$	Particle Matter smaller than 2.5 micro-meter
PPP	Purchasing Power Parity
SLH	Transport Model for the Capital area (Icelandic: Samgöngulíkan höfuðborgarsvæðisins)
VAT	Value Added Tax
Vkm	Vehicle km

LIST OF TABLES

LIST OF FIGURES

1 Executive summary

1.1 Summary in Icelandic – samantekt á íslensku

Hér er farið yfir niðurstöður félagshagfræðilegrar greiningar á Sundabraut, nýrri stofnvegatengingu í norðausturhluta höfuðborgarsvæðisins. Þrjár mögulegar útfærslur á tengingunni voru metnar, í samanburði við óbreytt ástand:

1. Sundabraut á brú með plangatnamótum (Brú I)
2. Sundabraut á brú með mislægum gatnamótum (Brú II)
3. Sundabraut í göngum (Göng)

Innviðaverkefni eins og Sundabraut getur leitt til lækkunar á ferðakostnaði á áhrifasvæði mannvirkisins. Sparnaðurinn felst í virði tímasparnaðar (tímavirði), minni aksturskostnaði og sparnaði í ytri kostnaði vegna áhrifa á öryggi og umhverfi yfir líftíma verkefnis. En verkefninu fylgir einnig kostnaður vegna framkvæmda, reksturs og viðhalds á líftíma þess. Félagshagfræðileg greining getur auðveldað stjórnvöldum að meta ávinning af verkefni á líftíma þess og vega á móti stofn- og rekstrarkostnaði. Félagshagfræðilegar greiningar, með leiðbeiningum sem settar eru m.a. af framkvæmdastjórn Evrópusambandsins, Alþjóðabankanum, IFC og stjórnvöldum Danmerkur, Noregs, Bretlands og Hollands o.fl., eru víða notaðar erlendis.

Verkefni er sagt vera þjóðhagslega hagkvæmt ef núvirtur nettóábati er jákvæður, þ.e. ábati fyrir samfélagið er meiri en kostnaður. Þær þrjár mögulegu útfærslur Sundabrautar sem eru skoðaðar í þessari greiningu, eru allar metnar þjóðhagslega hagkvæmar. Það þýðir að núvirtur ábati, á verðlagi ársins 2021, er meiri en núvirtur kostnaður. Þjóðhagslegur ábati af Sundabraut er hér metinn á bilinu 186 og 235 milljarðar, núvirt á verðlag ársins 2021 yfir 30 ára tímabil greiningarinnar. Innri raunvextir eru metnir á bilinu 11,5% - 12,2%, mismunandi eftir útfærslum. Allar þrjár útfærslur Sundabrautar eru vel yfir viðmiðunarþröskuldum sem eru að núvirtur ábati sé að minnsta kosti 0 og að innri vextir séu 3,5%. Niðurstöðurnar má sjá í eftirfarandi töflu.

Tafla 1. Niðurstöður félagshagfræðilegrar greiningar Sundabrautar, milljónir króna á verðlagi ársins 2021.

Milljónir ISK	Brú I Núvirði	Brú II Núvirði	Göng Núvirði
Framkvæmdakostnaður:	-40.902	-47.759	-57.567
Rekstrarkostnaður:	-4.654	-5.778	-13.335
Notendaáhrif:	216.392	247.317	292.567
Ytri áhrif:	22.633	22.478	21.582
Önnur áhrif:	-7.943	-7.658	-7.762
Núvirtur ábati:	185.525	208.601	235.486
Innri vextir:	12,2%	11,9%	11,5%
Ábata/kostnaðar hlutfall:	3,34	3,29	2,91

Heimild: COWI og Mannvit

Í heild nemur ábati notenda 216 milljörðum króna til 293 milljörðum króna, eftir útfærslu Sundabrautar (brú eða göng). Mesti ábatinn er vegna styttri ferðatíma bílnotenda, og einnig vegna styttri vegalengda fyrir bílnotendur. Þeir munu m.a. njóta góðs af minni umferðartöfum og möguleikanum á að geta valið beinni leið að áfangastað.

Tímasparnaðurinn og sérstaklega styttri vegalengdir munu einnig leiða til minni útblásturs CO_2, færri slysa, minni umferðarhávaða og minni mengunar. Jákvæð áhrif þessa nema á milli 21,6 milljarða króna og 22,6 milljarða króna yfir allt 30 ára greiningartímabilið.

Vegna óvissu í undirliggjandi breytum hefur niðurstaða félagshagfræðilegu greiningarinnar gengist undir næmnigreiningu þar sem frumforsendum hennar er breytt til að kanna áhrif þeirra á samfélagslega hagkvæmni Sundabrautar.

Á heildina litið breytir næmnigreiningin hvorki því að verkefnisútfærslurnar séu samfélagslega hagkvæmar, né röðuninni á hagkvæmni útfærslnanna. Í gegnum allar breyturnar er valkosturinn Brú I með hæstu innri vexti og hæstan þjóðhagslegan ábata, og allar þrjár útfærslurnar hafa innri vexti yfir 3,5%.

1.2 Summary in English

This report presents the socioeconomic analysis of Sundabraut, a new highway connection in the northeast part of the Reykjavik capital area. Three different options in the connection are evaluated, compared to unchanged scenario:

4. Sundabraut bridge with level intersections (Bridge I)

5. Sundabraut bridge with grade separated intersections (Bridge II)

6. Sundabraut tunnel (Tunnel)

An infrastructure project like Sundabraut has the potential to result in driving costs saving, travel time savings and a reduction in external cost of transport. However, it also imposes costs from construction, operation and maintenance during its lifetime. A socioeconomic study of the proposed infrastructure project helps policymakers evaluate the aforementioned benefits arising from the projects and compare it to the project costs. The socioeconomic analysis is therefore a management tool for policy makers in order to make a more informed decision for large public investments in e.g. transport infrastructure. Socioeconomic studies are widely used in the planning of infrastructure investments worldwide with guidelines set by e.g. the European Commission, World Bank, IFC, and the governmental bodies of among others Denmark, Norway, UK and the Netherlands.

The three alternatives for the Sundabraut connection analysed in this study, are all economically feasible. This means that the discounted socioeconomic benefits are higher than the socioeconomic costs related to the project. With a net present value between 186 and 236 billion ISK over the entire analysis period of 30 years and internal rates of return between 12,2 % and 11,5 % all three alternatives are well above the normal thresholds of a net present value of at least 0 and an internal rate of return of 3,5 %. This means that the benefits to society are larger than the costs imposed and the project is therefore deemed socioeconomically feasible.

The main benefit is the travel time savings for car users, and also savings in travel distance for the motorists. They will benefit from less congestion on the roads, and from the opportunity to choose a route that goes more direct to their destination. In total the user benefits amount to 216 billion ISK and 293 billion ISK, depending on the bridge or tunnel chosen.

The time savings and especially the shorter distance will also lead to less emissions of CO_2, less accidents, less noise and less pollution. The positive impact of this amounts to between 22,6 billion ISK and 21,5 billion ISK over the entire analytical period. The results are presented in Table 1-1.

Table 1-1 Sundabraut socioeconomic summary results, m.kr., 2021 prices

Million ISK	Sundabraut bridge w. level intersections (Bridge I) NPV	Sundabraut bridge w. grade separated intersections (Bridge II) NPV	Sundabraut tunnel (Tunnel) NPV
Construction costs:	-40.902	-47.759	-57.567
Operational costs:	-4.654	-5.778	-13.335
User impacts:	216.392	247.317	292.567
External impacts:	22.633	22.478	21.582
Other consequences:	-7.943	-7.658	-7.762
Net present value	185.525	208.601	235.486
Internal rate of return	12,2%	11,9%	11,5%
Net benefit to cost ratio	3,34	3,29	2,91

Source: COWI and Mannvit

Due to the uncertainty in the underlying parameters, the result of the socioeconomic analysis has undergone a sensitivity analysis where the primary assumptions are altered in order to investigate the impact on the socioeconomic feasibility of Sundabraut.

Overall, the sensitivity analysis does not change the economic feasibility of the project alternatives or the ranking between the three alternatives. Through all the parameters it is the Bridge I alternative that has the highest internal rate of return (IRR) and therefore the highest socioeconomic benefit.

2 Introduction

This report presents the socioeconomic analysis of Sundabraut, a new highway connection in the northeast part of the Reykjavik capital area. It creates a new connection from the northern part of Reykjavík City, through the Grafarvogur neighbourhood in Reykjavík, and to the highway system north of Reykjavík that further connects to the western part of Iceland. The alignment and project phases and alternatives of Sundabraut is described and shown in chapter 3.

The purpose of Sundabraut is to improve the flow of transportation in the Reykjavík capital area and improve connections both in the Capital area and to/from it to north and northeast. Sundabraut is one of six transportation projects that the Icelandic government has approved in its Transportation Plan 2020-2034 to be worked on as a PPP (Public Private Partnership) project.

In order to analyse the impact of the government's Transportation Plan a transport model is under development covering the Capital Area. The transport model has been used for this project to analyse the traffic related impact of Sundabraut.

Based on the transport model as well as cost estimates for constructing and operating the project, the socioeconomic analysis (often referred to as cost benefit analysis or CBA) provides a quantitative measure of the effects of the project. It seeks to answer whether a new project or initiative will bring the community benefits that exceed the costs of construction and operation.

Socioeconomic analysis can be a powerful framework for governments making investment decisions and is a vital tool for improving public spending. As such, it has been heavily promoted by various actors:

1. The European Commission has heavily promoted the use of socioeconomic analysis for major infrastructure projects and has introduced legislation for its members outlining basic rules for conducting CBA[1].

2. In OECD´s economic survey of Iceland one of the key recommendations for improving public spending is applying a more comprehensive cost-benefit analysis to infrastructure projects.[2]

3. In all Scandinavian countries, the UK and the Netherlands, a cost benefit analysis must be performed on all major infrastructural projects.

[1] (European Commision, 2014)

[2] (OECD, 2019), page 10, key policy insights.

Socioeconomic studies have been performed sporadically in Iceland in recent years:

1 "Hagræn úttekt á sex valkostum fyrir framtíðarstaðsetningu Reykjavíkurflugvallar"[3]

2 2014: "Svæðisskipulag höfuðborgarsvæðisins"[4]

3 2015: "Kostnaðar- ábatagreining á alhliða flugvelli í Hvassahrauni"[5]

4 2017: "Ásvallabraut - Hagræn greining"[6]

5 2020: "Borgarlína Socioeconomic Analysis"[7]

The aforementioned analyses were conducted using the Danish socioeconomic model for transport projects, TERESA[8]. Allowing the impacts of alternative transport projects to be compared using a consistent methodology. This project is carried out in TERESA as well.

This socioeconomic analysis of the project was carried out by Mannvit and COWI in 2021.

2.1 Structure of the report

The remainder of the report is structured as follows:

- Chapter 3 describes the Sundabraut project.
- Chapter 4 shortly summarises the main aspects, the principles of socioeconomic analysis and the impacts included in the analysis of Sundabraut
- In Chapter 5, all input and assumptions of the analysis are described in detail
- Chapter 6 presents the results of the socioeconomic analysis
- In Chapter 7, the robustness of the results presented in chapter 6 are investigated by changing the main input parameters. This is a so-called sensitivity analysis

[3] (ParX, 2007)
[4] (Various, 2015)
[5] (Hagfræðistofnun, 2015)
[6] (Mannvit, 2017)
[7] Borgarlína Scocioeconomic Analysis (Mannvit, Cowi, 2020)
[8] Transport- og Energiministeriets Regneark for Samfundsøkonomisk Analyse (DTU, TERESA 5.08, 2019)

- Chapter 8 looks into the wider economic impacts
- Chapter 9 concludes on the entire socioeconomic analysis

The subsequent chapters 10 and 11 list the studies used in the analysis and the appendices.

3 Sundabraut – project description

Sundabraut is a new highway connection in the northeast part of the Reykjavik capital area. It creates a new connection from the northern part of Reykjavík City, through the Grafarvogur neighbourhood in Reykjavík, and to the highway system north of Reykjavík that further connects to the western part of Iceland.

Figure 3-1 Aerial photo of the area where Sundabraut will be located

The Sundabraut project is split into two phases. Phase 1 is the crossing over the port area and the Kleppsvík bay, over to Gufunes in the Grafarvogur neighbourhood. Phase 2 continues from Grafarvogur and north to Kjalarnes where it connects to the Vesturlandsvegur highway. For phase 1 there are two options being evaluated, a bridge and a tunnel. For phase 2 only one option is evaluated.

Figure 3-2 Overview of the Sundabraut project. Phase 1 with bridge in orange, phase 1 with tunnel in blue and phase 2 with yellow

Phase 1 with bridge has an intersection in the south end to Holtsvegur, and north of the bridge, in Gufunes, it has two intersections, with Hallsvegur and with Borgarvegur. These three intersections can all be either level intersections (with traffic lights or roundabouts) or grade separated intersections, and have all been cost estimated as both options.

Figure 3-3 Phase 1 with bridge and level intersections in Lauganes and Gufunes

Phase 1 with tunnel has two connections south of Kleppsvík to Sæbraut, one to the south between Holtavegur and Kleppsmýrarvegur, and one to the west by Dalbraut. In Gufunes where it connects to phase 2 it has only one intersection, with Borgarvegur, and it will be a greade separated intersection. The tunnel lies too deep for a connection to Hallsvegur to be possible.

Figure 3-4 Phase 1 with tunnel with connection to both north and south and with grade separated intersection in Gufunes

Phase 2 lies from Gufunes to Kjalarnes. It is about 8 km long and includes 4 bridges and 5-6 intersections.

The socioeconomic analysis will comprise of four scenarios considered in a parallel traffic modelling task:

1. Baseline without Sundabraut (in year 2034).

2. Sundabraut with connecting bridge I (level intersections at Sæbraut, Hallsvegur and Borgarvegur) (in year 2034).

3. Sundabraut with connecting bridge II (in year 2034) (grade separated intersections at Sæbraut, Hallsvegur and Borgarvegur).

4. Sundabraut with connecting tunnel (in year 2034) (south and west connection).

Resulting in three socioeconomic scenarios:

1. Socioeconomic impact of Sundabraut w/bridge I (level intersections at Sæbraut, Hallsvegur and Borgarvegur) compared to baseline.

2. Socioeconomic impact of Sundabraut w/bridge II (grade separated intersections at Sæbraut, Hallsvegur and Borgarvegur) compared to baseline.

3. Socioeconomic impact of Sundabraut w/tunnel (south and west connection) compared to baseline.

4 Methodology

An infrastructure project like Sundabraut has the potential to result in driving cost savings, travel time savings and a reduction in external cost of transport. However it also imposes costs from construction, operation and maintenance during its lifetime. A socioeconomic study of the proposed infrastructure project helps policymakers evaluate the aforementioned benefits arising from the project and compare it to the project costs. The socioeconomic analysis is therefore a management tool for policy makers in order to make more informed decisions for large public investments in e.g. transport infrastructure.

The socioeconomic analysis can indicate whether a project is economically feasible, meaning that the present value of benefits over a project's lifetime outweigh its costs. The analysis can also (if used consistently) help policy makers prioritize projects or project alternatives by ranking economic feasibility.

A socioeconomic analysis is used to capture the benefits and costs for both the public and private sector such as neighbours or bus operators. Where possible the analysis includes impacts that are external to the project. These externalities include environmental effects, effects on traffic safety, road maintenance effects etc.

To be included in the calculations, all benefits and costs are monetized. This means that they are stated in monetary values. When using the same unit of measurement – ISK - it becomes possible to compare the benefits of e.g. reduced travel times of the commuters to the costs of building and maintaining the road. The socioeconomic analysis also makes it possible to compare the benefits and costs that are realised in different years.

The steps in a socioeconomic analysis are:

- Identify all relevant costs and benefits of the project
- Quantify and monetize the costs of the project
- Quantify and monetize the benefits of the project
- Compare the costs and benefits of the project in order to analyse the feasibility of the project

The socioeconomic analysis of Sundabraut is carried out in accordance with international guidelines for assessment of transport infrastructure investments[9].

The socioeconomic analysis results in three key indicators:

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[9] The quantitative analysis is performed in a version of the Danish official model TERESA modified to Icelandic conditions. The Danish guidelines are comparable with the Norwegian and EU guidelines though there are minor differences.

- Net present value. Since the costs and benefits of a new road connection accrue over several years, all the benefits and costs over the project life are discounted[10] to an estimated net present value (NPV). The NPV is therefore the value of all future benefits and costs should they have occurred today. Hereby, it is possible to compare costs and benefits that are realised in different years.

- Internal rate of return is the discount rate at which the discounted benefits equals the discounted costs. The internal rate of return (IRR) therefore demonstrates the attractiveness of a project. The internal rate of return should at least exceed the social discount rate, which is 3.5 % in real terms.

- Benefit-cost ratio. The ratio of discounted net benefits to the discounted public costs indicates the relationship between the net benefits of the project and public costs. A ratio higher than one indicates that the net benefits exceed the public cost of construction.

For a project to be socioeconomically feasible, the net present value should be positive, and the internal rate of return should exceed the social discount rate.[11] The net present value equals zero when the internal rate of return equals the social discount rate.

Net present value and internal rate of return

The formula for calculation of the net present value of the entire cost and benefit flow of a project is

$$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t}$$

Where n is the total number of time periods, R is the net revenue per period, *i* is the discounting rate and t is the time period.

The internal rate of return is the discount rate that will return a net present value of 0. Therefore, we know that if the net present value is positive the internal rate of return is higher than the specified discounting rate. The internal rate of return is resolved in an iterative process.

[10] Discounting of a future value corrects it to its current value. The social discount rate is therefore an expression of the rate of which society is willing to give up benefits today in order to receive additionally in the future.
[11] The socioeconomic analysis does not by itself determine whether a project should be implemented or not. It solely presents the analysed social return on investment. It can still be a political priority to implement projects with low or negative results.

The economic impacts of Sundabraut that are included in the analysis are described in Table 4-1. Each of these is then elaborated in detail in chapter 5.

Table 4-1 Impacts considered in the socioeconomic analysis of Sundabraut

IMPACTS MONETISED IN THE ANALYSIS			
Subject	Description	Quantification	Monetisation
Construction costs	The construction of the highway infrastructure, roads and -bridge or -tunnel imposes a cost on society up front.	The construction cost of the project being analysed (Sundabraut Phase 1 and 2, with phase 1 in three different variations, Bridge with normal intersections, bridge with graded intersections, and a tunnel (as described in Figure 3-2).	Cost of constructing the bridge or the tunnel and the connecting roads and phase 2.
Operational costs	The infrastructure has to be maintained due to wear and tear of vehicles and nature.	Driven kilometres by car users, and regular cleaning and maintenance of the construction.	Cost per kilometre driven by cars, and a fixed cost due to natures wear and tear and resulting maintenance.
Travel time savings	Travel time savings is usually the primary benefit of infrastructure projects, and relates to less time spent going from A to B.	The travel time savings is quantified using a transport model for the Capital Area.	Calculated unit prices for free travel time and congestion, and if public transport is affected also for time in transit, waiting time, and number of transfers.
Travel costs	Travel costs is a part of the cost of transport that the transport users take into account when deciding whether or not to perform a trip.	Change in km driven based on the transport model.	The average cost of driving for each transport mode incl. fuel, depreciation and taxes.
Accidents	Accidents come at a high cost for both the parties involved and the society. Changes in risk of accidents is therefore included and monetised in the analysis. The change in the risk of accidents stem from i.e. a reduction in vehicle kilometres and improvements of roads.	Number of avoided accidents based on reduction in vehicle km in the influence area. Sometimes a more detailed accident anaylsis is performed, based on accident history in the specific analysis area. But that has not been done for this analysis.	The cost of an accident regarding material damage, personal damage and cost to society due to health care services and loss of future productivity.
CO_2 emissions	The reduction in vehicle km as cars travel less kilometers and in less time due to the new road and less congestion time.	Change in vehicle km driven and emission factor.	Unit value for cost of CO_2 emission based on vehicle km.
Pollution	The reduction in overall vehicle km's driven lower the emissions of ambient air pollutants citywide.	Change in vehicle km driven.	Unit value for cost of pollution based per vehicle km.

IMPACTS MONETISED IN THE ANALYSIS			
Subject	Description	Quantification	Monetisation
Noise	Traffic noise imposes both nuisance and health related costs to society why there is a benefit of reduced kilometers driven.	Change in vehicle km driven.	Unit value for cost of noise based per vehicle km.

Source: COWI and Mannvit

In the socioeconomic analysis, we quantify and monetize the impacts for every year in the analysis period of 30 years. This allows us to investigate the feasibility of the project over time dependent on e.g. expected developments in traffic.

Generalized cost of transport and consumer surplus

The cost of transport is often referred to as a generalized cost of transport consisting of e.g. driving costs and time spent in traffic for private cars, and ticket costs, walking time, in vehicle travel time, waiting time and shift when using public transport.

Transport users decide to travel as the cost of transport is lower than the benefit they receive from realising the trip. This net benefit is called the consumer surplus. In socioeconomic analysis of infrastructure projects, we therefore analyse and monetise the change in consumer surplus for all transport modes. The methodology of quantification of changes in consumer surplus is elaborated in detail in Appendix B.

Public Private Partnership (PPP)

The Sundabraut project is expected to be a PPP (Public Private Partnership) project. A PPP-funding scheme won't influence the overall socioeconomic result. A PPP-scheme only influences the flow of money, and by that perhaps timing of payment. A capable PPP-partner will be able to account for that and the price for the public entity will be the same in the end, and will have to be funded by the government. Hence, the socioeconomic influence from tax distortion of labour supply and other socioeconomic aspects related to the funding scheme will be the same eventually when having a PPP project.

5 Description of Data and Assumptions

In this chapter, we describe the data and assumptions for the socioeconomic analysis.

5.1 Constructions Costs

Sundabraut consist of two phases; Laugarnes to Gufunes and Gufunes to Kjalarnes and for phase 1 there are three options being analysed. The cost of each option and phase is displayed below in Table 5-1 with all numbers in 2021 prices. A contingency[1] of 50 % has been added to the construction costs.

The total cost of Sundabraut with bridge and level intersections is thereby 88,2 billion ISK, with bridge and grade separated intersections total costs are 102,6 billion ISK, and with tunnel they are 124,3 billion ISK, in 2021 prices.

Table 5-1 Constructions costs incl. VAT, billion ISK

Section	Sundabraut bridge w. level intersections	Sundabraut bridge w. grade separated intersections	Sundabraut tunnel
Phase 1	34,1	43,7	58,2
Phase 2	24,7	24,7	24,7
Total construction costs	**58,8**	**68,4**	**82,9**
Contingency	29,4	34,2	41,4
Total construction costs incl. contingency	**88,2**	**102,6**	**124,3**

Note: The estimate is including VAT and has been validated by the Icelandic Road and Coastal Administration.

Source: Sundabraut - Sundabrú og Sundagöng. Efla. 2021[2]

The construction of Sundabraut is expected to take place over a six year period from 2028 to 2033 (both years included).

[1] In early phases of a project contingency is often added to the construction cost to take uncertainties into account.
[2] The construction cost is extracted from the report "Sundabraut - Sundabrú og Sundagöng" from Efla in January 2021.

5.2 Operational Costs

The operational costs include the costs and expenses related to maintenance of the construction in question. In this case the operational costs are related to maintenance of the highway infrastructure, including the bridge in the two bridge projects, and the tunnel in the tunnel project.

It has been assumed that the operational costs are 0,8 % of the total construction costs for the bridge-project-scenarios. The same is assumed for the tunnel. However, for the tunnel an additional 400 mio. ISK is added yearly to account for the tunnel's higher maintenance requirements.

Table 5-1 Operational costs mio. ISK per year

	Bridge I	Bridge II	Tunnel
2021 prices incl. VAT	470	547	1.063
2021-prices excl. VAT	409	476	924

Source: Vegagerdin Iceland

5.3 Traffic Impacts

The traffic related consequences of the construction of each of the Sundabraut project alternatives have been estimated in the transport model for the Capital Area. The transport model was developed for the purpose of analysing the traffic related impacts of infrastructure investments in the Capital Area under the government's Transportation Plan. The transport model includes several travel modes;

- cars - private cars, delivery trucks and HGV,
- bicycles,
- public transport

Based on the transport model, a forecast is made for the traffic flow and levels in the 'baseline 2034' scenario where none of the Sundabraut-connections are constructed and three scenarios where either the Bridge I, Bridge II og Tunnel is constructed. See Figure 3-2 to Figure 3-4 in chapter 3. The impact of Sundabraut is therefore the total changes in traffic flows from the 'baseline 2034' forecast to the forecast for 2034 with the project alternatives. For detailed information on the SLH traffic model see the description and documentation in Appendix D.

The transport model in this case is a network model which is an advanced model that allows for detailed study of the traffic impact in the modelled network.

Network transport models

Network models describe a defined impact area and are generally more advanced since they can involve 'feedback loops', where the resulting state of the network can impact user decisions. These complex models incorporate significant volumes of information on the demand structure, the transport network and its dynamics (e.g. timetables, interconnections, etc.) to describe large numbers of transport movements over a specified period. Data is typically coded in the form of attributes for each transport link in the network, including speed, quality, and the travel modes that use each link.

Source: Guide to Cost-Benefit Analysis of Investment Projects, European Commission December 2014

The transport model therefore allows the changes in travel times and distances to be valued. All benefits are shown with a positive sign whereas all costs are shown with a negative sign. For the valuation of the traffic consequences Icelandic unit values are applied.

Congestion is calculated in the traffic model with a function that estimates the delay in a road at a given level of volume. Each road has a predefined capacity and when traffic volumes are well below the roads traffic capacity, traffic is assumed to go by the allowed speed at that road in a free flow environment. When traffic volume increases towards the capacity limit the speed of the cars go down and they are unable to go by the allowed speed. Thus congestion time begins, i.e. congestion is calculated as time lost when not being able to go by the allowed speed on a road.

In the following sections, we will first describe the overall estimated traffic impacts and then we will describe the estimated impacts on travel time savings for each traffic mode. For each traffic mode, we will also present the unit value used in order to monetise the impact. We conclude with the net present value of that traffic mode.

5.3.1 Overall traffic consequences

The construction of a new northern link into Reykjavik can help with the increasing congestion in the capital area, and also decrease both time spent, and kilometres driven by cars in the area. The decreases are both a result of a more direct road into central Reykjavik from the western and northern regions and suburbs, and also less density of cars on the road, i.e. less congestion. For more details on the traffic model, network effects and change maps see Appendix D.

The decrease in congestion and kilometres driven also leads to a decrease in travel time. This means that more people will choose the car as their mode of transportation, and additional cars will come onto the road offsetting some of the reductions in travel time and kilometres driven. However, it's not all offset, and in total there is 142.000 and 140.500 less kilometres driven on daily basis respectively in the Bridge I and Bridge II scenarios and 128.000 km less kilometres driven in the Tunnel scenario.

This happens despite an increase in trips by car by 2.550 daily trips in the Bridge I scenario, and respectively 3.000 and 5.000 trips in Bridge II and Tunnel scenarios.

Decrease in bicycling

Sundabraut is estimated to lead to a minor reduction in bicycling traffic. This is due to a shift from bicycling towards car use, as the number of bike trips decrease and the number of car trips increase.

Shift towards private car

The number of trips in private cars is estimated to increase from appr. 1.352.900 daily trips to appr. 1.355.500, with a corresponding decrease in trips travelled by public transport. This indicates a shift from public transport (and bicycles as mentioned above) to private cars.

Unchanged number of trips for DT and HGV

Delivery trucks and heavy good vehicles are estimated to have a constant level of trips across scenarios. However, with the shorter travel distances the total amount of kilometres driven will decrease slightly.

Table 5-2 Project traffic impact per day.

Transport mode	Unit	Baseline 2034	Bridge I 2034	Bridge II 2034	Tunnel 2034
Public transport	Passenger km	401.539	395.180	393.828	382.776
	Vehicle km	43.595	44.204	44.204	43.595
	Passenger hours	13.489	13.269	13.224	12.879
	# trips	75.241	74.770	74.643	73.712
	# shifts	21.584	20.374	20.308	20.684
Bicycles	km	121.971	120.890	120.665	119.357
	Hours	8.006	7.936	7.921	7.834
	# trips	94.173	92.889	92.709	91.989
Private cars	km	6.276.139	6.134.146	6.135.583	6.148.120
	Hours free flow	159.821	158.360	158.044	157.710
	Hours congestion	25.444	24.058	23.847	23.435
	# trips	1.352.906	1.355.456	1.355.864	1.357.970
Delivery trucks	km	590.610	576.232	576.351	575.935
	Hours free flow	14.420	14.232	14.204	14.145
	Hours congestion	1.976	1.872	1.845	1.829
	# trips	126.911	126.911	126.911	126.911
HGV	km	298.072	291.021	291.063	290.953
	hours free flow	7.334	7.252	7.231	7.203
	hours congestion	1.056	986	980	970
	# Trips	63.731	63.731	63.731	63.731

Source: SLH Transport Model

5.4 Travel Time Savings

In the following sections we present the results from the transport model regarding the impact on travel time savings for all travel modes. Benefits are shown with a positive sign and costs with a negative sign.

Note that the presented travel time savings are for the opening year of the Sundabraut connection in 2034. In the socioeconomic analysis, the traffic impacts are forecasted with an annual growth of 2,3 %. The number is based on the average car traffic growth in the transport model between the years 2019 and 2034.

The traffic impacts are reported for existing, diverted and induced travellers where:

- Existing travellers are the travellers that perform a trip with the same transport mode both with and without Sundabraut.
- Diverted travellers are travellers that shift transport mode due to the opening of Sundabraut. If this has a negative value, there are less travellers than before. If there is a positive value more trips are performed by travellers that were previously using another mode of transport.
- Induced travellers represent new and additional trips when positive. These are caused by a reduction in the cost of transport leading to more trips. If negative they represent a reduction in overall number of trips by the specific transport mode.

5.4.1 Traffic Impacts for Cars

There is a positive effect on the driving time for car users, when any of the three Sundabraut scenarios are realised. The abiding drivers are estimated to experience shorter travelling times when going to and from the same places as today. This happens because there will be a faster connection in general, but also because there is less time spent in congested traffic.

Table 5-3 Changes in annual travel times for cars, hours

Type	Travel time	Bridge I	Bridge II	Tunnel
Existing	Free flow travel time	480.057	607.244	598.251
	Congestion	575.126	660.774	841.919
Diverted/induced	Free flow travel time	207.696	243.668	388.413
	Congestion	77.511	82.222	110.058
Total		1.340.390	1.593.908	1.938.641

Note: *The values in the table are the net changes. Thereby, they represent the changes in the consumer surplus which can be monetised using unit values. The impacts in this table are therefore not directly comparable with the gross impacts listed in Table 5-2.*
Benefits are with positive sign and costs with negative sign.
Source: *SLH Transport Model*

The traffic consequences for the road traffic are monetised based on the value per hour of less or extra time spent in traffic. To reflect that time spent on business trips is more costly than time spent off work, a set of unit prices are applied depending on the purpose. The unit value for time spent commuting and other travel purposes are valued at 2.761 ISK per hour whereas the time for business purposes is valued at 6.418 ISK per hour.

Time in congestion is valued higher than travel in free flow (approximately by a factor 1,5). This is due to the nuisance the driver experiences when travelling on congested roads.

Table 5-4 *Price per hour in traffic, ISK/hour*

Subject	Commute	Business	Other
Free flow travel time	2.761	6.418	2.761
Congestion time	4.142	9.627	4.142

Note: *2021 price level and in market prices*
Source: *See Appendix A*

By combining the time savings from Table 5-3 and the unit prices from Table 5-4, the net present value of the consequences for the car drivers is calculated. It amounts to the gains reported in Table 5-5 below, over the entire analysis period of 30 years.

Table 5-5 *NPV of the socioeconomic benefits for cars, billion ISK*

Subject	Bridge I	Bridge II	Tunnel
Free flow travel time	57,0	70,6	81,8
Congestion	81,1	92,4	118,4
Total	**138,2**	**163,0**	**200,2**

Source: *Calculations performed in TERESA by Mannvit and COWI*

5.4.2 Impact for Public Transport Passengers

The construction of the Sundabraut will also mean more room for public transport. Existing and new bus routes will travel faster on the new roads and waiting time will decrease, however transfer time becomes longer.

The effects are almost identical for the two Bridge-scenarios, as the construction plans are almost identical. Regarding the tunnel scenario it is not assumed that public transport routes servicing the capital area will use the tunnel, hence there is almost no effect on the existing public transport system in this scenario.

Table 5-6 Changes in annual travel times for public transport users, hours and number of shifts

Type	Travel time	Bridge I	Bridge II	Tunnel
Existing	Travel time	7.875	7.875	-630
	Delay	0	0	0
	Waiting time	-21.735	-21.735	0
	Origin/Dest. Time	-6.615	-6.615	1.575
	Transfer time	1.575	1.575	0
	Hidden waiting time	-9.135	-9.135	0
	Number of shifts	283.500	282.870	-630
Diverted/induced	Travel time	22.680	22.050	0
	Delay	0	0	0
	Waiting time	-8.505	-8.505	0
	Origin/Dest. Time	0	-315	315
	Transfer time	4.095	4.095	0
	Hidden waiting time	-4.410	-4.095	0
	Number of shifts	75.915	74.655	-315

Note: The values in the table are the net changes. Thereby, they represent the changes in the consumer surplus which can be monetised using unit values. The impacts in this table are therefore not directly comparable with the gross impacts listed in Table 5-2.
Benefits are with positive sign and costs with negative sign.
Source: SLH Transport Model

Travel time in public transport is valued at the same unit value as for private car. However, a trip with public transport also includes access time and waiting time. Furthermore, there may be transfer time in case the journey includes a shift. The access time is valued the same as in vehicle travel time whereas delays are valued at a factor three higher and waiting time as a factor of two higher than regular travel time. Transfer time is valued at a factor of one and a half. Shifts are valued at 270 ISK per shift.

Table 5-7 Price per hour and shift for public transport users, ISK/hour and ISK/shift

Travel time	Unit	Commute	Business	Other
Travel time	ISK/hour	2.761	6.418	2.761

Travel time	Unit	Commute	Business	Other
Delay	ISK/hour	8.283	19.254	8.283
Waiting time	ISK/hour	5.522	12.836	5.522
Origin/Dest. Time	ISK/hour	2.761	6.418	2.761
Transfer time	ISK/hour	4.142	9.627	4.142
Hidden waiting time	ISK/hour	2.209	5.134	2.209
Shifts	ISK/shift	276	642	276

Note: *2021 price level and in market prices*
Source: *See Appendix A*

The net present value of the benefit for the public transport passengers is next to nothing for all three scenarios. As indicated by the traffic results there are very little effects in the tunnel scenario. In the two bridge scenarios the small effects more or less off set each other, with a small negative net result of -0,3 billion ISK over the entire analysis period of 30 years. Waiting time is the biggest negative impact, and shifts are the largest positive impact.

Table 5-8 NPV of socioeconomic benefits for public transport passengers, billion ISK

Travel time	Bridge I	Bridge II	Tunnel
Travel time	2,6	2,6	-0,1
Delay	0,0	0,0	0,0
Waiting time	-5,2	-5,2	0,0
Origin/Dest. Time	-0,6	-0,6	0,2
Transfer time	0,7	0,7	0,0
Hidden waiting time	-0,9	-0,9	0,0
Shifts	3,1	3,1	0,0
Total	-0,3	-0,3	0,1

Source: *Calculations performed in TERESA by Mannvit and COWI*

5.4.3 Traffic Impacts for Delivery Trucks and HGV

Delivery trucks and heavy goods vehicles are, like the cars, estimated to experience improvements in travel time and congestion time. A time gain is experienced in all three scenarios. Most in the tunnel scenario, where a bit more than 200.000 hours are gained every year.

Table 5-9 Changes in travel times for DTV and HGV, hours

Type	Travel time	Bridge I	Bridge II	Tunnel
Existing	Free flow travel time	59.585	73.420	77.427
	Congestion	51.118	60.203	72.097
Diverted/induced	Free flow travel time	22.239	25.880	41.467
	Congestion	8.959	9.954	10.269
Total		141.901	169.457	201.260

Note: The values in the table are the net changes. Thereby they represent the changes in the consumer surplus which can be monetized using unit values. The consequences in this table are therefore not directly comparable with the gross consequences listed in Table 5-2. Benefits are with positive sign and costs with negative sign.

Source: SLH Transport Model

The traffic consequences for the commercial road traffic are monetised based on the value per hour gained or lost in traffic. The value per hour can be seen in Table 5-10 below. The trip purpose for DTV and HGV are defined as business trips, and therefore the unit values are higher for these kinds of vehicles than for commuting private cars. As with the private cars the cost of time spent in congestion is higher than the cost of driving in free flow traffic due to the nuisance the driver experiences.

Table 5-10 Price per hour in traffic, ISK/hour

Travel time	DTV	HGV
Free flow travel time	6.731	9.019
Congestion	9.423	12.627

Note: 2021 price level and in market prices

Source: See Appendix A

The gain of the decreased travel time for DTV and HGV amount to 31,9 bio. ISK. over the analysis period for Bridge I-scenario and 44,9 bio. ISK. for the Tunnel-sceanrio. In between is the Bridge II-scenario with 37,9 bio. ISK.

Table 5-11 NPV of the socioeconomic impact for DT and HGV, billion ISK

Travel time	Bridge I	Bridge II	Tunnel
Free flow travel time	15,5	18,9	22,7
Congestion	16,3	18,9	22,3
Total	31,9	37,9	44,9

Source: Calculations performed in TERESA by Mannvit and COWI

5.4.4 Traffic Impacts for Bicycles

Bicycles are estimated to experience an improvement in travel time, at least in the two bridge scenarios. As the tunnel is closed for bicycles the tunnel scenario will have no effect for the bicycle users.

Table 5-12 Changes in annual travel times for bicycles, hours

Type	Bridge I	Bridge II	Tunnel
Existing	945	945	0
Diverted/induced	630	315	0
Total	1.575	1.260	0

Note: The values in the table are the net changes. Thereby they represent the changes in the consumer surplus which can be monetized using unit values. The consequences in this table are therefore not directly comparable with the gross consequences listed in Table 5-2. Benefits are with positive sign and costs with negative sign.
Source: SLH Transport Model

The travel time for bicycles is monetised at the same value per hour as private cars and public transport. It is assumed that bicycles do not experience congestion.

Table 5-13 Price per hour in traffic for bicycles, ISK/hour

Travel time	Commute	Business	Other
Free travelling time	2.761	6.418	2.761

Note: 2021 price level and in market prices
Source: See Appendix A

The net present value of the consequences for the bicycles are minuscule. In the two bridge scenarios there is 0,1 billion ISK over the entire analysis period of 30 years. And as mentioned the tunnel scenario has no influence on bicycles.

Table 5-14 NPV of the socioeconomic impact for bicycles, billion ISK

	Bridge I	Bridge II	Tunnel
Total	0,1	0,1	0,0

Source: Calculations performed in TERESA by Mannvit and COWI

5.5 Vehicle Operating Costs

Cars, delivery trucks and heavy goods vehicles are estimated to have an increase in total vehicle operating costs because of the Sundabraut connection. The increase in net-kilometres driven by cars, delivery trucks and heavy goods vehicles are increasing regardless of the project scenario chosen. As the course of the road is almost the same in the three scenarios, the numbers reported in Table 5-15 are very similar.

Table 5-15 Annual net kilometres for cars, DT and HGV, km

Type	Bridge I	Bridge II	Tunnel
Existing travellers	37.610.055	37.299.465	34.924.680
New travellers	9.632.700	10.137.645	12.886.020
Total	47.242.755	47.437.110	47.810.700

Note: The values in the table are the net changes. Thereby they represent the changes in the consumer surplus which can be monetized using unit values. The consequences in this table are therefore not directly comparable with the gross consequences listed in Table 5-2 and Table 5-17.

Source: SLH Transport Model

The cost of driving is 58,48 ISK per km for commuting and for other purposes, whereas the cost is 53,39 ISK per km for business purposes. The cost of driving is 54,83 and 119,84 ISK per km for delivery trucks and heavy goods vehicles respectively.

Table 5-16 Price per km, ISK/km

Subject	Commute	Business	Other	DTV	HGV
Vehicle km	58,48	53,39	58,48	54,83	119,84

Note: 2021 price level and in market prices

Source: See Appendix A

The net present value of driving cost amount to just around 46 billion ISK for all three scenarios over the analysis period of 30 years. The vehicle operating costs amounts to a total gain as cars, DTs and HGVs is estimated to experience an increase in consumer surplus. Meaning the benefit, they gain is higher than the cost increase in vehicle operating costs.

5.6 Environmental impact

The project causes external effects to the environment, neighbours and others. These socalled externalities result from the change in modal split and kilometres driven by vehicles. The expected future shift towards a car fleet running on renewable energy is incorporated in the unit values for noise, air pollution and climate.

Valuation of externalities based on changes in vehicle km

The monetisation of externalities is based on the change in gross km for the different traffic modes. This is the common method for valuation of externalities.

The vehicle km of cars, busses, delivery trucks and heavy goods vehicles is estimated to decrease by approximately 162.800 kilometres, 161.200

kilometres, and 149.800 kilometres per day, respectively, with the Sundabraut dependent on whether Bridge I, Bridge II og Tunnel scenario is adopted. This is shown in Table 5-17.

Table 5-17 Changes in gross km per project scenario per day in 2034, km

	Bridge I	Bridge II	Tunnel
Basis	7.208.416	7.208.416	7.208.416
With Sundabraut	7.045.603	7.047.201	7.058.603
Change in km	-162.813	-161.215	-149.813

Note: *Change in gross kilometres.*
Source: *SLH Transport Model*

The unit values for externalities are based on the average air pollution, climate impact and noise impact per vehicle km driven per transport mode.

Table 5-18 Unit prices for externalities per km in 2021, ISK/km

Subject	Cars	DT	HGV
Air pollution	0,41	1,29	3,17
Climate	0,77	1,12	4,06
Noise	1,95	3,38	12,35
Accidents	10,87	9,21	81,78

Note: *2021 price level and in market prices. For busses the change in km is solely from the BRT and is therefore based on electric busses.*
Source: *See Appendix A*

As shown in Table 5-19 the net present value of externalities lies between 21,6 and 22,6 billion ISK over the entire period of analysis of 30 years, with the Tunnel scenario having the smallest value. The primary benefit stems from the decrease in km driven by cars and thereby a reduction in air pollution, CO_2 and noise.

Table 5-19 Socioeconomic benefit of externalities, billion ISK

Subject	Bridge I	Bridge II	Tunnel
Pollution	0,5	0,5	0,5
Climate	0,5	0,5	0,5
Noise	2,4	2,4	2,3
Accidents	19,3	19,2	18,4
Total	22,6	22,5	21,6

Note:	*2021 price level and in market prices*
Source:	*See Appendix A*

6 Results of the Socioeconomic Analysis

The three alternatives for the Sundabraut connection analysed in this study are all economically feasible. This means that the socioeconomic benefits are higher than the socioeconomic costs related to the project, when converted into present values. With a net present value between 186 and 236 billion ISK and internal rates between 12,2 % and 11,5 % all three alternatives are well above the normal thresholds of a net present value of at least 0 and an internal rate of return of 3,5 %. This means that the benefits to society are larger than the costs imposed.

The main benefit is the travel time savings for car users, and also savings in travel distance for the motorist. They will benefit from less congestion on the roads, and from the opportunity to choose a route that goes more direct to their destination. In total the user impacts amount to approximately 216 billion ISK and up to 293 billion ISK, depending in the bridge or tunnel chosen.

The time savings and especially the shorter distance will also amount to less emissions of CO_2, less accidents, less noise and less pollution. The positive impact of this amount to between 22.6 billion ISK and 21.5 billion ISK over the entire analytical period, depending in the bridge or tunnel chosen.

The detailed results from the socioeconomic analysis is reported in table 4 below.

Table 6-1 Sundabraut socioeconomic results (2021 prices)

Million ISK	Sundabraut bridge w. level intersections (Bridge I) NPV	Sundabraut bridge w. grade separated intersections (Bridge II) NPV	Sundabraut tunnel (Tunnel) NPV
Construction costs:	**-40.902**	**-47.759**	**-57.567**
Construction costs	-62.614	-73.027	-88.179
Scrap value	21.712	25.268	30.612
Operational costs:	**-4.654**	**-5.778**	**-13.335**
Operational costs	-4.026	-4.980	-11.295
Fare revenue in public transport	-628	-798	-2.040
User impacts:	**216.392**	**247.317**	**292.567**
Time value, Road (Cars, vans and trucks)	170.079	200.847	245.161
Time value, Road (Bikes)	136	109	0
Time value, Public transport	-252	-328	100
Time value, cargo	437	517	619
Driving costs, road (Cars, vans and trucks)	46.092	46.273	46.690

Million ISK	Sundabraut bridge w. level intersections (Bridge I) NPV	Sundabraut bridge w. grade separated intersections (Bridge II) NPV	Sundabraut tunnel (Tunnel) NPV
Driving costs, Road (Bikes)	3	3	0
Internal health effects (Bikes)	-104	-104	-3
External impacts:	**22.633**	**22.478**	**21.582**
Accidents	19.293	19.166	18.352
Noise	2.379	2.359	2.283
Air pollution	483	479	477
Emissions (CO2)	478	474	470
Other consequences:	**-7.408**	**-7.049**	**-7.177**
Tax impact	-9.578	-9.479	-8.879
External health effects, bikes	-506	-611	-1.223
Distortion of labour supply	-6.188	-7.112	-8.929
Increased labour supply	8.329	9.544	11.270
Net present value	185.525	208.601	235.486
Internal rate of return	12,2%	11,9%	11,5%
Net benefit to cost ratio	3,34	3,29	2,91

Note: *All benefits are with a positive sign whereas all costs are denominated with a negative sign.*

Source: *COWI and Mannvit*

The net present value of the construction costs consists of the construction costs of the Sundabraut link in the construction period as described in section 5.1, discounted to present value, as well as the benefit of the assets at the end of the analysis period discounted back to 2021, named the scrap value. The scrap value is included in the socioeconomic analysis as it is assumed that the asset is still of value when given an adequate level of maintenance and rehabilitation.

The construction costs are significantly higher for the tunnel than for the two bridge scenarios, which means that for the tunnel to be the economically best alternative, there should be high gains on other parameters to offset the higher construction costs.

The change in operational costs is divided into two, both giving a negative impact to the socioeconomic total:

- Increase in the operational costs of the general road infrastructure. These costs increase as there is more road to maintain and also either a tunnel or a bridge.

- Decrease in revenue from public transport tickets because of the decrease of the use of public transport when the cars give new and faster opportunities.

The tunnel scenario also has higher operational costs than the two bridge options, both because of higher maintenance costs and because of a more negative impact on the usage of public transport, which leads to less revenue from ticket sales in public transport.

The user impacts cover the travel time benefits for all analysed travel modes as well as the vehicle operating costs and the user health impacts (due to changes in biking). As mentioned earlier the main benefits accrue to cars and motorists as they get faster transportation and less distance to travel.

The tunnel scenario has more positive user impacts than the bridge scenarios, however the positive gains are not enough to offset the higher construction costs to make the tunnel the most feasible project alternative – relatively speaking – despite the tunnel scenario having the highest total NPV. When looking at external impacts and other consequences, they neither are enough to offset the higher construction cost nor operational costs.

Other consequences cover the impact on public funds and GDP due to funding of the infrastructure with public funds and productivity improvements due to lower travel times that can partly be used productively for society.

7 Sensitivity analysis

The socioeconomic analysis of the three project alternatives in the Sundabraut connection shows that they are all economically feasible. However, the result of the socioeconomic analysis is based on several underlying assumptions with regards to e.g. construction costs, traffic growth, time values etc. Hence, it is customary to perform a sensitivity analysis to see how robust the results are to changes in some of the central assumptions.

7.1 Results of the Sensitivity Analysis

In this case where all three project alternatives are economically feasible there will be special attention on the sensitivities towards higher costs as lower costs will only make the projects even more feasible. However, for sensitivities on lower costs we will focus on whether the internal ranking of the three project alternatives changes.

Overall, the sensitivity analysis does neither change the economic feasibility of the project alternatives nor the ranking between the three alternatives. Through all the parameters it is the Bridge I alternative that has the highest IRR, and all three projects maintain an IRR above 3,5 %.

The following describes each sensitivity parameter's possible influence on the result, and the actual result when changing the parameter.

Labour supply distortion: In the sensitivity analysis it is assumed that there is no distortion on labour supply when financing projects with public funds, accruing from increased taxes. The basic assumption is 8 % distortionary effect.

In this analysis, changing the distortionary effect decreases the IRR on all three projects, however it does not change the conclusion that all three projects are economically feasible, nor does it affect the internal ranking of the projects.

Construction costs: Higher construction costs can make the socioeconomic business case less positive. The sensitivity analysis investigates what happens if the construction costs are 25 % higher or 25 % lower than the basic assumption.

Changing the construction costs does not affect the overall results of this analysis. Hence all three projects are economically feasible even if the construction costs increase by 25 %. The internal ranking of the projects is unchanged both at higher and lower construction costs.

Driving costs: Higher costs of driving a vehicle can make the socioeconomic business case less positive. The sensitivity analysis investigates what happens if the driving costs are 25 % higher or 25 % lower than the basic assumption.

Changing the driving costs does not affect the overall results of this analysis. Hence all three projects are economically feasible even if the driving costs increase by 25 %. The internal ranking of the projects is unchanged both at higher and lower driving costs.

Operational costs: Higher costs of maintenance or lower revenue on public transport tickets can make the socioeconomic business case less positive. The sensitivity analysis investigates what happens if the operational costs are 25 % higher or 25 % lower than the basic assumption.

Changing the operational costs does not affect the overall results of this analysis. Hence all three projects are economically feasible even if the operational costs increase by 25 %. The internal ranking of the projects is unchanged both at higher and lower operational costs.

Personal time values: Lower time values for people in traffic can make the socioeconomic business case less positive. The sensitivity analysis investigates what happens if the time values are 25 % lower or 25 % higher than the basic assumption.

Since one of the main drivers of economic benefits in the Sundabraut project is saved travel time for motorists, this is an important factor to investigate. However, changing the value of time does not affect the overall results of this analysis. Hence all three projects are economically feasible even if the value of saved time is decreased by 25 %. The internal ranking of the projects is unchanged both at higher and lower personal travel time values.

Time value for goods: Lower time values for transporting goods can make the socioeconomic business case less positive. The sensitivity analysis investigates what happens if the time values are 25 % lower or 25 % higher than the basic assumption.

Changing the value of time for goods transported, does not affect the overall results of this analysis. Hence all three projects are economically feasible even if the value of saved time for goods is decreased by 25 %. The internal ranking of the projects is unchanged both at higher and lower travel time.

Only benefit for existing users: Some of the benefits from saved travel time comes from new users of transport. Thus, less travel time leads to more people using this mode of transportation, leading to even more people gaining from the new infrastructure, giving a better socioeconomic outcome. The sensitivity analysis investigates what happens if there were no new people choosing this mode of transport, but only existing users gained the benefits.

The assumption that only existing users experience the time gains does not affect the overall results of this analysis. Hence all three projects are economically feasible even if only existing users experienced the benefits of the new infrastructure in the Sundabraut project. Likewise, the internal ranking of the projects is unchanged when assuming no additional users.

External costs: Higher external costs of emissions, pollution, etc., can make the socioeconomic business case less positive. The sensitivity analysis investigates what happens if the external costs are 25 % higher or 25 % lower than the basic assumption.

Changing the external costs does not affect the overall results of this analysis. Hence all three projects are economically feasible even if the cost of externalities increases by 25 %. The internal ranking of the projects is unchanged both at higher and lower external costs.

Traffic growth: Lower traffic growth leads to fewer people gaining benefits of the new road in the future. The sensitivity analysis investigates what happens if the traffic growth is 1 % over the evaluation period. The basic assumption is traffic growth at 2,3 % over the evaluation period.

Changing the traffic growth does not affect the overall results of this analysis. Hence all three projects are economically feasible even if the traffic growth is 1 % instead of 2,3 %.

Lower traffic volumes on Sundabraut: Lower traffic volumes on Sundabraut leads to fewer people gaining benefits of the new road in the future. Lower demand could for example be caused by road toll or overestimation of available road capacity. The sensitivity analysis investigates what happens if the traffic volumes on Sundabraut is lowered by 33%.

Lowering the traffic volumes does not affect the overall results of the analysis. The three scenarios all have positive NPV´s and therefore are still ecenomically feasible. Also the Bridge 1 scenario had the highest IRR.

Less reduction in congestion: If the Sundabraut project does not clear up as much congestion as expected, less time saving will be materialized when opening the new road. A sensitivity analysis has been carried out reducing the time savings related to less congestion by 500 hours daily for cars in each of the three scenarios. This is equivalent to 33 % less time saving in congestion in the bridge II scenario.

Reducing the time savings coming from less congestion does not affect the overall results of the analysis. The three scenarios all have positive NPV's and are therefore still economically feasible. Also, the Bridge I scenario has the highest IRR.

The results of the sensitivity analysis regarding the Internal Rate of Return are summarized in Table 7-1.

Table 7-1 – Summary of sensitivity analysis

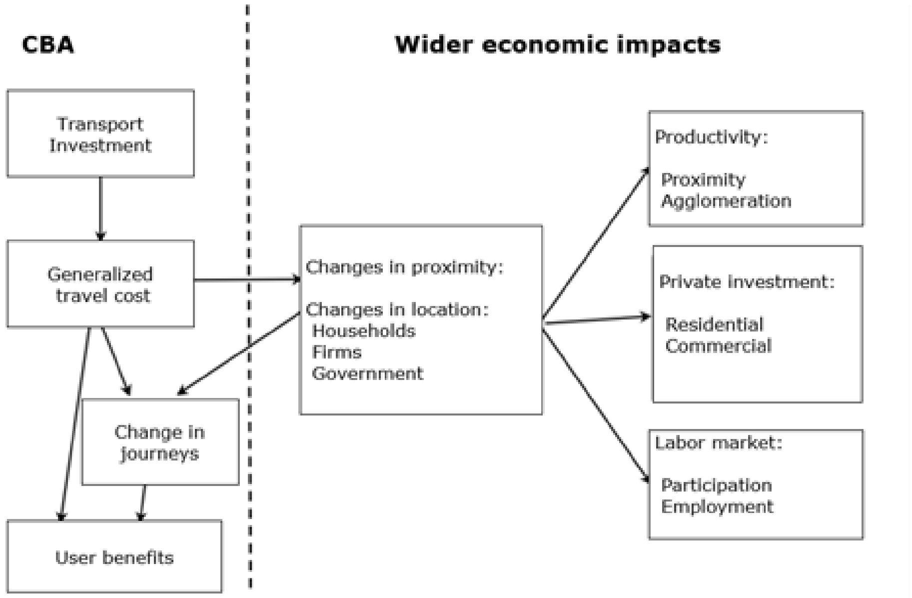
Internal Rate of Return	Bridge 1	Bridge 2	Tunnel
Basic assumptions	**12,2%**	11,9%	11,5%
Labour supply distortion from public financing 0%	**12,7%**	12,3%	11,9%
Low construction costs -25%	**14,9%**	14,5%	14,0%
High construction costs 25%	**10,5%**	10,2%	9,8%

Low driving costs -25%	**11,9%**	11,6%	11,2%
High driving costs 25%	**12,6%**	12,3%	11,8%
Low operational costs -50%	**12,2%**	11,9%	11,5%
High operational costs 50%	**12,2%**	12,0%	11,5%
Low unit prices for time values -25%	**10,6%**	10,2%	9,7%
High unit prices for time values 25%	**13,8%**	13,5%	13,1%
Only benefits for existing users	**10,5%**	10,2%	9,4%
Low external costs -50%	**11,8%**	11,6%	11,2%
High external costs 50%	**12,6%**	12,3%	11,8%
Low time values for goods -100%	**12,2%**	11,9%	11,5%
High time value for goods 400%	**12,3%**	12,0%	11,6%
Low Traffic growth 1 %	**11,2%**	10,9%	10,4%
Lower traffic volumes on Sundabraut –33%	**11,3%**	11,2%	11,0%
Less reduction in congestion	**11,6%**	11,4%	11,1 %

8 Wider economic impacts

New transport investment brings time and cost savings to the users of the network. Moreover, transport improvements result in positive externalities (reduction in external costs) for safety and environment. Those factors are monetized and discounted over a set period of time. If the benefits outweigh the costs the project is deemed economically feasible according to the principles set out by CBA. The result presented in chapter 6 for the socioeconomic value of Sundabraut is calculated according to those principles.

The case for investment in transport improvements is frequently made in those terms solely. While they constitute the centre of any transport appraisal, there are other effects which cannot readily be assessed within the scope of CBA, so-called wider economic impacts. Wider economic impacts are illustrated in the figure below.



In the short term, Sundabraut´s construction will stimulate economic growth but those effects are unlikely to be long lasting. In the long term however, Sundabraut will bring areas closer together (the capital area and the western part of the country for example) and may trigger relocation of economic activity (relocation of firms and labor). Together these changes may provide benefit to affected areas such as induced private investment and positive effects in the labour market, on both the supply and demand side. This could result in added productivity in excess of the productivity gains that are represented by the user benefits that are calculated in chapter 6.

9 Conclusion and Recommendations

This socioeconomic analysis of the Sundabraut project (Phase 1 and 2) is carried out to form a foundation for choosing between different project scenarios of the road connection. The alternatives evaluated are two options with a bridge connection and one tunnel. The socioeconomic analysis concludes that all three project scenarios are economically feasible, meaning the costs of undertaking the project is outweighed by the gains for society from having the road. Gains arise from faster travel due to less congestion and a more direct line of travel for the daily road users.

The main results of the Sundabraut socioeconomic analysis are:

- All three project alternatives are economically feasible with a positive net present value between 185,5 and 235,5 billion ISK and an internal rate of return of between 12,2 % and 11,5 %.

Table 9-1 Summary of main results

Billion ISK	Sundabraut bridge w. level intersections (Bridge I) NPV	Sundabraut bridge w. grade separated intersections (Bridge II) NPV	Sundabraut tunnel (Tunnel) NPV
Net present value	185,5	208,6	235,5
Internal rate of return	12,2%	11,9%	11,5%
Net benefit to cost ratio	3,34	3,29	2,91

- The Bridge I alternative has the lowest NPV of the three alternatives, however this project also has the highest internal rate of return, as it has the lowest construction costs. Evaluated by relatively highest return for the invested funds, the Bridge I alternative is the most favourable.

- The main contributor to positive economic results for all three alternatives is the value of time gains for private cars, delivery trucks and heavy goods vehicles.

- There are positive external impacts of Sundabraut with an estimated reduction in annual traffic accidents, as well is in noise, air pollution and CO_2 emissions, due to less kilometres driven.

- The sensitivity analysis shows that the feasibility of the project is robust towards changes in the primary assumptions.

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11 Appendices

Appendix A Unit prices methodology

The traffic impacts arising from Sundabraut are stated in time savings (hours) and kilometre savings in the traffic simulations underlying this analysis. In order to evaluate the traffic impacts in economic terms over the analysis period a set of *unit values/prices* need to be estimated. The unit values are entered into "Economic Transport Values" (Transportøkonomiske enhedspriser) to be used in TERESA (**T**ransport og **E**nergiministeriets **Re**gneark for **Sa**mfundsøkonomisk Analyse).

Table 1. Summary of unit values.

	Traffic impact	Unit values	Modes	Type	Variations
1	Time-savings	ISK/hour	Private traffic	Leisure/work/ other	Travel time/delays
			Public transport		Travel time /delays/waiting time/hidden waiting time/change time/change penalty
		ISK/ ton-hour	Freight	Average	
2	Vehicle operating costs	ISK/km	Private cars	Average/marginal	
			Bicycles	Average	
			Vans		
			Trucks		
		ISK/hour	Vans	Average	Travel time/delays
			Trucks		
3	External costs–emissions	ISK/kg	All	CO_2, $PM_{2.5}$, NO_x, SO2, CO, HC	Urban/rural
		ISK/km	Private	Gasoline, Diesel, Hybrid, Electric	
			Van	Gasoline, Diesel	
			Truck	Diesel	
			Bus	Electric	
	External costs-accidents	ISK/casualty	All	Killed/Severe injury/Minor injury	
		ISK/accident		Average	
		ISK/km	Private	Average	
			Van		
			Truck		
			Bus		
	External cost - noise	ISK/SBT	All	Average	
		ISK/km	Private	Gasoline, Diesel, Hybrid, Electric	
			Van	Gasoline, Diesel	
			Truck	Diesel	
			Bus	Electric	
	External cost - congestion	ISK/km	Private	Average	
			Van		
			Truck		
			Bus		

Varying methods need to be employed in the calculation of Icelandic unit values. This is partly due to the lack of Icelandic economic transport data and research as is to be expected for a small country. As a result, in some instances, conversion of Danish data is the preferred method. This "unit value transfer approach" is in line with international recommendations and is a common approach when applying TERESA in an international setting. The resultant uncertainty is taken into account in the sensitivity analysis of the CBA result.

The methodology for the calculations of Icelandic unit values which are adaptable into TERESA is explained in general in the relevant sections in this memo. For a more detailed description of Danish research and methodology underlying TERESA please refer to [12] [13].

A.1 Price level calculations, present value calculations and deadweight loss

The unit values have to be stated in market prices, i.e. consumer prices, and are inflated from the base year to the price year selected in "Transportøkonomiske Enhedspriser" according to a set of rules. The monetized traffic impacts over the analysis period are then discounted with a real discount rate to the year chosen. Moreover, TERESA applies a socioeconomic markup on the use of public funds in the analysis wherein the deadweight loss of taxation is accounted for with a so-called "tax distortion" rate:

i. **Economic assumptions:** Projections for real GDP/capita are used to project values based on willingness to pay (WTP) i.e. the value of time to different years in the projection period as WTP is assumed to depend on real wealth. Projections for unit values not based on WTP are calculated with the consumer price index. The real GDP growth and inflation up until 2026 is provided by Statistics Iceland (economic forecast). The real GDP growth is assumed to be 2,5% for the remainder of the period as well as as the inflation (CBI inflation target). The population projections are provided by Iceland Statistics until 2069 and are used to convert real GDP growth into real GDP growth per capita. The so called „net tax factor" represents an average tax rate and is used throughout the analysis to convert factor prices to market prices. The average tax is calculated as 15% and is calculated as the ratio between GDP in market prices and gross factor income over a 5 year period.

ii. **Discounting with a social real rate:** No extensive research has been conducted on the social real discount rate in Iceland. Thus, the real discount rate in the analysis is chosen as 3,5% in line with Danish recommendations for CBA of transport infrastructure. This rate represents the real discount rate for the first 35 years of analysis period in Danish CBA. 2,5% is used for year 36 to 70 and 1,5% for year 70 onwards. The rate represents a societal time preference rate and thus cannot be compared to present market real rates.[14]

iii. **The tax distortion rate (Icelandic: "umframbyrði skattlagningar" or "allratap"):** The rate reflects the deadweight loss of taxes and is a markup applied to the draw on public funds i.e. construction costs in Teresa[15]. The distortion rate is calculated as 8% and is scaled down from the Danish value of 10% with a ratio of total general government revenue as a share of GDP between Iceland and Denmark. This is in line with recommendations for Greenland.[16]

[12] A unit value catalogue for use in Danish CBA's of infrastructure and transport related projects is accessible here: https://www.cta.man.dtu.dk/modelbibliotek/teresa/transportoekonomiske-enhedspriser.
[13] The valuation in the catalogue is based on extensive research, for example: "Nøgletalskatalog 2004 - til brug for samfundsøkonomiske analyser på transportområdet." and Manual for samfundsokonomisk analyse: https://www.trm.dk/publikationer/2015/manual-for-samfundsoekonomisk-analyse-paa-transportomraadet/.

[14] See https://www.ft.dk/samling/20181/almdel/FIU/bilag/21/1967824.pdf

[15] PPP projects do not bear this markup.

[16] https://naalakkersuisut.gl/~/media/Nanoq/Files/Attached%20Files/Finans/DK/oekonomisk%20politik%202015/Vejledning%20i%20fremstilling%20af%20samfundsokonomiske%20konsekvensvurderinger%20-%20final%20-%20DK%20-%20april%202015.pdf

A.2 Time savings

The values of travel time savings are quantified with the so-called „value of time" and are split on travel purpose (commuting/other private = non business travel time, and business travel time) and types of travel time (ordinary travel time, delays, waiting time etc.):

i. **Commuting/other private time value (ISK/hr):** The methodology underlying the value of time for commuting/other private is based on the The Danish Value of Time Study[17]. The Icelandic value is calculated as 67% of disposable income per hour in line with the study.

ii. **Business time value (ISK/hr):** The value of travel time for business purposes is based on compensation of employees in the national accounts and total hours worked by employees in the base year according to Icelandic productivity statistics.

iii. **Travel purpose, time types and person per car (relative factors and percentages):** The relative factors used to calculate time values for ordinary travel time, delays, waiting time etc. are kept the same as in Denmark as no research has been conducted on relative time factors in Iceland (the value of delay-time savings for public transport is set at 3 times the value of ordinary travel time savings, for example). The travel purpose split and number of persons pr. car (according to purpose) is left unchanged from the Danish numbers as travel purpose surveys in Iceland do not provide a sufficiently detailed split so as to be adaptable into Teresa.

The value of time for person hours is displayed in table 2 below and for average vehicles in table 3.

Table 2. Travel time values for person hours in 2021 in 2021-prices.

ISK per person-hour	Commuting	Business	Other private purposes	Average
Public travellers				
Travel time	2.761	6.418	2.761	3.108
Delays	8.283	19.254	8.283	9.323
Waiting Time	5.522	12.836	5.522	6.216
Hidden waiting time (frequency)	2.209	5.134	2.209	2.486
Change time	4.142	9.627	4.142	4.662
Change penalty (DKK per change)	276	642	276	311
Car drivers				
Travel time	2.761	6.418	2.761	3.111
Delays	4.142	9.627	4.142	4.666
Cyclists				
Travel time	2.761	6.418	2.761	2.873
Delays	4.142	9.627	4.142	4.309

Table 3. Travel time values for vehicle hours in 2021 in 2021-prices.

ISK per vehicle-hour	Commuting	Business*	Other private	Average
Cars				
Travel time	2.965	7.023	4.198	4.149
Delays	4.448	10.535	6.297	6.223

[17] https://backend.orbit.dtu.dk/ws/portalfiles/portal/4046265/rap5_2007.pdf

A.3 Vehicle operating costs

Vehicle operating costs are estimated for private cars (leisure/business), vans, trucks and bicycles in average and marginal terms (for private cars) and fixed/variable terms for trucks and vans. The costs are split into propellant (gasoline, diesel, electricity), repair and maintenance, depreciation, battery (for hybrid and EV´s), salaries (for trucks and vans) and taxes. Icelandic data does not allow for exact calculation of driving costs in the Icelandic setting so a unit value transfer approach is applied in many cases as before:

i. **Average car/truck/van:** The Danish unit values are representative of an average vehicle which is based on a compilation of Danish transport data. Thus, the main cost components i.e. deprecation and maintenance is representative of that average car/truck/van/bicycle. The assumptions regarding the "average car" is left unchanged in the Icelandic unit values as no comparable data of similar quality has been compiled in Iceland thus far.

ii. **Cost components:** PPP price level indices for personal transport equipment is used to convert Danish data for depreciation into Icelandic unit values. PPP price level indices for GDP are used to convert repair and maintenance, tires and battery costs. Icelandic data is used for gasoline, diesel and electricity costs. The salary for van and truck drivers is calculated according to Icelandic data but average annual running hours for trucks and vans are left unchanged from Danish data.

iii. **Future projection of costs:** The future projection of real prices of propellant is left unchanged from the Danish projection i.e. Icelandic real prices are thought to fluctuate from the base year accordingly. The future projections for energy usage in the car fleet (car share split) is based on a memo compiled by „VSÓ ráðgjöf" for the Association of municipalities in the Capital area and the Road Administration. The wages for truck and van drivers are from Statistics Iceland and increase in line with real GDP/capita throughout the analysis period.

The main posts for vehicle operating costs are shown on the next page.

Table 4. Driving costs for private passenger cars in 2021 in 2021-prices.

ISK per km	Average excl. tax	Average incl. tax	Marginal excl. tax	Marginal incl. tax
Propellant	6,4	14,3	6,4	14,3
Battery (hybrids and EV's)	0,4	0,5	0,2	0,2
Tires	2,4	3,0	2,4	3,0
Repair and maintenance	19,1	23,7	7,3	9,1
Car taxes	-	1,1	-	-
Depreciation	11,1	15,9	2,6	3,8
Total	**39,4**	**58,5**	**18,9**	**30,3**

Table 5. Distance related driving costs for vans in 2021 in 2021-prices.

ISK per km	Prices	*Value*
Propellant	Factor price	9,3
Tires	Factor price	3,1
Repair and maintenance	Factor price	15,2
Depreciation	Factor price	2,5
Costs excl. taxes	Factor price	**30,1**
Taxes (not refundable)	Factor price	17,6
Costs incl. tax	Factor price	**47,7**
Costs incl. tax	Market price	**54,8**

Table 6. Time related driving costs for vans in 2021 in 2021-prices.

ISK per km	Prices	*Value*
Depreciation	Factor price	127
Salary	Factor price	4.586
Repair and maintenance	Factor price	253
Other costs (e.g. administrative)	Factor price	890
Costs excl. taxes	Factor price	**5.857**
Taxes (not refundable)	Factor price	-
Costs incl. tax	Factor price	**5.857**
Costs incl. tax	Market price	**6.731**

Table 7. Distance related driving costs for trucks in 2021 in 2021-prices.

ISK per km	Prices	*Value*
Propellant	Factor price	31,3
Tires	Factor price	8,7
Repair and maintenance	Factor price	14,2
Depreciation	Factor price	6,0
Costs excl. taxes	Factor price	**60,2**
Taxes (not refundable)	Factor price	44,1
Costs incl. tax	Factor price	**104,3**
Costs incl. tax	Market price	**119,8**

Table 8. Time related driving costs for trucks in 2021 in 2021-prices.

ISK per km	Prices	*Value*
Depreciation	Factor price	1.065
Salary	Factor price	5.234
Repair and maintenance	Factor price	357
Other costs (e.g. administrative)	Factor price	1.192
Costs excl. taxes	Factor price	**7.848**
Taxes (not refundable)	Factor price	-
Costs incl. tax	Factor price	**7.848**
Costs incl. tax	Market price	**9.019**

A.4 External costs

Traffic imposes negative externalities on society in the form of air pollution, noise, accidents, congestion and wear on the infrastructure. Those externalities need to be quantified in a standard CBA analysis.

Emissions, climate, noise and congestion

The values for air pollution, noise and congestion stated below have been converted from Danish unit values and are primarily linked to willingness to pay i.e. WTP for avoiding health damage[18]. The common approach for WTP unit transfers between countries recommended by the „Handbook on the external costs of transport"[19] consists of multiplying the unit values by the ratio of PPP income in the policy country to income in the study country with an income elasticity of 0,8 (see screenshot from the handbook below):

Recommended approach: unit value transfer with income adjustments

Transferring the unit value from the original country to the remaining Member States and countries considered in this Handbook requires the following adjustments which control for differences across locations:

- *Differences in prices*. Controlling for differences in prices is crucial to minimise errors when transferring values across locations. The recommended approach is to use *PPP-corrected exchange rates* to take into account the cost of living. If appropriate, adjustments can also be made in line with differences in living costs between regions within the same country.
- *Differences in income*. A central issue when converting values between countries is to consider differences in income. The common approach consists of multiplying the unit values by the ratio of income in the policy country to income in the study country as such:

$$WTP_{PS} = WTP_{SS}\left(\frac{I_{OS}}{I_{SS}}\right)^{\varepsilon},$$

Where WTP_{PS} is the WTP transferred to the study site, WTP_{SS} is the WTP at the study site, I_{OS} and I_{SS} are income at the other and study sites, and ε is income elasticity of WTP. Income is defined as PPP-adjusted GDP/capita in this Handbook[7]. For the income elasticity a value of 0.8 is recommended, indicating that environmental goods can be considered normal goods. This value of the income elasticity is based on an extensive meta-analysis of the OECD, which concludes that the income elasticity for the WTP of environmental and health related goods falls between 0.7 and 0.9.

Table 9. Marginal external costs for 2021 in 2021-prices.

ISK per km		Capacity	Total	Air pollution	Climate change	Noise	Congestion
Passenger car	Petrol	4 pers	23,9	0,3	0,9	2,1	8,8
	Diesel	4 pers	24,2	0,7	0,8	2,1	8,8
	Electricity	4 pers	21,3	0,0	0,0	0,7	8,8
Van	Petrol	1,5 t	27,8	0,6	1,6	3,4	12,7
	Diesel	1,5 t	28,0	1,3	1,1	3,4	12,7
Truck	Diesel	16 t	143,1	3,2	4,1	12,3	19,7
Buss	Diesel	40 pers	53,4	0,3	0,0	2,4	16,2

[18] For a detailed explanations on the rationale underlying external costs see https://www.trm.dk/media/3738/1streport.pdf

[19] https://op.europa.eu/en/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1

The climate change or CO_2 emission costs are based on market prices for CO_2 quotas.

Accidents

Accidents costs can be divided into the following social cost categories:

i. Direct public expenditures i.e. police and rescue costs and medical treatment costs.

ii. Indirect costs for society i.e. net production loss associated with fatalities.

iii. Loss of ”human value”, more commonly known as “Value of statistical life”.

iv. Other direct costs such as property damage costs.

The various cost components are calculated separately for fatalities, severely and lightly injured in the Danish unit values following the official European classification of accident casualties and Danish research on relative costs. Comparable quality data on accident costs in Iceland is limited however. Thus the direct costs components are converted to ISK with price level indices from Eurostat. The Value of statistical life is converted to ISK with the aforementioned approach suggested by the Handbook on external costs of transport for values based on WTP.

Table 10. Accident costs for 2021 in 2021-prices.

ISK per	
Death	663.415.420
Seriously injured	103.977.526
Lightly injured	13.417.168
Average	22.994.020

Appendix B Prerequisites for calculations

In order to calculate the socioeconomic value of Sundabraut and taking into account the effect on public budgets, a series of assumptions are necessary. These are summarised in Table 11-1 below.

Table 11-1 Additional assumptions

Subject	Assumption
Price level	2021 prices, market prices
Dead weight loss	8%
Factor for cost of public funds	1,15
Opening year	2034
Construction period	2028-2033
Year of NPV	2021
Social discount rate	3,5% for the first 35 years hereafter 2,5%
Annual traffic growth	2,3%

Source: COWI, Mannvit and Vegagerdin

Appendix C Methodology for Consumer surplus and Rule of a half

THE RULE OF HALF

The Rule of Half (RoH) relies on the consideration that, without the project, non-travelling users Willingness To Pay (WTP) is lower than the (prior) generalised cost of transport. After project implementation the (new) generalised cost of transport is lowered so that some previously non-travelling people decide to travel.

Although the absolute WTP is not known, the average change in consumer surplus of the generated traffic can be estimated as half of the difference between the original and the new generalised costs of transport on the improved mode for a given origin-destination (O-D) relation. It is half because a linear demand/cost graph is assumed where new users are spread evenly between two extremes: those requiring marginal motivation to start travelling (their WTP is already on the cusp between travelling and not travelling, so they get the full benefit of the change in generalised costs) and those requiring the full benefit of the change to the transport system to be motivated to travel (they get marginal net benefit). The RoH can be therefore expressed by the following formula:

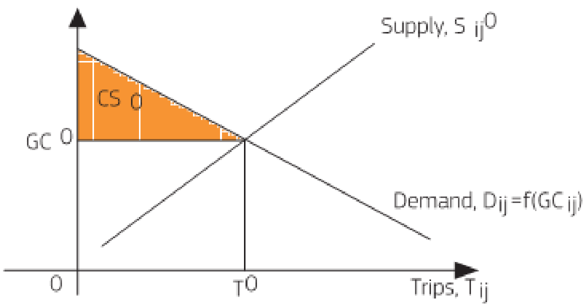
$$gc = p + z + v\tau$$

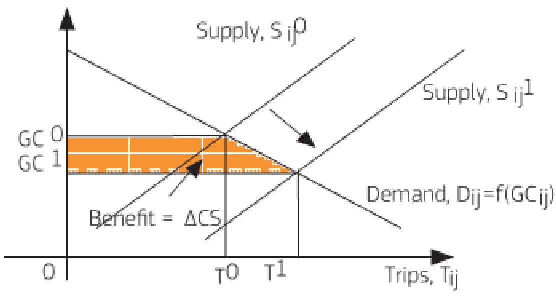
where: *p* is the amount paid for the trip by the user (tariff, toll); *z* is the perceived operating costs for road vehicles (for public transport is equal to zero);*τ* is the total time for the trip; *v* in the unit value of travel time.

Total consumer's surplus (CS^0) for a particular *i* and *j* in the Business As Usual (BAU) scenario is shown diagrammatically in the first figure. It is represented by the area beneath the demand curve and above the equilibrium generalised cost, area CS^0.

$$\text{User benefit} = \text{Consumer's surplus}_{ij}^{1} - \text{Consumer's surplus}_{ij}^{0}$$

where: 1 is the do-something scenario and 0 is the BAU scenario.





If there is an improvement in supply conditions the consumer's surplus will increase by an amount of ΔCS, due to a reduction in equilibrium generalised cost and the total user benefit (for existing and new users) can be approximated by the following function, known as the rule of a half:

$$\Delta CS = \int_{GC_1}^{GC_0} D(GC)\,dGC \approx \text{Rule of one Half (RoH)} = \frac{1}{2}(GC_0 - GC_1)(T_0 + T_1)$$

For the generated demand only (i.e. for new users), the benefits may be approximated by the following formula :

$$\Delta CS(\text{generated}) \approx 1/2 * (GC0 - GC1) * (T1 - T0)'$$

In the case of a totally new infrastructure, the RoH will not be directly applicable and the measurement of the benefits depends on the nature of the new mode, its placement in the mode hierarchy and transport network, and will often need to be derived from the users' WTP or calculated with other approaches. For example see various integration and other methods suggested in World Bank Transport Note No. TRN-11 2005.

Source: Authors

Source: *Guide to Cost-Benefit Analysis of Investment Projects, European Commission December 2014*

Appendix D Sundabraut traffic analysis memo