Estimating transport externalities from highway induced urban sprawl

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It is often argued that highway investments promote urban sprawl. One consequence of this can be increased settlement in car-dependent areas, leading to higher car use and an increase in negative transport externalities. This study estimates potential transport externalities arising from urban sprawl induced by the ferry-replacement investment Ryfast.

INTRODUCTION

The interaction between the land-use and transport system is widely acknowledged among planners. Transport investments can significantly shape long-term land use patterns, which in turn form the basis for travel demand and a potential need for new transport infrastructure (Acheampong & Silva, 2015). Highway investments, particularly those that provide substantial travel time savings near urban areas, are often argued to promote sprawling land use development (Andersen et al., 2018; Tennøy et al., 2019).

In Norway, highway investment appraisals usually assume fixed land use between the build and no-build scenarios. Critics of this approach argue that it may overlook long term consequences of urban sprawl, such as increased settlement in car-dependent areas associated with higher motorized transport and an increase in negative transport externalities (Litman, 2022). Despite this critique, there appear to be relatively few studies that have analyzed how land-use changes induced by highways might impact transport externalities, particularly for investments expected to generate substantial land-use changes (Volker, 2020; Eliasson, 2020).

Therefore, this paper aims to increase knowledge on this topic. The study estimates changes in transport externalities from the ferry replacement Ryfast with and without accounting for land-use changes. Here, land-use changes mean changes in the distribution of population growth due to the investment. Other land use aspects, such as the location of jobs or other activities, are assumed to remain fixed. Transport externalities in this study are limited to changes in vehicle kilometers traveled (VKT) by car and their impact on energy consumption, emissions, and traffic accidents.

METHOD

This section gives an overview of the Ryfast investment case, and the relocation model applied to estimate land use changes. Additionally, a description of the model calculations carried out and assumptions are provided.

The Ryfast investment

Ryfast is an undersea tunnel that opened in 2019. The investment replaced the former ferry connection between Ryfylke and the urban area of Stavanger, providing a travel time saving of approximately 45 minutes. Figure 1 illustrates the location of the Ryfast investment and the population distribution in the Stavanger region.

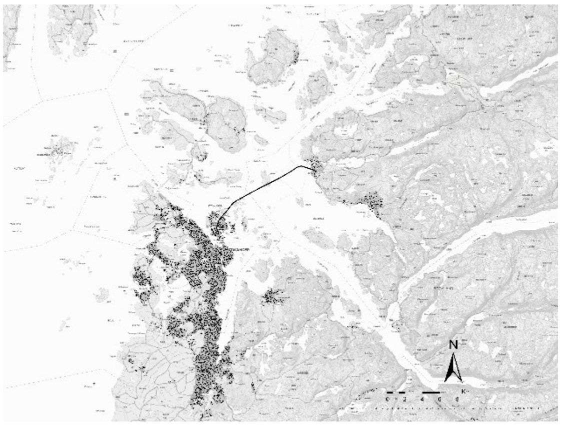

Figure 1: The Ryfast investment.

The relocation model

The relocation model redistributes the population growth after opening of the investment within a defined commuting area affected, here limited to a 60-minute travel time from the investment's endpoints. The total population remains fixed. The model is an ordinary least square model estimated based on the existing relationship between population density and accessibility to the job market. Despite being relatively simple, the model's results align reasonably well with empirical findings from other ferry replacements in the same region (Andersen et. al 2018). A more detailed description of the relocation model and its validation can be found in Stigen et. al (2024). Figure 2 illustrates the estimated model.

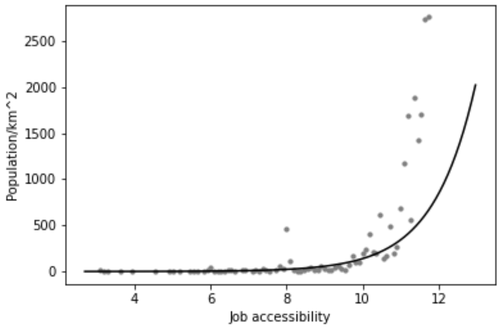

Figure 2: Estimated model (line) and observed density across different levels of accessibility (dots).

Model calculations and assumptions

For this analysis, transport externalities are estimated for three scenarios: 1) the no build scenario, 2) the build scenario with fixed land use, and 3) the build scenario with dynamic land use. Changes in estimated transport externalities between the no build and build scenarios are externalities caused by Ryfast either with or without considering land use changes.

Because land-use changes typically occur gradually and tend to become more pronounced over time, transport externalities are estimated for both a shorter and a longer analysis period of either 40 or 80 years. This is done to demonstrate how land use changes might have larger impact when expanding the time horizon for the analysis. Additionally, two different projections for population growth by Statistics Norway (SSB) have been applied. An expected population growth, and a high growth projection are shown in figure 2. In the expected scenario, growth in the affected commuting area stagnates around 20 % within 2060, while in the high growth scenario the population increases by 80 % within 2100

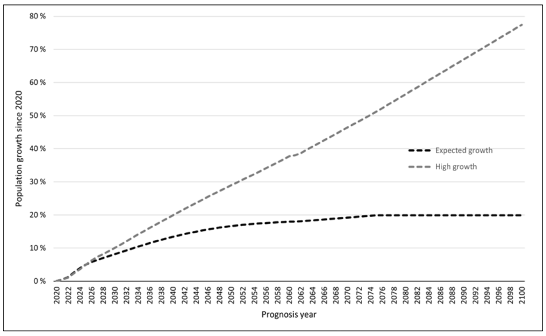

Figure 2: Illustration of the population growth projections

Transport demand for all scenarios is calculated with the regional transport model covering the western part of Norway (RTM Vest). All scenarios are calculated in the transport model for the years 2020, 2060 and 2100. When land use is allowed to change (scenario 3), the population growth between 2020 and 2060/2100 within the defined commuting area is redistributed.

Transport externalities are calculated for each road link using the cost-benefit analysis tool EFFEKT6. The externalities are interpolated between 2020, 2060 and 2100 and summed up for the entire analysis period, either 40 or 80 years.

It is worth mentioning that this study assumes no tolls on the Ryfast investment. Additionally, the ferry service that is replaced in the build scenario is assumed to be electric in the no build scenario.

ESTIMATED TRANSPORT EXTERNALITIES

This section presents relative differences in estimated transport externalities between the assumptions of dynamic and fixed land use. Additionally, as a basis for interpreting these results, the section starts with presenting the estimated population for Strand municipality when assuming both fixed and dynamic land use. Strand municipality is estimated to receive the highest population increase due to Ryfast. Table 1 shows the estimated population in Strand in 2060 and 2100 with and without accounting for land-use changes for both population growth projections by SSB.

Tabell 1: Estimated population in Strand municipality with dynamic and fixed land use assumptions.

Year	Growth scenario	Fixed land use	Dynamic land use	Change
2060	Expected	15 000	19 300	+ 29 %
	High	17 300	26 000	+ 50 %
2100	Expected	15 300	20 000	+ 31 %
	High	22 300	39 400	+ 77 %

In the expected growth scenario, the total population in Strand is estimated to be about 30% higher in 2060 when accounting for land use changes caused by Ryfast. Because the expected population projection assumes marginal population growth after 2060, the relative difference in population with/without accounting for land-use changes does not further increase towards 2100. In the high-growth scenario, the population is 50% in 2060 and 77% higher in 2100 when accounting for land use changes.

The population increase in Strand municipality is redistributed from other municipalities that do not get similar changes in accessibility when Ryfast is built. For example, the population in Stavanger municipality is estimated to be about 1–3 % across the different forecast years and population growth scenarios when accounting for land use changes.

Table 2 shows relative differences in estimated transport externalities caused by Ryfast between the assumptions of fixed or dynamic land use. Only relative changes in externalities are presented to limit the number of tables and figures.

Tabell 2: Differences in externalities from Ryfast under between the dynamic and fixed land use assumption.

	Expected growth		High growth	
Transport externality	**40 years**	**80 years**	**40 years**	**80 years**
Vehicle kilometer (VKT)	7 %	9 %	9 %	14 %
Electricity consumption	12 %	13 %	17 %	21 %
Fuel consumption	3 %	3 %	3 %	3 %
Direct emissions	4 %	4 %	5 %	5 %
Costs of direct emissions	4 %	4 %	5 %	5 %
Total emissions	6 %	8 %	8 %	12 %
Costs of total emissions	6 %	7 %	7 %	12 %
Traffic accidents	8 %	12 %	11 %	12 %
Traffic deahts	5 %	6 %	6 %	8 %
Accident costs	6 %	7 %	7 %	10 %

Table 2 show that the increase in VKT due to Ryfast is 7–14 % higher when dynamic land use is considered. When the analysis period is extended, the increase between fixed and dynamic land use becomes larger because land use changes gradually gain more influence.

The increase in electricity consumption from transport is 12–21% higher when land-use changes are considered. This increase is stronger than what is found for VKT and can be explained due to the inclusion of electricity consumption from the ferry operating in the no-build scenario.

The increase in vehicle fuel consumption (gasoline/diesel) and the direct emissions from vehicles are only 3-5 % higher when dynamic land use is assumed. The modest increase is due to an increasing share of electric vehicles throughout the analysis period. However, the increase in total emissions (also including emissions from vehicle and electric energy production) are 6–12% higher with dynamic land use.

Ryfast increases the number of traffic accidents both when fixed and dynamic land use is assumed. The increase can be explained as the investment is a new road connection that does not replace an existing high-risk road. The increase in traffic accidents is 8-12 % higher when dynamic land use is assumed, and the increase in traffic deaths and accident costs is 5-10 % higher. The increase in deaths and accident costs is relatively lower than the increase in number of accidents. This is because the model assumes that the number of accidents involving severe injuries is expected to decrease over time.

DISCUSSION

The results of this study indicate that potential long-term land use changes induced by Ryfast may provide a notable increase in VKT belonging to transport externalities. However, this increase due to land use changes is estimated to be relatively modest compared to the overall change in VKT and externalities. This also applies for the scenario assuming the highest population growth and the longest analysis period. This is due to several reasons.

First, transport investments with the potential to trigger substantial land use changes are also likely to cause large changes in other travel behavioral responses, e.g. trip frequency, mode and destination choice. Thus, the relative increase in VKT and externalities from land use changes may remain small. *Secondly*, the increase in VKT caused by land use changes manifest relatively late in the analysis period. Consequently, the associated increase in externalities is also influenced by other model assumptions, such as projections for vehicle efficiency, accident frequency and economic cost trajectories and discount rates.

The results in this study show that land use changes from highways might be significant and of high interest for policy makers. However, the policy relevance is likely to vary a lot dependent on the investment case and context. Ryfast represents a transport investment with large travel-time savings close to an urban area. Such investments have been found in previous studies to have greater potential to trigger significant land use changes (Andersen et al., 2018). However, for many transport investments, land use changes are likely to be lower with more modest policy implications.

It is important to highlight that this paper only examines how land use changes may impact negative transport externalities. However, land use changes triggered by improved accessibility also represent welfare gains. e.g. because households may consider new residential areas attractive for settlement. Such effects clearly generate changes in consumer surplus both in the land-use and transport markets. These aspects are not assessed here.

Beyond the direct impacts of including land use changes in a cost–benefit analysis, it is important to emphasize that considering land use changes may provide other valuable insights. For instance, such considerations can support local authorities in planning for increased housing demand and adjustments in local infrastructure. They may also improve travel demand estimates on the new transport investment. Furthermore, land use changes impact local property values, which is of relevance if considering land value capture and other distributional effects.

The relocation model used in this study redistributes population growth based on the existing relationship between population density and job accessibility. While it has been shown to replicate empirical patterns in the region reasonably well (Andersen et al., 2018).), it is simpler than more advanced land use models that consider multiple variables when modeling residential location choices (Acheampong & Silva, 2015). However, the study estimates externalities under different population growth scenarios and analysis periods that may provide a range for what to expect of changes in externalities due to land use changes. It is worth noting that a few other studies, e.g. Borjesson et. al (2014), estimates smaller relative changes in transport externalities due to land use changes.

CONCLUSION

This paper estimates how accounting for land-use changes induced by the ferry replacement Ryfast impact vehicle kilometers traveled by car and associated transport externalities. Externalities are calculated over a 40- or 80-year analysis period. The results indicate that considering land use changes from Ryfast may have a notable impact on transport externalities and vehicle kilometers travelled. However, despite significant land use changes, the increase in transport externalities due to land use changes remain relatively modest compared to the overall increase in externalities caused by the investment. This is because investments that trigger substantial land-use changes also often lead to significant transport externalities arising from changes in other travel behavior**.**

LITERATURE

Acheampong, R. A., & Silva, E. A. (2015). Land use – transport modelling: A review of the literature and future research directions. *Journal of Transport and Land Use, 8(3). https://doi.org/10.5198/jtlu.2015.806*

Andersen, S. N., Gutiérrez, M. D., Nilsen, Ø. L., & Tørset, T., 2018. The impact of fixed links on population development, housing and the labour market: The case of Norway. *Journal of Transport Geography, 68, 215–223. https://doi.org/10.1016/j.jtrangeo.2018.03.004*

Börjesson, M., Jonsson, R. D., Berglund, S., & Almström, P., 2014. Land-use impacts in transport appraisal. *Research in Transportation Economics, 47(1), 82–91. https://doi.org/10.1016/j.retrec.2014.09.021*

Eliasson, J., Savemark, C., & Franklin, J., 2020. The impact of land use effects in infrastructure appraisal. *Transportation Research Part A: Policy and Practice, 141, 262–276. https://doi.org/10.1016/j.tra.2020.09.026*

Litman, T., 2022. Generated traffic and Induced travel: Implications for transport planning. *Victoria Transport Policy Institue.*

Stigen, T. A., Nilsen, Ø. L., & Stevik, T. K. (2024). Impacts of highway induced land use changes on transport demand. *Transportation Research Procedia, 78, 578–585. https://doi.org/10.1016/j.trpro.2024.02.072*

Tennøy, A., Tønnesen, A., & Gundersen, F., 2019. Effects of urban road capacity expansion – Experiences from two Norwegian cases. *Transportation Research Part D: Transport and Environment, 69, 90–106. https://doi.org/10.1016/j.trd.2019.01.024*

Volker, J. M. B., Lee, A. E., & Handy, S., 2020. Induced Vehicle Travel in the Environmental Review Process. *Transportation Research Record, 2674(7), 468–479. https://doi.org/10.1177/0361198120923365*