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Evaluating the STRATMOD transport model, case Trondheim

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Abstract
The purpose of this paper is to discuss the usefulness of the transport model 'STRATMOD', a simplified transport model. Transport models are often complex and have long run-times which STRATMOD improves by aggregating travel matrices from a baseline strategic transport model, and using elasticities to calculate the effects of measures. The model is tested with a sensitivity analysis on input-elasticities, and by analysing the metro-bus project in Trondheim. The model is useful, especially when analysing public transport measures with improvements in quality factors. It is however a bit inaccurate in practical use, because of insecurities with input- elasticities, and difficulties in deciding what effect the planned measures will have for the quality factors of the public transport system as a whole.

1 Introduction
In Norway the Regional Transport Model (RTM) is used to analyse different measures and policy suggestions. Having been continuously developed since its introduction around two decades ago, RTM still lacks some explanatory factors to be able to accurately represent the development of the transport system, especially with regards to public transport and soft modes. It is not designed to include factors such as reliability, delays, comfort and capacity, and studies show that it often underestimates the impact of public transport measures, especially within cities (Tørset et al., 2015).

The transport-modelling tools used today, both in Norway and in other Scandinavian countries (such as RTM, SAMPERS, OTM or LTM etc.) are often very complex and have long run-times, making them unpractical in the initial strategic planning phases. Here, policy suggestions are analysed with long time frames, often 10-40 years. Within these long timeframes, simplified models can be used to test a broader range of policy and strategy options (Furnish & Wignall, 2009). STRATMOD (Strategic Model) improves the problem of complexity and run times, by aggregating the initial runs of a baseline transport-model into larger zones, and imports level of service (LoS) data and travel matrices into a spreadsheet model. This reduces the run times drastically. It also requires less transport modelling experience and should be easier to use than the traditional tools, because of its spreadsheet interface.

The model tries to improve some of the weaknesses of RTM, by using input variables such as delay, comfort and capacity. It can also analyse measures and policies on areas such as driving speeds for public transport and improvements for soft mode users. It also includes a cost-module and can be used to analyse project returns, operation cost reductions and cost-benefit (Berg et al., 2017).

STRATMOD uses general principles and can be developed independent of which source transport model the travel matrices come from. Today it can be run with both RTM (then called STRATMOD) or with SAMPERS (then called HUT-model). Up until now, verification projects of the model give satisfactory results (Betanzo et al., 2016a,b). However, as the model is relatively new, and further verification is needed.

The goal for this project is to test the usefulness of STRATMOD, using projects already analysed with RTM, and reveal additional benefits or weaknesses from using the model. This research will use the city of Trondheim as a case study.

Research questions

- What indications does STRATMOD show on the results of planned transport measures in Trondheim in the coming years?
- Does STARTMOD show a more realistic representation of the development in the public transport sector compared to other tools, mainly the Regional Transport Model?
- Does STRATMOD have a high enough degree of accuracy in order to be representative for use in transport modelling?

2 Methods

This research was initiated by a literature study, mainly focused on transport modelling principles, elasticity based transport models and factors affecting the demand for public transport.

The main method of this study has been modelling with the regional transport model and STRATMOD. The metrobus-project was examined by running RTM with a baseline 2016 scenario, before adding the metrobus as the single measure to keep other variables constant. These scenarios where imported into STRATMOD where further analyses where done, mainly changing quality factors and using local values of time.

To examine how the results of the model vary with different input-elasticities a sensitivity analysis on these parameters are to be done. The analysis is done by running a scenario with increased generalized cost, and the variation of the demand changes for different modes is examined. The changes in GC are about 9% for both public transport and car. The measures are shown in table 1.

Table 1 – Measures in sensitivity analysis

Measure	Change
Tolling rush	+ 40%
Parking cost rush	+ 40%
Tolling low	+ 40%
Parking cost low	+ 40%
PT fare	- 20%
On-board time rush	- 10%
On-board time low	- 10%

3 The STRATMOD-model

STRATMOD uses the results from a baseline RTM model and aggregates the travel matrices it into larger zones, and then combines the aggregated data with other inputs, such as relevant data for the public transport system, parking cost etc. The LoS data is then distributed on different travel modes, and the generalized cost (GC) for the different modes are calculated based on local time values. The different GCs makes it possible to analyse the competitive conditions between cars and other transport modes.

In order to calculate the effects of measures, STRATMOD uses elasticities based on input from the user. The change in GC from the reference scenario to the analysis scenario is calculated based on these elasticities, and new competitive conditions between the modes are found. See Figure 1 for an overall description of the calculation order of the model.

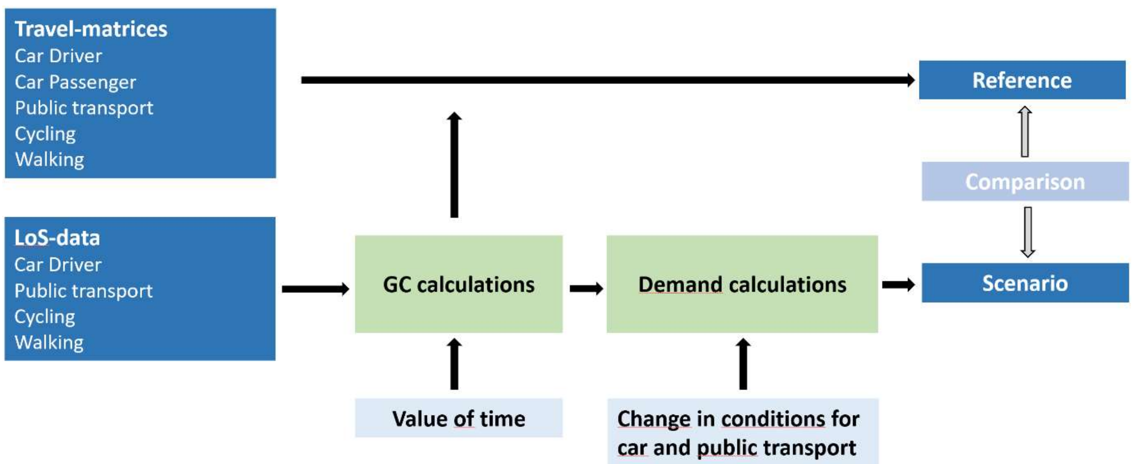

Figure 1 - Overview of data- and calculation order in STRATMOD, translated from Berg et al. (2017)

3.1 Early experiences with the model

Urbanet analyse has shown with in their early projects with STRATMOD that the model gives good results in a back-casting scenario for Oslo, where the development from 2007-2014 was investigated (Betanzo et al., 2016a). The model improves the results for public transport from RTM when including the development in quality factors. The model overestimates the growth in public transport when used with local values of time. The results from the back-casting are shown in figure 2.

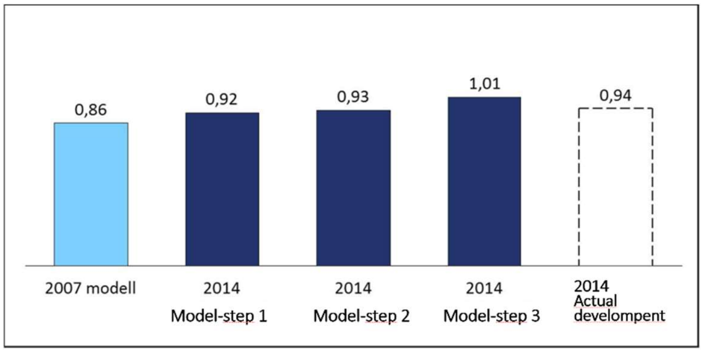

Figure 2 - Development in public transport trips per person in Oslo with STRATMOD, compared with actual development (Betanzo et al., 2016a) (translated)

4 Study area

Trondheim has approx. 200 000 habitants and is one of the larger cities in Norway. Trondheim has reached the zero growth target since its adaptation in the beginning of 2000s (Lervåg, 2016), but will need to be even more progressive in it's transport policies to reach the goals in the future (Vegvesen, 2017).

Because of population growth and the zero-growth target Trondheim has decided to introduce a new bus system in order to provide more efficient public transport to the public. The project was originally communicated as Bus Rapid Transit system, but because of lack of separate infrastructure the municipality has decided to name it "metrobus". The project will use some of the concepts from BRT, with high frequency and high capacity lines as trunk bus lines, but will not be fully separated from other buses and cars throughout the city.

5 Literature

Transport models are important for the decision making in the transport sector, but they often lack important explanatory factors and have shown mixed results when forecasting development in urban areas. Hatzopoulou and Miller (2009) state that model results are often not relied on in the decision-making processes, and because of accuracy problems other factors such as historical figures and experience are relied on more than they potentially would if the results from the models where more trustworthy.

Givoni et al. (2016) state that in order for the transport models to be a bigger part in the decision-making transport models must be made simpler in order for the modelling to be more useful. The decision makers need to understand the modelling process (i.e. the data used, assumptions and results) to be able to rely on the results.

5.1 Calculations in STRATMOD

Using generalized cost to estimate demand changes

With STRATMOD, impacts from improvements in the transport system are calculated with generalized cost elasticities, building on price elasticities and valuation of the time components and other quality factors. The method is explained in Balcombe et al. (2004). The generalized cost elasticity is found implicitly trough price elasticity, as the generalized cost cannot be measured directly. The approach relies on the assumption that reductions in whatever cost included in generalized cost will give the same relative impact on demand as reductions in price. The elasticity of reduction of price is possible to measure, and price is also included in generalized cost, thus the generalized cost elasticity is scaled according to price elasticity. The general definition of generalized cost is defined in equation 1. The generalized cost elasticity is calculated as the price elasticity divided by the price share of generalized cost, with known levels of price and generalized cost; weighted so that the elements included in generalized cost are expressed in the same units as price. This is presented in equation 2.

$$\text{GC} = \text{price} + \sum(\textit{Hard cost components} \times \textit{Weight}) + \sum(\textit{Hard cost components} \times \textit{Weight}) \quad (1)$$

$$\text{Public transport: } \varepsilon_{GC} + \frac{\varepsilon_{Fare}}{\frac{Fare}{\Sigma GC}} \qquad Car: \varepsilon_{GC} + \frac{\varepsilon_{Fuel\ price}}{\frac{\Sigma distance\ cost}{\Sigma GC}} \qquad (2)$$

These calculations are relatively ‘simple’ in comparison with the typical calculations involved in a traditional four step model-based transport model, making STRATMOD an efficient and quick model in practical use. The strengths and weaknesses of the calculation method when using generalized cost elasticities are discussed in Fearnley et al. (2015), and it is stated that: ‘’If the elements of GC are calculated correct and internally consistent, it is reasonable to assume that a change in GC would yield the same demand change independent of what was causing the change in GC.” However, it is discussed that it might not be a direct link between the value of a travel component and demand. Travelers often value delays quite high, but the demands changes are often small when the delays are reduced. This might be caused by few mode change possibilities for the users.

Elasticities

Short-term fare elasticities for public transport are normally found in the range -0.3 - -0.4 (Balcombe et al., 2004). To examine the elasticities further, the RTM model for Trondheim was run with a 10% increase in public transport fares. The model showed a reduction in public transport demand by -3.7%, indicating a fare elasticity of -0.37 in Trondheim. This value was kept in the further calculations.

Values for fuel price elasticities are less documented than PT-fare elasticities. Good- win et al. (2004) indicate short term fuel price elasticities of around -0.1. Odeck and Johansen (2016) has estimated fuel price elasticities in Norway between 1980 and 2011, and finds a short term fuel price elasticity of -0.11. Fridstrøm and Alfsen (2014) has examined several Norwegian studies and found elasticities in the range of -0.08 to -0.18. Both Odeck and Johansen (2016) and Fridstrøm and Alfsen (2014) state that the elasticities varies from region to region, and from cities to rural areas. The fuel price elasticities are examined by increasing the distance cost in RTM. A 10% increase in distance cost gives a demand change of 6% to 12%, depending on if the changes are measured in the city of Trondheim or if the areas outside the cities are included. Based on a combination of the fuel price elasticities found in the literature, and the results from RTM, the fuel price elasticities for the calculations is set to -0.1.

Valuation of time and comfort values

STRATMOD makes it possible to include local values of time in the analyses. Ellis and Øvrum (2014) has found that the local values of time differ quite significantly from the national values, as shown in table 2. Especially the valuation of comfort factors are found to be higher than used in the national values. This is mainly caused by that inconveniences with lower comfort and delay is not valued in the national values of time.

Table 2 - Different values of time used in the analysis , [2016 NOK] (Betanzo et al., 2016a)

Types of time	National values (Østli et al., 2015)	Four norwegian cities (Ellis and Øvrum, 2014)
On-board time, seated	64,5	50,2 -
On-board time, standing (weight)	1,0	1,7
Delay (weight)	1,0	6,0
Walking time, to/from stop (weight)	1,0	1,6
Walking time, interchange (weight)	1,0	1,8
Waiting time first stop (weight)	2,3	1,2
Waiting time, interchange (weight)	3,0	1,8
Interchange cost (NOK/inter- change)	6,5	15,9

6 Results

6.1 Sensitivity analysis

To understand how the results of the model vary with different input-elasticities a sensitivity analysis on public transport fare elasticity and fuel elasticity is done as discussed in section 2. As shown in section 5.1 the short-term elasticities for public transport are expected to vary in the range of -0.3 to -0.5. With the measures shown in table 1, the demand changes with a PT-fare elasticity of -0.4 (baseline), -0.3 and -0.5 are shown in in table 3. These changes correspond to a decrease in GC of about 9%.

Table 3 - Variation in demand changes with different PT-fare elasticities

	-0.4 - basis			-0.3			-0.5		
	Rush	Low	AADT	Rush	Low	AADT	Rush	Lav	AADT
Car - driver	-4,5 %	-3,7 %	-4,1 %	-4,0 %	-3,2 %	-3,6 %	-5,1 %	-4,1 %	-4,6 %
Car - passenger	0,3 %	0,5 %	0,4 %	0,8 %	1,0 %	0,9 %	-0,3 %	0,0 %	-0,1 %
Public transport	15,1 %	15,0 %	15,1 %	11,9 %	11,8 %	11,9 %	18,4 %	18,3 %	18,4 %
Cycling	-0,1 %	0,2 %	0,0 %	0,6 %	0,7 %	0,6 %	-0,8 %	-0,3 %	-0,5 %
Walking	0,4 %	0,4 %	0,4 %	0,7 %	0,6 %	0,6 %	0,0 %	0,1 %	0,1 %

The expected fuel price elasticities lie in the range of -0.08 to -0.18. Since the RTM- evaluation of indicated an elasticity as low as -0.06, the elasticities chosen in the sensitivity analysis are -0.1 (baseline), -0.07 and -0.13. The demand changes of a 9% increase in GC for cars, result in the changes shown in table 4

Table 4 - Variation in demand changes with different fuel price elasticities

	-0.1 - basis			-0.07			-0.13		
	Rush	Low	AADT	Rush	Low	AADT	Rush	Lav	AADT
Car - driver	-4,5 %	-3,7 %	-4,1 %	-3,8 %	-3,1 %	-3,4 %	-5,2 %	-4,2 %	-4,7 %
Car - passenger	0,3 %	0,5 %	0,4 %	-0,4 %	-0,2 %	-0,3 %	1,0 %	1,2 %	1,1 %
Public transport	15,1 %	15,0 %	15,1 %	14,2 %	14,2 %	14,2 %	16,0 %	15,8 %	15,9 %
Cycling	-0,1 %	0,2 %	0,0 %	-0,8 %	-0,4 %	-0,6 %	0,6 %	0,8 %	0,7 %
Walking	0,4 %	0,4 %	0,4 %	-0,1 %	0,0 %	0,0 %	0,8 %	0,7 %	0,8 %

6.2 Analysis on metrobus-system

The metrobus-project is interesting to analyse because it touches on a lot of aspects where the RTM model lacks some explanatory factors in order to show the expected growth. The project should have the potential of reducing some of the quality factors that STRATMOD is able to analyse, especially delay and crowding, because of improvements in the road network and higher capacity buses.

Step 1: Aggregating results from RTM

In the first step of STRATMOD, results from RTM are aggregated into the spreadsheet model, where the results from RTM are shown. In this analysis the RTM-model is run with a baseline 2016 scenario and with the public transport system changed to the metrobus lines. The different generalized cost for rush hours, low traffic and AADT are shown in figure 3. Here we see that the GCs are relatively similar in the baseline and metrobus scenario. The only notable changes are the reductions in on-board times and increase in waiting times in the metrobus scenario. This is expected, because the metrobus will have higher speeds but also more interchanges, because of its trunk line design.

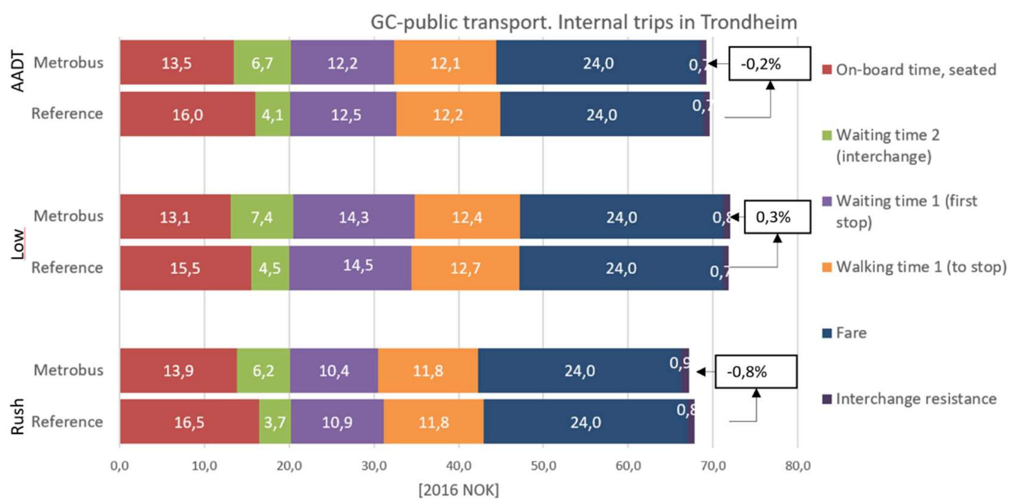

Figure 3 - Change in GC after aggregating RTM results from the metrobus project.

Step 2: Including and improving the qualitative factors

With STRATMOD it is possible to include quality factors such as delay, crowding and disadvantages with interchange. The metrobus is assumed to influence all these factors. The buses will have more public trans- port lanes and be prioritized trough intersections. This will reduce the delays. The new buses will have a more modern design, and higher passenger capacity, which should reduce the crowding.

Table 5: Assumed potential reduction in quality factors when with metrobus, 30% reduction

Quality factor	Base	Metrobus
Delay rush, % on-board time	11.1%	7.5%
Crowding cost rush (NOK/trip)	7kr	5kr
Interchange cost rush	6.5kr	4.5kr
Delay low, % on-board time	4.3%	3%
Crowding cost low (NOK/trip)	4kr	3kr
Interchange cost low	6.5kr	4.5kr

The bus stops will also be redesigned to better facilitate interchanges.

When the quality factors are included and reduced as in table 5 the generalized costs will change as shown in figure 4. We see here that the GC will be reduced by 4.7%, corresponding to a demand increase of 5.2%.

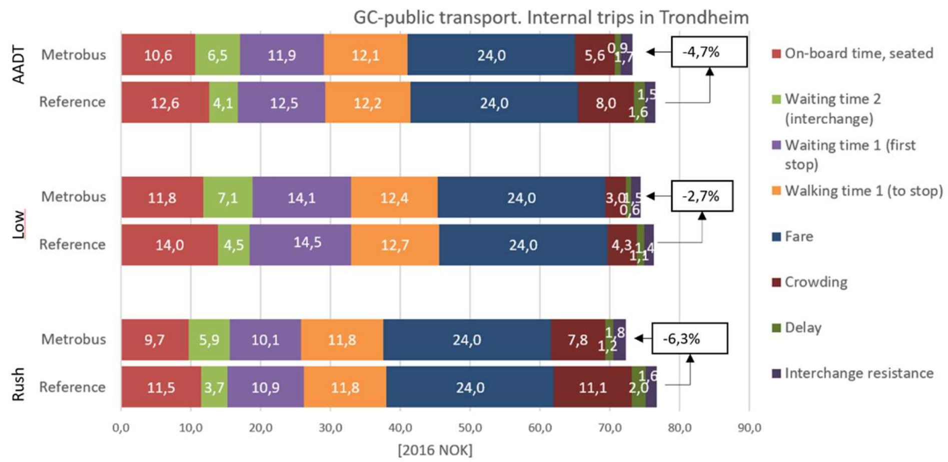

Figure 4 - Change in GC after step 2 of STRATMOD, including quality factors

Step 3: Using local values of time

When using the values of time "four Norwegian cities" in table 2 we get the change in GC as shown in figure 5. Here the qualitative factors are valued much higher than with national values of time. The model then estimates a demand increase for public transport by about 9%.

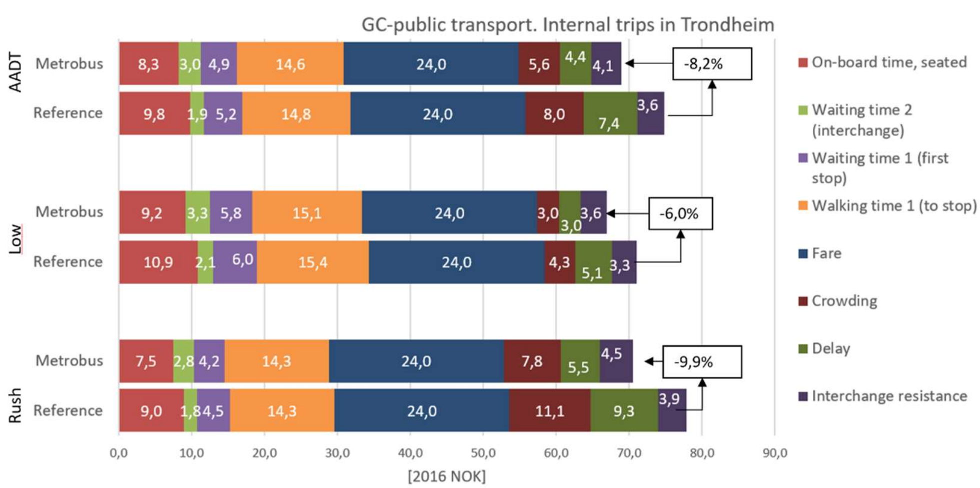

Figure 5 - Change in GC after step 3 of STRATMOD, including qualtiy factors and local values of time

7 Discussion

The aim of this study has been to test the usefulness of STRATMOD, and to investigate if it can reveal additional benefits to public transport improvements in Trondheim. The results show that the model is useful when improvements in quality factors for the public transport system are expected, showing demand effects that RTM would not be able to reveal.

Research questions

What indications does STRATMOD show on the results of planned transport measures in Trondheim in the coming years?

This analysis shows that there can be a bigger potential in the metrobus-project compared to what the regional transport model (RTM) shows. This difference is a result of an assumed change in quality factors, of which RTM is not able to include.

The analysis does however include major assumptions that must be met to achieve such results. They assume that the delays in the public transport system are reduced by 30%. In practice this means that the metrobus-system must run almost without delays, because the rest of the bus system will have the same priority on the roads as today. If this is realistic or not depends on the success of the improvement in the road network for the metro-buses. The upgrades on the bus stops must also be a success and be appreciated by the users in order to reduce the “cost” of interchange.

Does STARTMOD show a more realistic representation of the development in the public transport sector compared to other tools, mainly the Regional Transport Model?

As shown in this analysis, STRATMOD is able to show effects on factors that RTM does not include, mainly delay, crowding and comfort. The model does however often only yield a potential for changes, because the effects on measures concerning the quality factors are often hard to determine, especially when a whole transport system is considered. This means that the results in this analysis must be re-examined after the implementation of metrobus, in order to fully answer if the model is more realistic than RTM.

The benefit of the model will rely on having representative data on the quality factors. The model would be more reliable if crowding and comfort where included in the national travel surveys, in order to know the development of these factors.

Does STRATMOD have a high enough degree of accuracy in order to be representative for use in transport modelling?

As shown in the sensitivity analysis the results vary quite substantially with different input-elasticities. It seems necessary to do further research on both PT-elasticities and fuel-price elasticities to improve the accuracy of the model. Since the model is a strategic model with a long time span, it might be acceptable with a lower degree of accuracy but the insecurities should be commented on when the model is used.

Application and potential

Even with the uncertainties in input-elasticities there still is a need for STRATMOD, especially in Norway where comfort factors are not implemented in the main modelling tool, RTM. When analysing project with expected improvements in either delay, crowding or reliability there are few alternatives to STRATMOD, other than using experience numbers and 'rules of thumb'.

It seems however necessary to both develop the model further and do more research on some of its input-factors. Both elasticities regarding car-usage, and demand effects when improving quality factors needs further investigation. As discussed by Fearnley et al. (2015) improvements of quality factors in public transport are often not directly linked with demand changes. This also applies to the use of local values of time: valuation of inconveniences does not directly mean a direct demand change if it the inconveniences are reduced. These effects should be investigated further.

Because RTM was originally designed for road and tolling projects it still has weaknesses when analysing public transport. Combining STRATMOD and RTM improves some of these weaknesses, and can be a great asset when analysing public transport projects. The model can be based on any transport model that produce travel matrices divided into travel purpose and travel mode. In theory it can also be used with data produced through traffic counts and public transport data. It can be used without having full information regarding the quality factors, but to use it with its full potential it is necessary to have information about delay, crowding and comfort factors. The model is at the moment only documented in Norwegian.

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