Rapport 0609

Jens Rekdal

Evaluation of the Norwegian long distance transport model (NTM5)

Main report

HØGSKOLEN I MOLDE

MØREFORSKING Molde AS

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EVALUATION OF THE NORWEGIAN LONG DISTANCE TRANSPORT MODEL (NTM5)

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Sammendrag:

Møreforsking Molde AS (MFM) har evaluert NTM5 på oppdrag fra NTP-transportanalyser. Evalueringen er delvis gjennomført ved å kjøre modellen med historiske inputdata som grovt sett representerer årstallene 1998, 2001 og 2004. Resultatene er sammenliknet med det vi har av informasjon om de lange reisene fra andre datakilder (RVU[1]1998, RVU2001, RVU på fly i 1998 og 2003, trafikktellinger for biltrafikk og togreiser over snitt, statistikk for passasjervolumer på flyplasser, med mer). Med utgangspunkt i disse datakildene har vi bl.a. kunnet danne oss et bilde av modellens treffsikkerhet når det gjelder trafikk over snitt, geografisk fordeling av reiser totalt og etter transportåte, avstandsfordelingen for reisene og når det gjelder flypassasjerer på lufthavner. Den andre delen av evalueringen har bestått i å beregne elastisiteter (nasjonale, i korridorer, mellom regioner) med NTM5 og sammenlikne disse mot elastisiteter beregnet med tilsvarende modeller i andre land, elastisiteter fra andre studier (norske og internasjonale) og med annen metodikk (tidsserier). Evaluerngen er altså todelt, hvor den ene delen ser på modellens evne til å reprodusere kjente situasjoner, og den andre delen ser på hvordan modellen fungerer i forhold til effekter av tiltak.

Hovedinntrykket fra evalueringen er at NTM5 gir et godt bilde av trafikkutviklingen for de lange reisene over tid, gitt presisjonen i inputdata i beregningene, samt usikkerhet og relevans i de data vi sammenlikner modellresultatene mot. Vår oppfatning er bl.a. at modellresultatene for 2001 gir et bedre og mer dekkende bilde av trafikksituasjonen for de lange reisene enn oppblåste tall materialet for de lange reisene fra RVU2001. Når det gjelder elastisitetene fra modellsystemet, plasserer disse seg pent inn i det relativt brede intervallet som rapporteres i litteraturen. Det er grunn til å bemerke at det som hovedregel er ganske store forskjeller mellom elastisiteter beregnet på nasjonalt nivå (generelle landsdekkende virkemidler) og elastisiteter som er geografisk avgrensede i den forstand at variable endres i geografiske delmarkeder, slik at trafikantene også kan tilpasse seg ved å endre sine destinasjonsvalg.

[1] RVU=Reisevaneundersøkelse

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Preface

Molde Research Institute has in this project evaluated the Norwegian **N**ational **T**ransport **M**odel for long distance trips (NTM5). The client for the work is the work group for transport analysis in the National Transport Plan in Norway. The project is managed by a reference group consisting of employees of the authorities in the different transport sectors; Oskar Kleven, The Norwegian Public Roads Administration (project manager), Anita Vingan and Frode Hammer, The Norwegian National Rail Administration, Knut Fuglum and Øystein Tvetene, Avinor AS (state owned air traffic and airport company) and Erik Ørbeck, The Norwegian Coastal Administration.

From Molde Research Institute Jens Rekdal has been the project manager, and he has also carried through the evaluation. Svein Bråthen and Odd Larsen have been discussion partners and have also been responsible for the quality control of the work.

This report is the main report summarizing the work. The work is more detailed reported in five working papers from the different phases of the project. These five working papers are written in Norwegian and they are published in one single document, *Evaluation of the Norwegian long distance transport model (NTM5), a collection of five working documents*.

Jens Rekdal, 06.03.06

Summary and conclusions

Molde Research Institute has in this project evaluated the Norwegian **N**ational **T**ransport **M**odel for long distance trips (NTM5). The client for the work is the work group for transport analysis in the National Transport Plan. The evaluation is performed firstly by running the model using historical input data, roughly representing the base years 1998, 2001 and 2004. The results from the model runs are compared with information about the travel pattern from other sources (travel surveys, traffic counts, statistics, etc.). The comparison makes it possible to discuss the reliability of the model results with respect to the geographical distribution of trips by mode, traffic volumes over borderlines, trip distance distributions by mode, and passenger volumes at domestic airports. In the second part of the evaluation different elasticities at different aggregation levels are calculated, discussed and compared with elasticities from other models and analysis.

The main impression from the study is that NTM5 gives a fairly reliable picture of the development in the long distance travel pattern in Norway, especially when the uncertainty and relevance of the information in the evaluation data is taken into account. In our opinion, the model gives a more reliable picture of the long distance travel pattern for 2001 than the data for the national travel survey conducted in 2001 (when applying these data on the total population). The elasticities (direct and cross) calculated using the model system falls into the rather wide range of empirical evidence. It is important to point out however, that the differences between elasticities at different aggregation levels can be quite considerable. National aggregated elasticities reflecting a national change in a particular variable, and the demand effect of this change at the national level, can differ to a large extent from geographical disaggregated elasticities reflecting the same change, and from elasticities reflecting local changes in variables. The elasticities are highly dependent on the market shares and the level of service both which can vary significantly in the geographical dimension. Elasticities reflecting local changes in variables will also include effects on destination choices, which is not the case in national aggregated elasticities.

The evaluation has however also revealed some obvious weaknesses both in the specification of the model system and in the input data used in model runs. Most of these weaknesses are critical both when it comes to reproducing known situations, and the effects of changes in the variables.

The variables describing the mode specific travel costs are for different reasons transformed with a logarithmic function. This specification can give a lower sensitivity for travel costs than other transformations. The elasticity for travel costs will with this transformation not include direct effects from the level of the travel costs (ie. high prices will give the same sensitivity as low prices), which is not a very reliable result. The effects from the level of the cost will however enter through the market share (ie. high prices, low market share, high elasticity).

The variables describing departure frequencies for public transport (air, bus, boat and train) are specified as the square root of the number of departures per day. This formulation will give a higher (isolated) sensitivity for changes in departure frequencies when the frequencies are high than when frequencies are low. This effect also is reduced indirectly by the size of the market share (ie. High frequencies, high market shares, low elasticity).

The trip length distribution especially for travel by air and car from the model results do not fit very good with the corresponding data from the surveys. There seems to be way too many short trips by air, and too few long trips by air, and the situation is almost reversed for car trips. In the trip distribution for car trips from the model system there are too few short trips (100 km – 200 km) and too many medium distance trips (400 km – 600 km). These problems can partly be explained by too low prices for short distance air trips, and partly by unobserved important cost and time variables connected to the need to stay overnight when conducting long distance car (and also bus, boat and train) trips, a phenomenon often referred to as heteroscedasticity in the literature. The problems with the trip distributions can also be the cause of other problems with the geographical trip distribution in the model results, as a reliable trip distribution is a necessary condition for a reliable geographical trip distribution. The problems could be solved or reduced by introducing dummy variables for different trip distance intervals, or other more sophisticated variable formulations, into the mode and destination choice models.

There are also some problems and weaknesses connected to parts of the data input to the model system, especially with the data calculated in the network models. The national network models are used to calculate level of service data before a model run, and to assign the resulting demand after a model run. There seem to be problems both connected to the price information for air travel, and to the representation of the air lines and train service in the network models for some of the base years. These problems give unintentional effects on the level of service data and hence also on the resulting travel demand calculated by the model system.

In spite of these problems and weaknesses the model system produces fairly reliable results. Elimination of the problems will make the model system even more reliable. Many of the problems can be eliminated with a limited amount of resources. Such an effort will probably make the model system a more reliable and useful tool in long distance transport planning for many years to come.

Sammendrag og konklusjoner

Møreforsking Molde AS (MFM) har evaluert NTM5 på oppdrag fra NTP-transportanalyser. Evalueringen er delvis gjennomført ved å kjøre modellen med historiske inputdata som grovt sett representerer årstallene 1998, 2001 og 2004. Resultatene er sammenliknet med det vi har av informasjon om de lange reisene fra andre datakilder (RVU[2]1998, RVU2001, RVU på fly i 98 og 2003, trafikktellinger for biltrafikk og togreiser over snitt, statistikk for passasjervolumer på flyplasser, med mer). Med utgangspunkt i disse datakildene har vi bl.a. kunnet danne oss et bilde av modellens treffsikkerhet når det gjelder trafikk over snitt, geografisk fordeling av reiser totalt og etter transportmåte, avstandsfordelingen for reisene og når det gjelder flypassasjerer på lufthavner. Den andre delen av evalueringen har bestått i å beregne elastisiteter (nasjonale, i korridorer, mellom regioner) med NTM5 og sammenlikne disse mot elastisiteter beregnet med tilsvarende modeller i andre land, elastisiteter fra andre studier (norske og internasjonale) og med annen metodikk (tidsserier). Evalueringen er altså todelt, hvor den ene delen ser på modellens evne til å reprodusere kjente situasjoner, og den andre delen ser på hvordan modellen fungerer i forhold til effekter av tiltak.

Hovedinntrykket fra evalueringen er at NTM5 gir et godt bilde av trafikkutviklingen for de lange reisene over tid, gitt presisjonen i inputdata i beregningene, samt usikkerhet og relevans i de data vi sammenlikner modellresultatene mot. Vår oppfatning er bl.a. at modellresultatene for 2001 gir et bedre og mer dekkende bilde av trafikksituasjonen for de lange reisene enn materialet fra RVU2001 (når materialet blåses opp og kontrolleres mot uavhengig informasjon). Når det gjelder elastisitetene fra modellsystemet, plasserer disse seg pent inn i det relativt brede intervallet som rapporteres i litteraturen. Det er grunn til å bemerke at det som hovedregel er ganske store forskjeller mellom elastisiteter beregnet på nasjonalt nivå (generelle landsdekkende virkemidler) og elastisiteter som er geografisk avgrensede i den forstand at variable endres i geografiske delmarkeder, slik at trafikantene også kan tilpasse seg ved å endre sine destinasjonsvalg.

Evalueringen har imidlertid avdekket noen åpenbare svakheter i modellsystemet og i datamaterialet som beregningene baseres på. De fleste av disse er forhold som i og for seg er kritiske for hvor godt modellen "treffer" både når det gjelder trafikksituasjonen i utgangspunktet, og når det gjelder effekter av endringer i variable. Det er imidlertid også på kort sikt mulig å gjøre noe med en rekke av disse svakhetene innenfor en relativt begrenset ressursinnsats.

Variablene som beskriver transportmiddelspesifikke reisekostnader er av ulike estimeringstekniske årsaker transformert med en logaritmisk funksjon. I evalueringen mener vi å ha grunnlag for å hevde at dette sannsynligvis gir en del lavere følsomhet for reisekostnader enn en hvilket som helst annen transformasjon. Årsaken til dette er at følsomheten for reisekostnader ved logaritmisk transformasjon i liten grad vil avhenge av prisnivået isolert sett. Prisnivået vil kun spille en rolle gjennom det forhold at høy pris vil gi lavere markedsandeler, og at lavere markedsandeler igjen gir høyere følsomhet. Den direkte effekten av høyt prisnivå vil imidlertid være begrenset. Variablene som angir de kollektive transportmåtenes avgangsfrekvens er også noe uheldig transformert (kvadratroten av antall avganger). Denne transformasjonen gir den uheldige effekt at følsomheten for endringer i avgangsfrekvensene isolert sett er høyere når avgangsfrekvensen er høy i utgangspunktet, og lavere når avgangsfrekvensene er lave i utgangspunktet.

[2] RVU=Reisevaneundersøkelse

Dette er den direkte effekten av i endringer i antall avganger. Det vil også her være en indirekte effekt gjennom markedsandelene. Jo høyere avgangsfrekvens desto høyere markedsandel og lavere følsomhet for endringer. Vi har imidlertid en del områder hvor enkelte transportmidler har relativt høye markedsandeler på tross av relativt lave avgangsfrekvenser. Store deler av det sekundære rutenettet for fly har for eksempel en slik situasjon. Her vil variabelformuleringen for avgangsfrekvensene virke spesielt uheldig inn på effektene av endringer i tilbudet.

En annen svakhet ved NTM5 er at modellen gir en noe annerledes avstandsfordeling enn det vi bl.a. finner i RVU. Sammenliknet med RVU for få reiser i intervallet mellom 100 km og 300 km og over 600 km, og for mange i intervallet mellom 300 km og 600 km (mellom storbyene). Årsaken til dette er trolig et fenomen som i litteraturen kalles heteroskedastisitet (varierende restleddsvarians, som er brudd på forutsetninger i estimeringen). Dette skyldes igjen trolig at modellen mangler aspekter knyttet til behov for overnatting når reisene overstiger 200-300 km og gjennomføres med andre transportmåter enn fly. Disse aspektene er generelt sett problematisk å ivareta i estimeringen (bl.a. pga. uklare årsakssammenhenger og uobserverte kostnadsvariable), men problemene kan trolig reduseres ved å innføre transportmiddelspesifikke dummyvariable for ulike avstandsbånd.

At modellen gir gode resultater når det gjelder avstandsfordelingen av reisene er en viktig forutsetning for å få en god geografisk fordeling av reisene. Med en bedre avstandsfordeling vil dermed modellen også treffe bedre geografisk. Det kan likevel være et behov for å oppnå bedre geografisk treffsikkerhet, og dette kan gjøres ved å innføre geografiske dummyvariable, både når det gjelder fordeling på destinasjoner og generering av reiser. Med slike dummyvariable, som nåværende versjon ikke har, vil modellsystemet bedre kunne fange opp eventuelle geografiske forskjeller i reisevanene som ikke skyldes geografiske forskjeller i transporttilbudet.

Det er også avdekket svakheter ved deler av modellsystemets input, spesielt knyttet til nettverksmodellene hvor reisetids- og reisekostnadskomponentene beregnes. Spesielt ser billettprisene for fly på korte strekninger ut til å være urealistisk lave, og det er også problemer knyttet til koding av ruter både for fly og tog.

Nettverksmodellene i modellsystemet benyttes både til å beregne variable som beskriver transportstandarden (reisetider, reisekostnader, mm) i forkant av en kjøring av modellsystemet, og til fordeling av trafikk på veger og kollektivruter i etterkant av modellkjøringen. Kvaliteten på disse nettverkene er derfor naturligvis avgjørende for at modellen skal produsere troverdige resultater. Det er derfor viktig at nettverkene kvalitetskontrolleres løpende i forbindelse med analyser og prosjekter, og at man oppdaterer basisnettverkene når feil oppdages. I denne forbindelse kan det være verdt å påpeke at nettverket for 1998, som er modellens basisår både når det gjelder estimeringsgrunnlag og som utgangspunkt for alle beregninger, er spesielt viktig å oppdatere. Modellen kalibreres mot data for dette årstallet, og dette medfører at feil og unøyaktigheter i disse nettverkene vil bli videreført til alle andre årstall man gjennomfører beregninger for.

Prinsippene for kodingen av flyrutene er endret fra 1998 til 2001 på en måte som sannsynligvis gir konsekvenser for etterspørselsberegningene. For å unngå disse uønskede etterspørselseffektene bør de opprinnelige prinsippene gjenopptas. Når det gjelder kvaliteten på beregninger av flyreiser har vi ellers funnet at innføring av Flytoget som tilbringertransport til og fra Gardermoen gir mer troverdige trafikkvolumer på hovedflyplassen.

Nettverkene for de øvrige kollektive transportmidlene inkluderer en del korte lokale ruter. Modellsystemet dekker kun reiser som er lengre enn 100 km én vei. I enkelte tilfeller kan en oppdatering av de korte lokale rutene gi effekter på etterspørselen som tilslører etterspørsels-effektene som skyldes endringer i de langdistanse rutene. I de beregninger som er gjennomført i dette prosjektet er det f.eks. indikasjoner på at en kvalitetsforbedring når det gjelder koding av lokale togruter har gitt en relativt markant økning i etterspørselen etter lange togreiser. I en eventuell fremtidig reestimering av modellsystemet bør man derfor vurdere å fjerne de lokale rutene. Dette vil også gjøre det mindre ressurskrevende å oppdatere og kvalitetskontrollere nettverkene.

På tross av disse svakhetene gir modellen brukbare resultater, men en utbedring av de forholdene som er påpekt over vil etter all sannsynlighet gjøre modellsystemet vesentlig mer troverdig. Ved å ta utgangspunkt i de eksisterende datafiler og estimeringsprogrammer for NTM5 kan mange av disse forholdene utbedres med relativt begrensede ressurser.

Modellsystemets store fortrinn er at alle sektorene og delmarkeder som dekkes av modellen, behandles under ett. Tiltak eller utviklingstrekk innenfor en av sektorene, eller et av delmarkedene, påvirker også situasjonen i andre sektorer eller delmarkeder. Dette gjør at modellsystemet er spesielt godt egnet til å studere konkurranseforholdene mellom sektorene og delmarkedene. Her er det imidlertid viktig å påpeke at selve transporttilbudet er eksogent gitt i modellsystemet. Utviklingen i transporttilbudet over tid er det med andre ord analytikerens eller modelloperatørens oppgave å ivareta. Dette gjelder både den historiske og den fremtidige utviklingen. Modellen kan dermed ikke benyttes til å belyse hvordan eller hvorfor endringer i transporttilbudet finner sted. Modellen kan imidlertid gi gode svar på hva som skjer med etterspørselen som en konsekvens av endringene i transportilbudet.

I langsiktige trafikkprognoser er det en tendens til at det legges relativt lite ressurser og oppfinnsomhet i spesifiseringen av det fremtidige transporttilbudet. Trafikksituasjonen 20-30 år frem i tid vil utvilsomt være et resultat av bl.a. relativt store endringer i transporttilbudet. Hva som skjer med transporttilbudet, når det skjer og hvorfor det skjer er det imidlertid analytikerens ansvar å diskutere.

Modellsystemet gir kun effekter på etterspørselen av endringer i de variable som er inkludert i de ulike modellene. Endringer i bakenforliggende strukturer, som f.eks. det generelle avgifts- og skattenivå for ulike aktører innenfor sektorene, vil kunne behandles i den grad det er mulig å gjøre noen antakelser for hvordan slike endringer eventuelt vil slå ut i endrede priser for trafikantene. Resultatene vil i slike situasjoner ikke være mer presise enn de antakelser man eventuelt baserer seg på.

Ulike tiltak eller politiske virkemidler kan være av generell art, dvs at situasjonen påvirkes mer eller mindre likt (f.eks. en 10 % økning eller reduksjon i en variabel) i alle deler av landet, eller være av mer spesifikk karakter, dvs at situasjonen påvirkes i ulik grad i ulike områder. I dette prosjektet har vi vist at etterspørselseffektene og dermed også elastisitetene, kan være svært forskjellige i ulike deler av landet, både når det gjelder spesifikke tiltak eller politikk, og når det gjelder generelle tiltak som endrer situasjonen (en variabel) mer eller mindre likt i hele landet. Effektene på etterspørselen og dermed også elastisitetene vil bl.a. variere med markedsandelene og nivået på den variabel som studeres, og dette er forhold som varierer betydelig geografisk. Det er altså ikke slik at man kan komme opp med én generell, fast og sann elastisitet som er gyldig i alle situasjoner og for hele landet.

Dette leder oss inn i en diskusjon om hvorvidt det er best å bruke modellen til å analysere tiltak, eller om det er best å benytte elastisiteter fra modellen og elastisitetsberegninger til å analysere de samme tiltakene. Generelt sett kan det vel hevdes at modellen, når man går litt detaljert inn i resultatene, ikke alltid treffer så godt som man skulle ønsket. Tar man f.eks. en spesifikk flyplass kan det godt være at modellen ligger vesentlig under eller over det man har av trafikk over flyplassen fra andre kilder. I slike situasjoner kan det være fristende å heller benytte elastisiteter fra modellen, i stedet for selve modellen, til å gjennomføre en analyse. Dette kan imidlertid gi resultater som bare tilsynelatende er bedre enn å benytte modellen direkte, fordi de problemer og unøyaktigheter som er årsak til avviket i utgangspunktet også vil være innbakt i elastisiteten.

Det er også et noen andre viktige poenger ved bruk av elastisiteter fra modellen til elastisitetsberegninger. En nasjonal aggregert elastisitet reflekterer hva som skjer med etterspørselen nasjonalt sett i sum, når en variabel endrer seg med en fast prosentsats i hele landet. En nasjonal disaggregert elastisitet reflekterer hva som skjer lokalt (med trafikken mellom avgrensede områder) når en variabel endrer seg med en fast prosentsats i hele landet. En lokal elastisitet reflekterer hva som skjer lokalt (med trafikken mellom avgrensede områder) når en variabel endres lokalt (mellom de samme avgrensede områder). Det kan være relativt store forskjeller på elastisitetene avhengig av aggregeringsnivået.

I forhold til elastisitetsberegninger kan det i denne sammenheng påpekes at nasjonale aggregerte elastisiteter kun bør benyttes dersom analysen dreier seg om tiltak som endrer situasjonen på nasjonalt nivå relativt likt for hele landet, og man ser på nasjonale totaltall når det gjelder etterspørsel. Dersom analysen dreier seg om nasjonale tiltak, men hvor man ser på etterspørsel som er avgrenset geografisk, bør basere analysen baseres på nasjonale disaggregerte elastisiteter som reflekterer den geografiske avgrensningen. Dersom man ser på geografisk avgrensede tiltak, bør man benytte lokale elastisiteter som passer med den geografiske avgrensningen.

Et viktig argument for å benytte modellsystemet til analyser, i stedet for elastisitetsberegninger, er at anvendelse genererer kunnskap om modellens fordeler og svakheter. Anvendelse er dermed på mange måter en nødvendig men ikke tilstrekkelig betingelse for videreutvikling og kvalitetsforbedringer.

Introduction

The Norwegian **N**ational **T**ransport **M**odel, version 5 (NTM5), is a system of different integrated models simulating the different choices people face with respect to long distance travel activities. The development of the model system is reported in three reports written in Norwegian:

- ✓ *TØI-rapport 523/2001*, Tilrettelegging av data for estimering av nye langdistansemodeller i Den Nasjonale persontransportmodellen (NTM fase 5),
- ✓ *TØI-rapport 606/2002*, Utvikling av Den nasjonale persontransportmodellen i fase 5 (del B, estimering av modeller)
- ✓ *TØI-rapport 555/2002*, Den nasjonale persontransportmodellen, versjon 5).

These reports are written in Norwegian and they have a short English introduction.

The model system cover trips longer than 100 km with both origin and destination in Norway, conducted by Norwegian residents. The transport modes in the model system are car, train bus, boat and air. The geographical dimension in the model system is represented by a zone system dividing Norway into 1428 zones, where traffic originates and terminates. There are four types of models in the system:

- ➢ Network models
- ➢ Segmentation models dividing residents into car availability segments
- ➢ Mode and destination choice models
- ➢ Trip frequency models.

Networks describing the level of transport service between the zones for the different modes are implemented in EMME/2 (and Cube/Trips). The network models are used to (1) calculate the level of service matrices (LoS-data, mode specific time and cost components) which are important input to the transport demand models, and (2) to assign the resulting mode specific demand matrices.

The car availability models divide the residents (for each zone specified by age groups and gender) into five mutually exclusive segments with different car availability (full access to car as driver, partly access to car as driver, poor access to car as driver, full access to car as passenger only, no access to car). Information about driver licence holding, the total number of licence holders in the household and the number of cars in the household are used to define these groups. There are three different models for household types separated by the number of adult (>18 years) household members (1, 2 and 3+).

The mode and destination choice models are structural multinomial logit models, which distribute the number of trips on the full set of mode and destination combinations. There are four models representing the travel purposes: Work related trips, private visits, leisure trips, and all other travel purposes. The corresponding travel frequency models calculate the average number of trips for each travel purpose.

1 Preparation of input data for 1998, 2001 and 2004

In The Norwegian National Transport Model (NTM5) for long distance trips (>100 km one way) five main modes of travel is included, private car (driver and passenger), bus transport, air transport, rail transport and boat transport. In this project the model system is to be used to calculate the average long distance travel patterns in 1998, 2001 and 2004. This means that network scenarios representing these periods have to be created for all of the modes of transport.

1.1 Network information

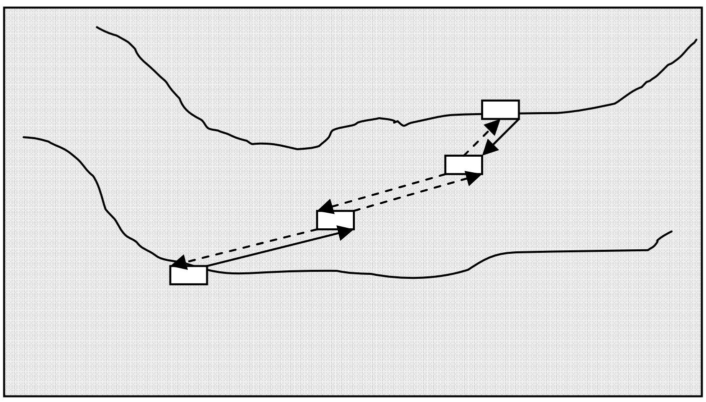
The national networks in NTM5 are coded in the software EMME/2. The road network consists of over 40000 links representing ordinary road links, toll links and ferries. Road links is specified with length and a time/speed function as the most important attributes. The functions used to calculate travel times on ordinary road links is shown in Table 1. On links with a maximum speed limit of 50 km/h and below, the average speed is assumed to be 80 % of the speed limit. On links with higher maximum speed limits the average speed is assumed to be 85 % of the limit. On links with more than one lane per direction the average speed will be slightly higher than on links with only one lane.

Table 1 Functions for calculating travel times on auto links

No = max speed	Function
fd30	60 * (length / (.8 * (1.05 ^ lanes) * 30))
fd40	60 * (length / (.8 * (1.05 ^ lanes) * 40))
fd50	60 * (length / (.8 * (1.05 ^ lanes) * 50))
fd60	60 * (length / (.85 * (1.05 ^ lanes) * 60))
fd70	60 * (length / (.85 * (1.05 ^ lanes) * 70))
fd80	60 * (length / (.85 * (1.05 ^ lanes) * 80))
fd90	60 * (length / (.85 * (1.05 ^ lanes) * 90))
fd99	60 * (length / (.85 * (1.05 ^ lanes) * 100))

The links representing ferries has specific functions that include time components connected to waiting and sailing time. The principle of representing ferries in the road network is exemplified in Figure 1.

Figure 1 Principles of representation of ferries in auto networks



As we can se a ferry can be represented by several links in each direction. One of the links in each direction represents the actual departure link, where the headway and docking time are specified. The other links are specified with sailing time only.

There are 9 different functions representing different headways as shown in Table 2. The actual waiting time is assumed to be half of the headway but maximum 30 minutes. The docking time is assumed to be 3 minutes.

Table 2 Functions for calculating travel times on ferry links

No	Function	Headway (min)
fd1	10 + 3 + 60 * (length / 22)	20
fd2	12.5 + 3 + 60 * (length / 22)	25
fd3	15 + 3 + 60 * (length / 22)	30
fd4	17.5 + 3 + 60 * (length / 22)	35
fd5	20 + 3 + 60 * (length / 22)	40
fd6	22.5 + 3 + 60 * (length / 22)	45
fd7	25 + 3 + 60 * (length / 22)	50
fd8	27.5 + 3 + 60 * (length / 22)	55
fd9	30 + 3 + 60 * (length / 22)	60 and more
fd10	60 * (length / 22)	Sea speed only

The cost of going by ferries and passing toll stations is specific for each ferry and toll station. These data are specified in specific data files that are accessed whenever necessary (usually when traffic assignments are performed).

The four public transport modes in NTM5 all have their own sub network of mode specific links and nodes. The transit lines is specified with headways and itineraries (a sequence of nodes specified with travel time between them, and dwell time at stops, etc) as the most important attributes. The bus network is the most comprehensive network, consisting of approximately 600 transit lines. The boat and rail network consist of about 100 transit lines each.

1.2 Creating network scenarios for 1998, 2001 and 2004

In this project, network scenarios are to be created for three different time periods, representing the "transport supply" in 1998, 2001 and 2004. The network data collected and processed for the estimation of the model system is used as a base for this work. The model system is estimated on data form the national travel survey conducted in 1997/98 (RVU98), and the network data used in the estimation roughly represent this period of time (TØI report 523/2001). The network data for 1998 has been subject of some quality control, and some errors and inaccuracies have been eliminated. Most of the network data for 2001 is provided by our client for this project. These data are either produced directly of our client or by other projects conducted by our client. These data has also been subject to some quality control in this project. The data for 2004 are mainly developed in this project, mainly by manual coding, but to some extent also based on data from other projects (the changes in the road network from 2001 to 2004 are based on data documented in TØI report 582/2002).

The creation of different network scenarios for 1998, 2001 and 2004, imply that we have to have control over both the changes in infrastructure and transit lines between these years. In the road network we need to know when a huge amount of road projects are finished and opened for traffic. Most of the road projects in Norway the recent years, is partly financed by the road users, which in practice means that toll is collected ether manually or by queue-free systems. There is a substantial variation in the toll-ticket fares, mainly depending of the total cost of the project, the traffic volumes on the roads, and the time horizon of the toll scheme. Some of the road projects replace ferry connections by a bridge or a tunnel or both, and this type of projects are almost always (partly) financed by user tolls. Therefore, in addition to the changes in the road infrastructure, it is important to keep track of the changes in toll stations and ferry connections, when the network scenarios is created.

In 1998 there are 118 ferry connections on the national road network represented in the long distance network (regional and local roads are not represented). From 1998 to 2001, 7 of these connections are replaced by roads, leaving us with 111 connections in 2001. From 2001 to 2004 only one connection is replaced, and the total number of ferry connections is 110. There has been made a considerable effort in updating and quality control of the toll roads in the national network, both when it comes to the location of the toll stations, the time of which the toll collection is opened or closed, and how the actual fare varies between the three years. The overall number of toll schemes is 47, but only 16 of these have been operated all three years. In 1998, 29 toll roads are operated, and 6 of them are closed down in 2001 and 7 more are closed down in 2004. On the other hand, 8 new toll schemes are opened from 1998 to 2001, and 10 more between 2001 and 2004. Thus, the number of toll schemes in the national network is 29 in 1998, 31 in 2001, and 34 in 2004.

When it comes to the four transit modes, the lines are coded into the infrastructure that exists in the base years. For bus, boat and train, timetables (Information from Rutebok for Norge published by Norsk Reiseinformasjon AS (Norwegian Travel Information)) roughly representing the actual years are used as main data source. The route information for each mode, and timetables for each and line, are used as data source to detect changes in the number of lines for each mode, changes in the itineraries, and frequencies between the base years. Table 3 (all lines) and Table 4 (national long distance lines) gives a short transit line summary by mode and base year.

Table 3 Transit line summaries from the national networks by base year. Regional and national lines.

	1998			2001			2004		
	# of lines	# of depart.	Veh. Km (in 1000)	# of lines	# of depart.	Veh. Km (in 1000)	# of lines	# of depart.	Veh. Km (in 1000)
Scheduled bus lines	595	3079	549	599	3170	570	604	3194	646
Scheduled boat routes	114	373	Na	97	299	Na	96	305	Na
Scheduled rail lines	82	352	83	116	594	108	96	558	104
Scheduled air service	123	115	231	241	1071	357	231	815	270

Table 4 Transit line summaries for the national network by base year. National long distance lines only.

	1998			2001			2004		
	# of lines	# of depart.	Veh. Km (in 1000)	# of lines	# of depart.	Veh. Km (in 1000)	# of lines	# of depart.	Veh. Km (in 1000)
Scheduled bus lines	118	667	254	124	757	280	129	782	336
Scheduled boat routes	12	33	Na	10	23	Na	9	28	Na
Scheduled rail lines	66	245	76	70	382	96	58	391	95
Scheduled air service	123	115	231	241	1071	357	231	815	270

Rutebok for Norge (RFN) is published 4 times a year and contains detailed descriptions of the timetables for all regional and national scheduled public transport services in Norway. For the base year 1998, almost all of the bus lines represented in the RFN (national and regional) also are represented in the national network model. Only 20 % of these lines however can be characterized as national long distance lines, and since NTM5 only cover travel longer than 100 km (one way), our focus in this project is to update the long distance lines. The number of scheduled long distance bus lines increase by 5 % from 1998 to 2001 and by 9 % from 1998 to 2004. The number of departures by long distance lines increases by 14 % and 17 % in the same period, and the transport production (measured in vehicle km) for the long distance lines increase by 10 % and 32 %.

For 1998, also almost all of the boat lines represented in the RFN (national and regional) is coded into the national network model. Only 10 % of these routes are long distance. The service by boat has been reduced in the period, the number of routes and the number of departures has declined by 17 % and 32 % from 1998 to 2001, and by 25 % and 17 % from 1998 to 2004.

The rail mode in the network model is the mode of which our client has done the most effort with regard to quality control and updating to the base year 2001. The rail transit line description for 2001 is therefore far more detailed and comprehensive than the initial description for 1998. In the description for 2001 different variants of routes are coded separately, whereas the routes in the 1998 description are treated at a far more aggregate level. The number of long distance rail lines has increased by 6 % from 1998 to 2001 but has decreased by 12 % from 1998 to 2004. The number of departures by long distance lines has increased by 56 % in the first period and by 60 % in the whole period. The transport production measured in vehicle km (for departures) has increased by 26 % in the first period and by 25 % in the whole period.

Data for the air mode in the national network model originates from the OAGmax database of domestic and international air traffic database provided by Avinor. It is important to point out that the original network data, used for the base year 1998, is organized different than the data for 2001 and 2004. In the data for 1998 the movements of aircrafts between domestic airports defines the itinerary. Each aircrafts movements between airports during one day is registered and processed for the air network sub model. The air route itineraries for 1998, thus represents a complex description of aircraft movements, and there is one itinerary for each aircraft. For 2001 and 2004 this principle of describing the air lines is left and the lines are instead represented by airport to airport descriptions, where the movements are chopped up, and the lines have a headway representing the number of times per day an aircraft serves each pairs of airports. With this principle of representing the air service, passengers can no longer travel through an airport in transit on board the aircraft but will have to alight and board a different line. It is worth mentioning that the consequences of the change of principles of coding the air transit lines on the route choice for air traffic passengers have never been investigated, and the same assignment procedures and parameters are used both for the 1998 situation and 2001/2004. As we will see, this is a major source of error when we compare the demand for travel between the different base years in this project.

The change of coding principle for air traffic makes it difficult to compare the situation in 1998 with the situation in 2001 and 2004. The transport production in terms of vehicle km should however be comparable, and the increase is 55 % from 1998 to 2001, and 17 % from 1998 to 2004. It is important to point out that these growth rates can differ quite substantially from official data reflecting vehicle km each year. The growth rates here are calculated on the basis of the air transit lines represented in the base scenarios in national network modelfor each year, each representing only one day during each year.

1.3 Changes in travel costs and income

Since the model system is estimated on data reflecting the situation in 1998, all fares, travel cost and income indicators, used as variables in the model system, have to be specified in real prices at a 1998 level. Table 5 shows the changes between the base years for all the most important model variables. The original data are provided by Statistics Norway, and most of it is available at the bureaus website (www.ssb.no). The data is however processed in different ways in this project, and we have to point out that it represents rather strong assumptions rather than the actual development in these variable. There are aspect connected to both the accuracy of these indicators used at a geographical and sub market level (long distance trips), as well as measurement problems, and several other points, that makes us treat them as strong assumptions rather than facts.

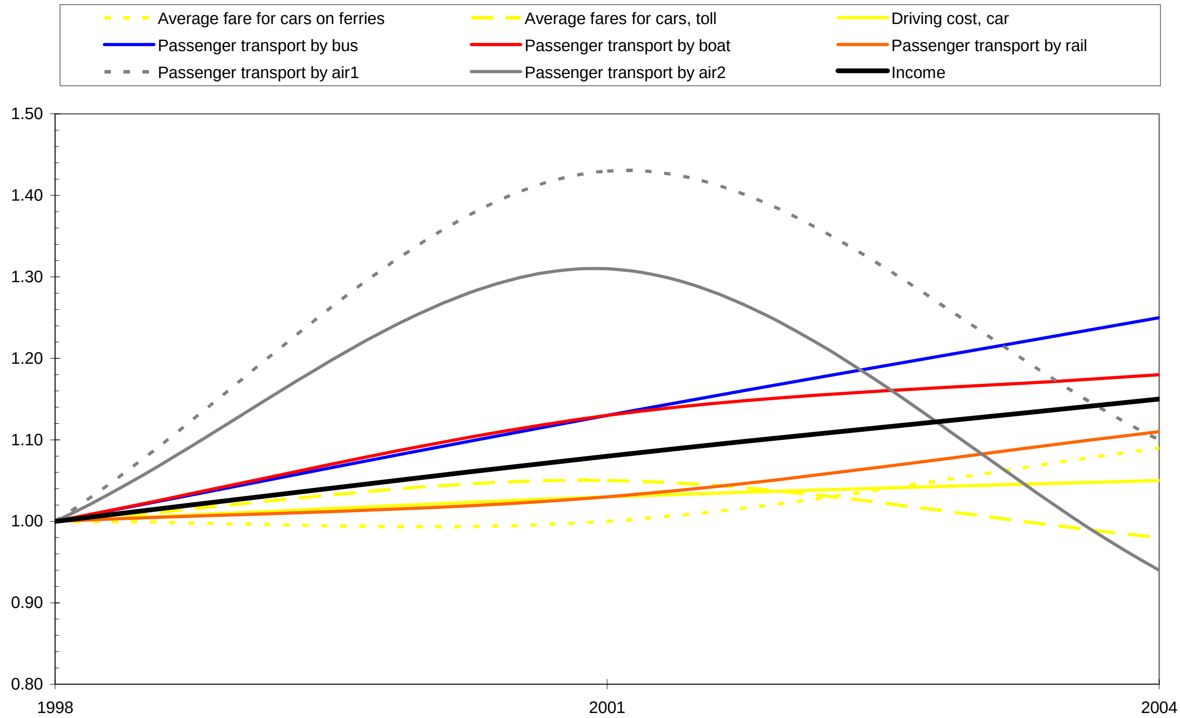
Table 5 Indexes for changes in travel costs by mode of transport. Real prices at 1998 level (nominal prices deflated by the consumer price index).

	Average fare for cars on ferries	Average fares for cars, toll	Driving cost, car	Passenger transport by bus	Passenger transport by boat	Passenger transport by rail	Passenger transport by air[1]	Passenger transport by air[2]	Income
1998	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2001	1.00	1.05	1.03	1.13	1.13	1.03	1.43	1.31	1.08
2004	1.09	0.98	1.05	1.25	1.18	1.11	1.10	0.94	1.15

1) Between Oslo and Bergen, Trondheim and Stavanger. 2) Rest of the country.

Figure 2 gives a better visual illustration of the indexes in the table above. Its worth noting, that the mode specific costs that increase less than the increase in income (black line), as the costs for driving a car or travel by train, will make travel with these modes cheaper in real prices than they where in 1998. Travel costs that increase more than the increase in income will make travel more expensive compared to 1998. As we can see, the costs of travel by air have the most unique development from 1998 to 2001 and 2004. In 2001 the air fares for domestic travel in Norway, according to the data, was 30 % to 40 % higher than in 1998, and the costs in 2004 is back to its 1998 level.

Figure 2 Changes in travel costs by mode of transport Real prices at 1998 level (nominal prices deflated by the consumer price index).



air1): Travel by air between Oslo and Bergen, Trondheim and Stavanger. air2): Travel by air in the rest of the country.

1.4 Demographic data and other data for zones

The demographic input to the model system describes the number of residents (in private households) in each of the 1428 zones by age (5 years cohorts) and gender. In this project the original data collected for the implementation of the model system is used for the base year 1998. For 2001 we use data collected for the implementation of the Norwegian regional model systems, and for 2004 we use demographic forecasts made in 2000 describing the assumed situation in 2005 (the forecasts made for 2005 in total is very close to the actual aggregates in 2004). The two following figures shows the changes in cohorts for male and females aggregated to the national level for the base years 1998, 2001 and 2004. The assumptions made for the demographic situation in 2004 seems to fit the other data quite well except perhaps for the cohorts in the age of 65 and older, where the numbers seems to be a little bit too low, especially for women.

Figure 3 Male cohorts in the demographic input for NTM5, national totals.

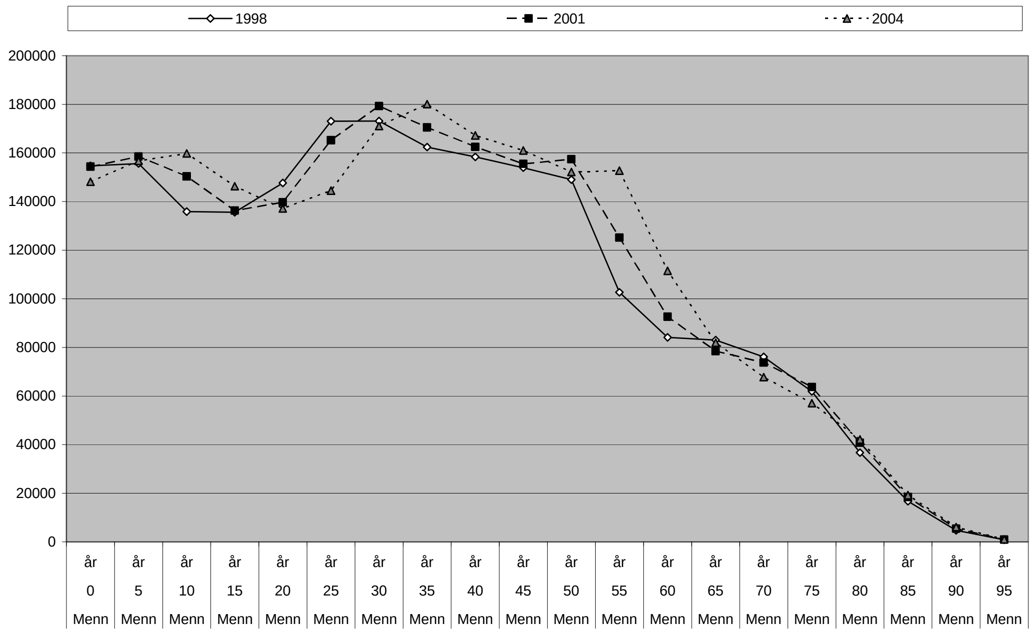
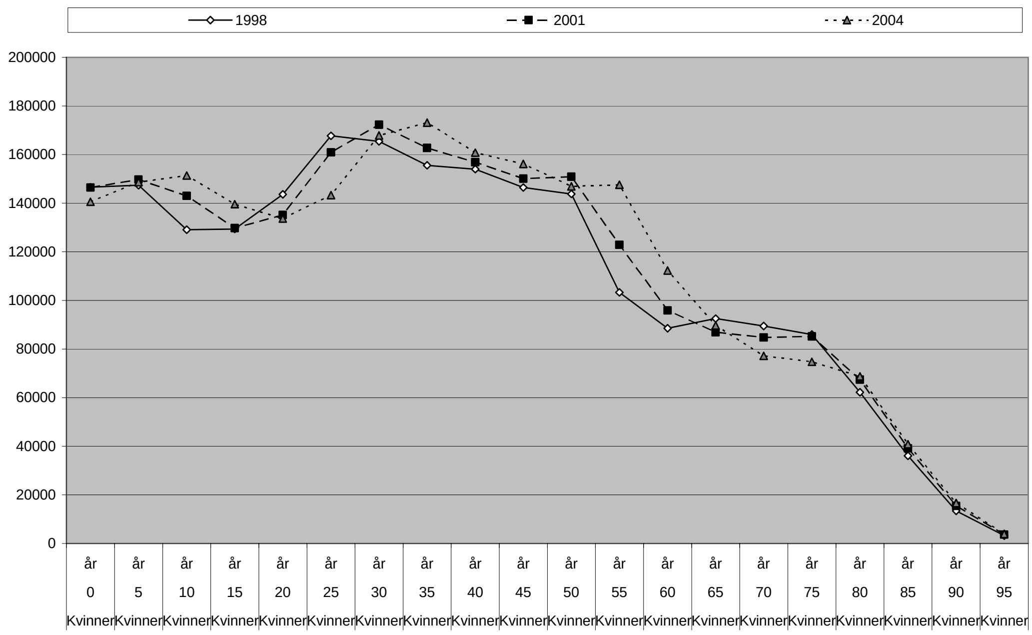


Figure 4 Female cohorts in the demographic input for NTM5, national totals.



The original ambition in this project was to collect and prepare zone data for each of the base years 1998, 2001 and 2004. A comparison of the original data for 1998, with data for 2001 collected for the implementation of the Norwegian regional models, gave however differences that can not be explained by the actual change from 1998 to 2001 but have to be the result of errors in the public registers from which data originates. It was thought that the data for 2001 is far more reliable than the data from 1998 and therefore it was decided that the data for 2001 should be used for all the three base years. The table below shows the types of data involved and national totals for each data type (2001 level).

Table 6 Zone data in NTM5

Data field	Data type	National total
1	Population	4489549
2	Employed population	2080250
3	Work places	2013585
4	Area	303968
5	Number of hotels	1473
6	Employed in hotels	24497
7	Number of cottages and recreational houses	416393
8	Workplaces in primary sector	23340
9	Workplaces in oil and mining	20848
10	Workplaces in industry	578344
11	Workplaces in commodity trade	320950
12	Workplaces in hotels and restaurants	75762
13	Workplaces in finance and services	266201
14	Workplaces in public administration	126397
15	Workplaces in education	180783
16	Workplaces in public health/social sector	380546

2 Data for the evaluation

The ambition in this project is to evaluate the results from The National Transport Model for long distance travel in Norway by comparing them with independent data from different sources. However, we have to realize that the number of data sources that gives information about long distance travel in Norway, is very limited. In this project, we have focused on a few of the best and most comprehensive data sources available for the long distance travel marked in Norway:

- Traffic counts (train and car)
- National travel surveys (all modes)
- Mode specific travel surveys for air
- Statistics of passenger volumes on airports

As we can se from the list the, there is not much passenger information available for scheduled long distance bus and boat routes in Norway. The National travel surveys are the only source of information for these two modes, and the information in these surveys is also very scarce because of very modest market shares. Ticket sales statistics is available for some routes but not nationwide and these fragments of information can not be processed within the frames of recourses in this project. When it comes to data collection for passenger volumes at a geographical level, mode specific surveys, as those conducted for air passenger traffic, is considered to be a far more cost effective way to get information than national surveys. In mode specific surveys informants can be recruited when travelling, en route or on terminals serving the different modes, while the informants in national surveys is interviewed at home. Since long distance travel is not a very frequent activity, recruitment en route will be a more successful method. It is however necessary to point out that mode specific surveys can not replace the national surveys as data source for model estimation. Mode specific surveys are very useful supplementary data sources both when it comes to estimation and evaluation of transport models. In our opinion there is a shortage on data for long distance travel for all modes except for air, and one of our main proposals to our clients is clearly to do something with this situation.

2.1 Counts for road traffic and train passengers

One way of evaluating the OD-matrices produced by NTM5, is to compare volumes between areas form the matrices with observed volumes on roads and transit lines between the same areas. The national road administration conduct **counts of road traffic** on different locations on most of the main roads in Norway. Local short distance traffic will dominate the counts on most of these observation points. In this project we have defined 3 main borderlines between different parts of the country. The borderlines in general pass through very low populated mountain areas, so that the proportion of local traffic is minimized. The three borderlines each divide the country into two parts:

- Borderline 1 Between eastern parts of Norway and the western and northern parts
- Borderline 2 Between northern parts of Norway and southern parts
- Borderline 3 Between the county Finnmark and the rest of the country

Traffic counts for car are collected on all (main) roads passing these three borderlines in 1998, 2001 and 2004. The dataset is however not quite complete but traffic volumes for missing observations are roughly estimated.

NSB (main Norwegian rail company) also conduct **rail passenger counts** on different locations in the rail network. In this project our client has provided access to some of these data, and although the observation points are not located exactly on the same sites, we have managed roughly to reproduce the same three borderlines as for road traffic. We have passenger volumes passing the borderlines for 1998, 2001 and 2004. It is worth noting that even though the areas around the borderlines are scarcely populated, the observed traffic volumes will include an unknown proportion of local short distance travel.

2.2 National travel surveys

In Norway national travel surveys was conducted in 1998 (RVU98) and in 2001 (RVU2001). In this project we where not able to get access to data from the most recent travel survey conducted in 2005. 8800 informants were interviewed in RVU98, and 21000 in RVU2001. The different sub models in NTM5 transport model system are estimated on data from RVU98. The original ambition in this project was to estimate the *number of trips by mode and travel purpose* from these surveys, by using sample proportions in municipalities as factors to make the surveys representative for the total population. Its important to point out that this gives practically the same result as using weight factors correcting for the sample proportions and then study the *percentage distributions on mode and travel purpose*. The latter is the common way results from travel surveys are reported, at least in Norway. However this estimation procedure as we shall see gave results that do not fit with other information available for long distance trips in Norway. The estimated national totals by mode and purpose is shown in Table 7. As we can see the results imply an overall reduction in the number of long distance trips from 1998 to 2001 of 20 %. This change is not very reliable.

Table 7 Number of trips[3] per day by mode of transport and travel purpose estimated from RVU98 and RVU2001, changes from 1991 to 2001.

			1998			2001	Diff. 1998 – 2001 percent		
	Work related	Private	Total	Work related	Private	Total	Work related	Private	Total
Car, driver	11761	44836	56598	8216	38654	46870	-30 %	-14 %	-17 %
Car, passenger	2106	25762	27869	1627	24454	26080	-23 %	-5 %	-6 %
Scheduled bus	573	4156	4730	467	3446	3913	-18 %	-17 %	-17 %
Train	2470	8665	11135	898	5711	6609	-64 %	-34 %	-41 %
Air	13086	8999	22085	7433	7006	14439	-43 %	-22 %	-35 %
Scheduled boat	429	2404	2833	330	1586	1916	-23 %	-34 %	-32 %
Total	30425	94823	125248	18971	80857	99828	-38 %	-15 %	-20 %

The main focus in this project is to evaluate the national transport model, and not the national travel surveys. However, results as those shown in Table 7, indicate that there may be severe bias problems with respect to travel activities for long distance trips in both surveys. RVU98 seems to fit data from other sources far better than RVU2001, but the sample in RVU98 is not as representative with respect to cohorts as the sample in RVU2001 (Denstali et al 2003). This is partly due to larger a fraction non-response in RVU98. The problems we observe can also be connected to differences between RVU98 and RVU2001 in design and implementation of the two surveys. There can be differences when it comes to education, motivation and

[3] Only trips longer than 100 km one way, with origin and destination in Norway, and by modes covered by NTM5 is included.

incentives of the interviewers, duration of the interview (average 20 minutes in RVU98, and 24 in RVU2001, maximum up to 45 minutes. Denstali, 2003), reporting procedure of the long distance travel section, procedures when sampled informants is not reached, procedures when informants refuse to participate, etc. Non-response is perhaps a bigger problem for long distance trips than for short distance travel, and its particular important to get interviews of informants which is not home at the first time of contact. They could be away travelling.

Even though the two surveys does not give reliable results when it comes to the changes in mode choice and travel frequency between 1998 and 2001, the trip length distribution by modes, and geographic distributions of trips by modes on different geographical levels, from the two national travel surveys is used to evaluate the performance of the model in these two dimensions. The hypothesis is that the survey material describes these dimensions better, i.e. response informants and non-response individuals is more equal when it comes to trip distance and destination choice, than they are with respect to mode choice and choice of trip frequency.

2.3 Mode specific travel surveys for air passengers

Mode specific travel surveys for air passengers are conducted by Avinor in 1998 and in 2003. Informants (40000 in 1998 and 63000 in 2003) in these surveys are recruited on domestic airports, but include both Norwegian residents and foreigners trips in Norway, as well as the domestic part of all international trips. Since NTM5 only cower Norwegian residents domestic trips, foreigners trips in Norway and the domestic part of Norwegians international trips, is excluded from the material. In this project these surveys are mainly used to evaluate the geographic dimension of NTM5 at different levels of detail.

2.4 Statistical information of passenger volumes at airports

On their web pages, www.avinor.no, Avinor publish statistical information for passenger volumes at Norwegian airports. The material shows domestic and international departures, arrivals, transit and transfer for scheduled flights and charter flights. As pointed out earlier, NTM5 only covers trips with both origin and destination in Norway undertaken by Norwegian residents. Avinors statistical information on passenger volumes at airports therefore must be processed to reflect the same demarcations. The problem using this data in the evaluation of the model results is that depending on the ticket type and the combination of airlines in use, the same trip can be represented in different ways in the statistics. An international trip from Trondheim via Oslo to London using *SAS Braathens* only will be registered as a domestic departure at Trondheim airport, with international transfer at Oslo airport. The same trip using *Norwegian* from Trondheim to Oslo and *BA* from Oslo to London, will be registered as a domestic departure at Trondheim Airport, as a domestic arrival at Oslo airport, and as an international departure at Oslo Airport. The same types of differences of registration of essentially identical trips except for chosen airlines can also occur in the registration of domestic trips in this data.

We have used data from the mode specific travel survey for air passengers conducted in 2003 to try to reduce this type of problems for international trips, in the data material used for evaluation of the model. We also have reduced the data to take into account that a small proportion of the domestic trips are conducted by foreign residents. The result of these calculations is shown in Table 8. As we can see the passenger volumes at Norwegian airports dropped by 2 % from 1998 to 2001. The domestic traffic dropped by 5 % from 1998 to 2001. In fact 1999, the year after the opening of the new main airport at Gardermoen, was the top year when it comes to passenger volumes by air in Norway. In 2002 the passenger volumes reached its bottom level 10 % lower than in 1999. In 2004 the volumes have increased to exceed the 1998 level, mainly because of the increase in international traffic. The domestic traffic is more stable over time than the international traffic. In 2004 the domestic passenger volumes are still slightly lower than they where in 1998. The last row in the table shows the average number of domestic trips, which, since each trip is registered both on departure and arrival, simply is number of departures/arrivals divided by 2.

Table 8 Departures/arrivals (average per day) at Norwegian airports for domestic and international trips, 1998, 2001, 2003 and 2004.

	1998	2001	2003	2004	1998 - 2001	1998 - 2003	1998 - 2004
Domestic departures/arrivals	48056	45541	44336	47274	-5 %	-8 %	-2 %
International departures/arrivals (incl. domestic part)	24403	25569	26759	30127	5 %	10 %	23 %
Total	72459	71109	71094	77401	-2 %	-2 %	7 %
Domestic trips	24028	22770	22168	23637	-5 %	-8 %	-2 %

The average number of trips by air per day is according to these calculations 24000 in 1998 and 22800 in 2001. The number of trips per day estimated from the national travel surveys shown in Table 7 is 22000 in 1998 and 14500 in 2001. Even though there is a certain level of uncertainty connected to the calculation of the domestic trips from the statistics, and there are issues connected to differences in the population for the two types of data, this indicates that the bias with respect to travel activities in the surveys (especially the 2001 survey) is quite substantial.

3 Evaluation of NTM5

3.1 Aggregated model results at the national level.

One of the main ambitions in this project is to evaluate the model results for the three base years 1998, 2001 and 2004, with respect to the different data collected and processed for this purpose. The model system is calibrated on the national level with respect to mode and purpose totals for the situation in 1998, mainly using corresponding data from the national travel survey from 1998 (RVU98) as target values. However, some adjustments had to be made to make the model give a better fit to observed car passenger volumes.

Shortly prior to this project, a new version of the model system was made. In this new version, trips are segmented with respect to travel party size, dividing between people travelling alone and people travelling in party sizes of two and more. This distinction was made partly to minimize aggregation errors on travel costs that will occur when average travel party sizes are used to calculate travel costs per person, and party because the calculation of car driver and car passenger matrices were quite inaccurate. The number of reported trips as car driver and car passengers in the surveys gives car occupancy of 1.5, but the average number of car passengers reported by car drives in the same surveys, is 2.3. The current model version is calibrated to produce an average car occupancy of 1.75 persons per car (1.5 in the old version) and the car occupancy, even though it enters exogenously as input to the model, vary by trip distance.

Table 9 shows the result of the calibration for 1998. The calibration results differ from RVU98 with respect to the number of car passengers, and a slightly higher number of trips by air. Both of these differences are intentional, as they make the model produce results more in line with data from other sources.

Table 9 Number of trips per day by mode and base year (1998, 2001 and 2004), change from 1998 to 2001 and to 2004. NTM5.

	1998	Percent 1998	2001	Percent 2001	Change from 1998	2004	Percent 2004	Change from 1998
Car, total	102227	71 %	114804	75 %	12 %	120535	74 %	18 %
Car, driver	58574	40 %	65705	43 %	12 %	68942	43 %	18 %
Car, passenger	43653	30 %	49100	32 %	12 %	51593	32 %	18 %
Scheduled bus	4766	3 %	4976	3 %	4 %	5229	3 %	10 %
Train	11242	8 %	12403	8 %	10 %	12364	8 %	10 %
Air	23782	16 %	19107	12 %	-20 %	21153	13 %	-11 %
Scheduled boat	2850	2 %	2693	2 %	-5 %	2682	2 %	-6 %
Total	**144866**	**100 %**	**153983**	**100 %**	**6 %**	**161964**	**100 %**	**12 %**

In our opinion the model system gives fairly reliable results for both when it comes to the total number of trips and the trip distribution on modes. Table 10 summarizes assumed changes in the level of service data (generalized time and monetary costs) by mode, and indicates the possible effects the changes may have on the total demand. The time and monetary cost of travel by car is reduced both in the first and in the second period, according to presumptions. The travel times by car get reduced as new road construction projects (new freeways and fjord crossings) gets completed (long distance travel by car in Norway is not much affected by congestion), and the cost of travel by car increase slower than the increase in income. One would therefore expect a positive effect on the number of trips conducted by car, in both periods. The model results for travel by car, 12 % increase in the first period and

18 % in the whole period, seems to fit changes in traffic counts fairly good (10 % increase from 1998 to 2001 and 22 % in the whole period).

The scheduled bus services in Norway are improved (more lines, higher departure frequencies) in the entire period, but the bus fares increase more than the increase in income, leaving the total effect on demand for bus travel uncertain. The model predicts an increase of 4 % in bus travel from 1998 to 2001 and 10 % in the whole period. There is no source of information to verify these results.

Travel times by train decreases in the first part of the period (new lines and higher frequencies) but increase slightly in the second. Travel cost by train is reduced in both periods. This indicates a positive effect on the demand for travel by train in the first period and a more uncertain effect in the second. Passenger statistics for rail indicate a reduction in travel from 1998 to 2001 and status quo from 2001 to 2004. This information seems to be somewhat in conflict with what one should expect as indicated in Table 10. The reason could be related to inaccuracies in the model networks for train. The quality of the model network in 2001 is reported to be far better than the quality of the network in 1998. There has been made some efforts with quality control and coding of the 2001 network (local short distance trains in the Oslo area are included in the 2001 network), and the same amount of improvements is not done in the 1998 network. The model result, implying an increase of 8 % in long distance train travel, could therefore be a result of better network quality in the model, and not reflecting real changes from in the level of service from 1998 to 2001.

Table 10 Changes in input data by mode, and expected effects on demand from 1998 to 2001 and from 2001 to 2004.

	Change from 1998 to 2001			Change from 2001 to 2004		
	Generalized Time	Monetary costs	Expected effect on total demand	Generalized time	Monetary costs	Expected effect on total demand
Car	Reduced	Reduced	+	Reduced	Reduced	+
Scheduled bus	Reduced	Increased	+/-	Reduced	Increased	+/-
Train	Reduced	Reduced	+	Increased	Reduced	+/-
Air	Reduced	Increased	+/-	Increased	Reduced	+/-
Scheduled boat	Increased	Increased	-	Increased	Increased	-

Comparing the actual results form the model runs and the expected effects in Table 10, shows that the model in general gives the results that one should expect. The magnitude of the differences between the three base years for air travel, is however quite large. The model predicts a reduction in air passengers from 1998 to 2001 of 20 %. This is a considerable larger reduction than what can be found in the airport statistics, from which the estimates of passenger reductions from 1998 to 2001 is 5 %. From 1998 to 2001 several relatively large changes are included in the input data to the model.

- Main national airport moved from Fornebu (FBU) to Gardermoen (OSL)
- The supply in terms of aircraft kilometres, increased by 50 % on average
- The air fare in average increased by 40 % on average

In the late autumn of 1998 the new national airport in Norway was opened at Gardermoen (OSL), 40 km north of Oslo. The old airport, located 10 km from Oslo, was closed. An airport express train between Asker (30 km west of Oslo) and OSL was build and opened for traffic to improve the access to the airport. In NTM5, access and egress to/from terminals is described in detail. The passengers are assumed to access terminals using the road network with different access-mode specific speeds (40 km/h for air mode access) and the road distances (and its model parameter estimates) are assumed to reflect the generalized cost for he access/egress part of the trip. In the base runs with NTM5, the airport express train is not represented in the network. To investigate the possible effect of leaving the airport express service out of the networks, an also to show the isolated effects of the different assumptions with respect to airfares and the level of service by air, several alternative model runs are made. Results from four of these runs are shown in Table 11:

a. Network form 1998 with 2001 airfares
b. Network from 2001 with airport express train[4]
c. Network from 2001 with 1998 airfares
d. Network form 2004 with airport express train[4]

As we can see from the model run marked a), the isolated effect on travel demand by air in 1998 of introducing the high level of airfares as assumed for 2001, is a reduction in demand by 9 %. On the other hand the run marked c) shows that when introducing airfares at the level as assumed for 1998 in the model run for 2001, a reduction on travel demand by air of 12 % results as compared to the base situation in 1998 (20 % in the base runs). In this run the level of service in terms of aircraft km is 50 % higher than in 1998, and the airfares are at the same level as in 1998. Therefore it seems that the reduction in air traffic as compared to the 1998 base situation is mainly due to longer and more expensive access to the new national airport.

The results also indicate that there may be some problems connected to leaving the original principle[5] of coding/representing the airlines in the networks. Leaving this principle from one base year to another, gives unintentional implications on the calculated level of service between OD-pairs with more complex route choices[6], and hence unintentional effects on the traffic volumes for travel by air. We recommend that the effects of changing the network coding principles is investigated further, both when it comes to route choice effects at the network level, effects on level of service calculations, and demand predictions.

In the runs marked b) and d), simulating the airport express service in 2001 and 2004, results in reductions in travel demand by air of 14 % and 5 % respectively. These results indicate that introducing the OSL express train gives more reliability in the model calculations. However, the specific assumptions about generalized costs per kilometre (i.e. speed for the airport train access mode) can be investigated further.

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[4] A new access mode is introduced on rail links from Asker to OSL with double speed as compared to the ordinary air access mode.

[5] In the network for 1998, the movement of aircrafts between domestic airports defines the itinerary. Each aircraft movements between airports during one day is registered and processed for the air network sub model. The air route itineraries for 1998, thus represents a complex description of aircraft movements, and there is one itinerary for each aircraft. For 2001 and 2004 this principle of describing the air lines is left and the lines are instead represented by airport to airport descriptions. The movements are chopped up, and the lines have a headway representing the number of times per day aircrafts serve each pair of airports. With this principle of air service representation, passengers can no longer travel in transit, but will have to alight and board a different line.

[6] Avinor's passenger information indicates that in 2001, 5 % of passenger volumes at Norwegian airports are transit passengers (ca 2750 per day). In the model runs for 1998, the number of passengers in transit at airports is 2800, which is 6 % of the traffic. In the networks for 2001 and 2004, travel in transit is no option.

Table 11 Number of trips per day by mode and base year, change from 1998 base year to actual scenario. NTM5 model runs: a) network form 1998 with 2001 airfares, b) 2001 with airport express train, c) 2001 with 1998 airfares, and d) 2004 with airport express train.

	a. 1998 with 2001 airfares			b. 2001 with airport express			c. 2001 with 1998 airfares			d. 2004 with airport express		
	1998	Percent 1998	Change from 1998	2001	Percent 2001	Change from 1998	2001	Percent 2001	Change from 1998	2004	Percent 2004	Change from 1998
Car, total	103567	72 %	1 %	113963	74 %	11 %	113641	74 %	11 %	119621	74 %	17 %
Car, driver	59330	41 %	1 %	65228	42 %	11 %	65049	42 %	11 %	68425	42 %	17 %
Car, passenger	44237	31 %	1 %	48735	32 %	12 %	48592	31 %	11 %	51195	32 %	17 %
Scheduled bus	4861	3 %	2 %	4936	3 %	4 %	4906	3 %	3 %	5186	3 %	9 %
Train	11439	8 %	2 %	12277	8 %	9 %	12237	8 %	9 %	12237	8 %	9 %
Air	21544	15 %	-9 %	20403	13 %	-14 %	20989	14 %	-12 %	22552	14 %	-5 %
Scheduled boat	2937	2 %	3 %	2670	2 %	-6 %	2632	2 %	-8 %	2656	2 %	-7 %
Total	144349	100 %	0 %	154249	100 %	6 %	154405	100 %	7 %	162252	100 %	12 %

3.2 Traffic counts over borderlines

Traffic counts for cars and passengers on train in 1998, 2001 and 2004 are collected for three borderlines each dividing the country into two parts:

- Borderline 1 Between eastern parts of Norway and the western and northern parts
- Borderline 2 Between northern parts of Norway and southern parts
- Borderline 3 Between the county Finnmark and the rest of the country

It is worth noting that even though the areas surrounding the borderlines are scarcely populated, the observed traffic volumes will include an unknown proportion of local short distance travel. Norddal, 2004 have conducted car driver surveys on some of the locations, and the proportion of trips longer than 100 km one way on these locations is reported to vary between 84 % and 96 % depending of season and location.

In the sections below the traffic counts for car and train are compared with the model results from the base years and data from the national surveys. For air traffic we compare the model results wit the data from the national and mode specific air surveys. For bus and boat the only data available is the national travel surveys. Since these two modes have a very small market share over the borderlines the data from the surveys is not very reliable.

3.2.1 Borderline 1

Figure 5 shows the situation for the number of cars over borderline 1 from the three data sources. The model results are placed in the middle between the two other data sources. Both the model and the traffic counts increase in the period from 1998 to 2004. Since the traffic counts include a certain amount of short distance trips (shorter than 100 km), assumingly to the extent of 20 – 30 %, the model results can be a little bit too high. The survey data seems however too low, compared with the traffic counts.

Figure 6 shows the comparison between the model results for bus passenger and the data in the national surveys over borderline 1. The model results are twice the size of the survey data. Since there is no other source of information, and considering the small amount of informants travelled by bus in the surveys, it is very hard to conclude which of the data sources which is most reliable.

Figure 5 Trips by car as driver over borderline 1, Survey data, Traffic counts, and model results

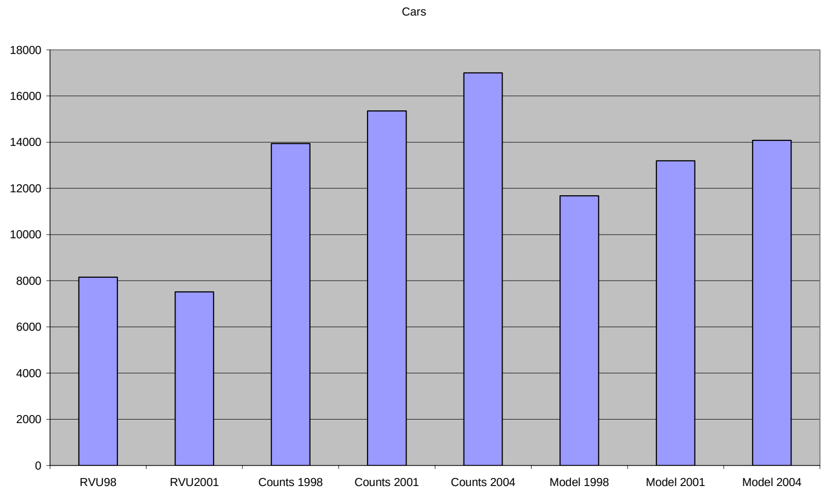


Figure 6 Trips by bus over borderline 1, Survey data, and model results

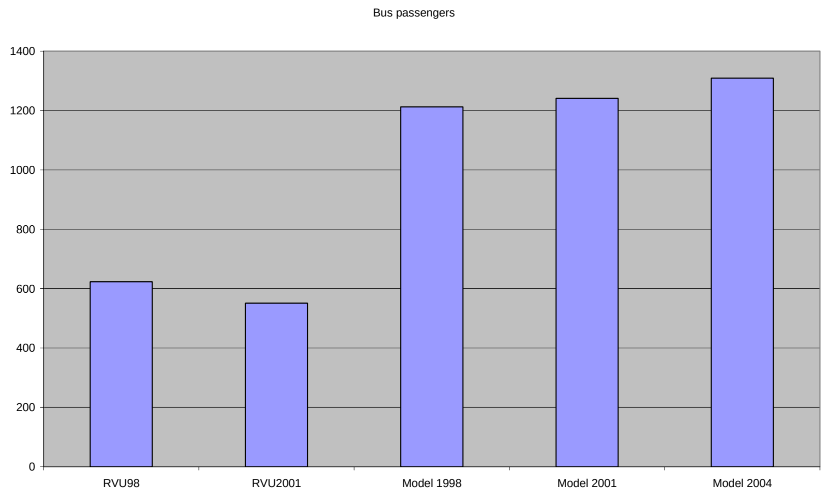


Figure 7 Trips by train over borderline 1, Survey data, Traffic counts, and model results

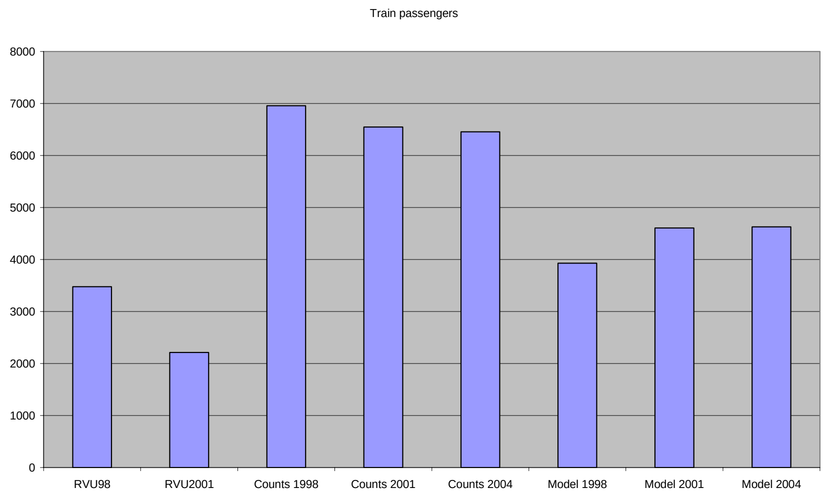
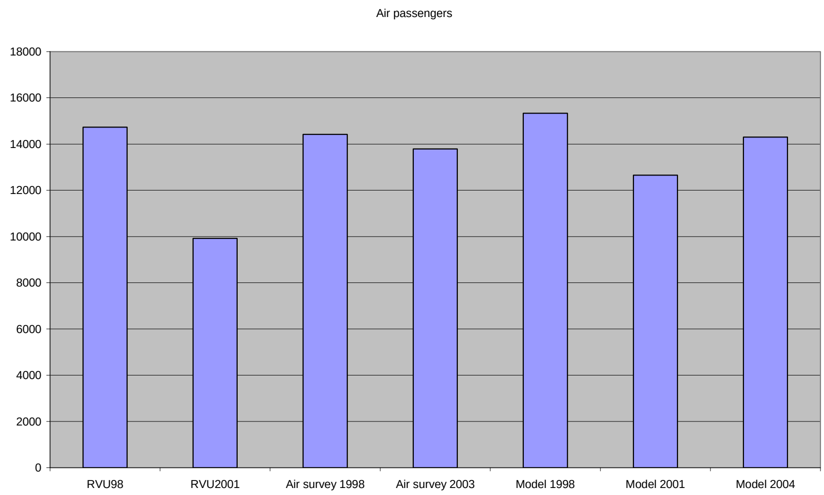


Figure 7 shows the number of train passenger over borderline 1 from the travel surveys, from the passenger counts, and from the model results. The model results are lower than the traffic counts, but higher than the survey data. The traffic counts indicate a reduction in traffic from 1998 to 2001, and a slight reduction also from 2001 to 2004. When the model results shows a increase from 1998 to 2001, this cold be connected to the poor state of the network for rail for 1998 as compared to the network quality in 2001 and 2004.

Figure 7 shows that the air traffic over borderline 1 for the base year 1998 is quite similar between the three data sources, and that all three data sources indicates a traffic reduction between 1998 and 2001/2003. Other data sources provided by Avinor indicate that the minimum point of domestic air traffic in Norway the recent years was 2001, and that the traffic in 2004 almost is back on its 1998 peak point level. This seems to fit reasonably well with the NTM5 model results for air traffic over borderline 1.

Figure 8 Trips by air over borderline 1, Survey data (national and for air passengers), and model results



3.2.2 Borderline 2

Figure 9 shows the number of cars over borderline 2 from the three data sources. The number of cars from traffic counts is almost twice the size of the numbers produced by the model. The traffic count also indicates a steeper increase than the increase produced by the model. These results can be explained by a higher share of local traffic in the counts over this borderline, and a higher increase in the local traffic as compared to the long distance traffic.

The figures for passenger on bus, train air and boat, presented below shows some differences between the different data sources. The main impression is however that the model results fits relatively good with the data from other sources, given the accuracy and quality of the data for comparison.

Figure 9 Trips by car as driver over borderline 2, Survey data, Traffic counts, and model results

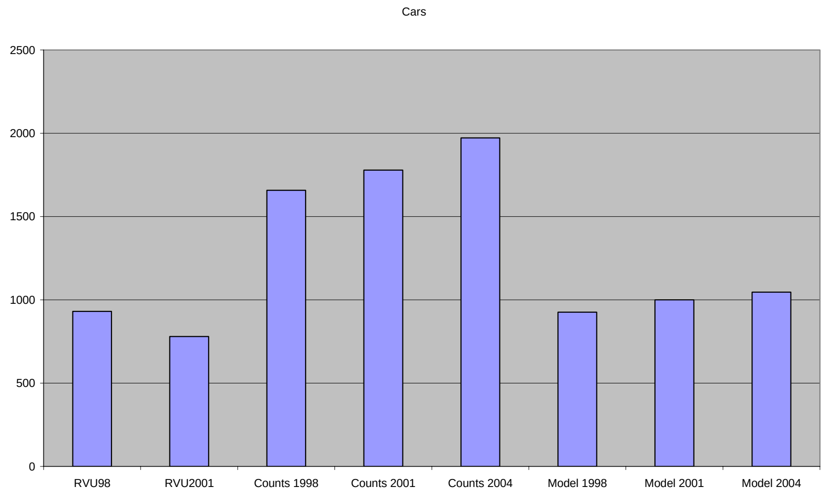


Figure 10 Trips by bus over borderline 2, Survey data, and model results

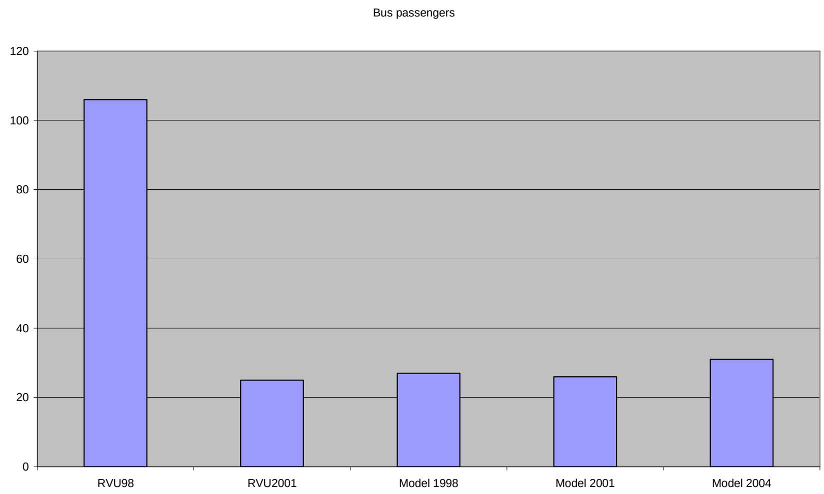


Figure 11 Trips by train over borderline 2, Survey data, Traffic counts, and model results

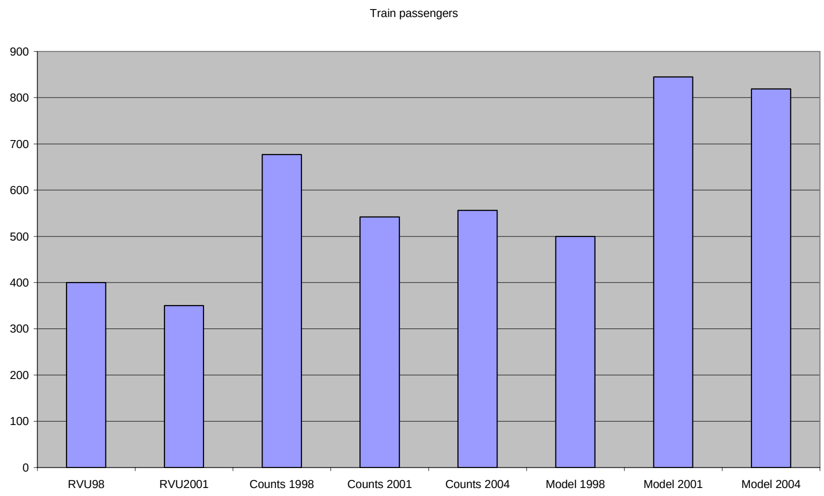


Figure 12 Trips by air over borderline 2, Survey data (national and for air passengers), and model results

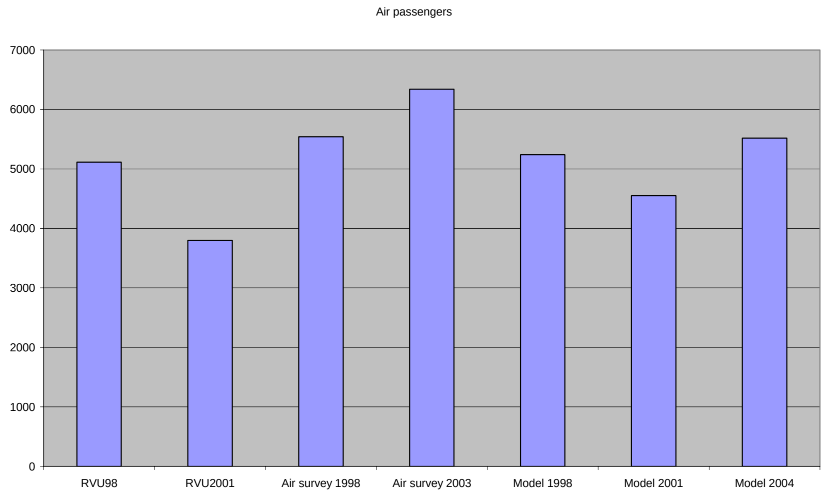
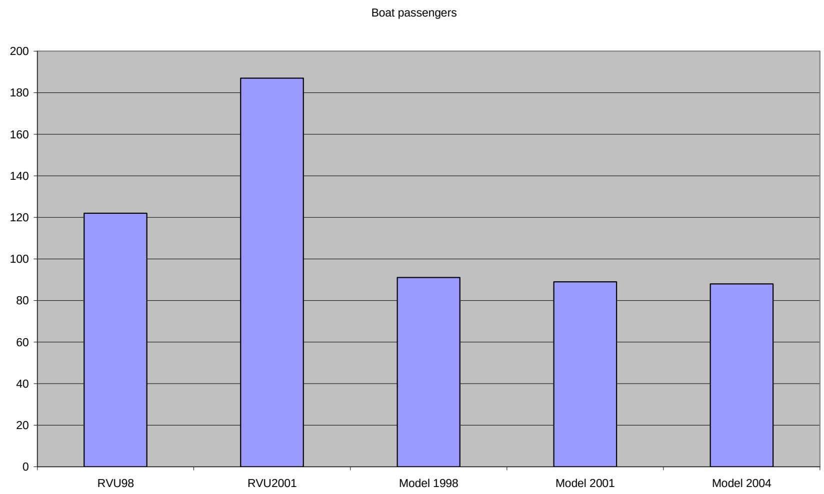


Figure 13 Trips by boat over borderline 2, Survey data, and model results



3.2.3 Borderline 3

The following figures show the number of cars and passengers over border line three from the different data sources. The main impression is that the model results fits relatively good with the data from other sources, given the accuracy and quality of the data for comparison. The air traffic however, seems a little bit low in the model results for this borderline. The mode specific travel survey for air traffic conducted in 1998 is 40 % higher than the model result for 1998 over this border line.

Figure 14 Trips by car as driver over borderline 3, Survey data, Traffic counts, and model results

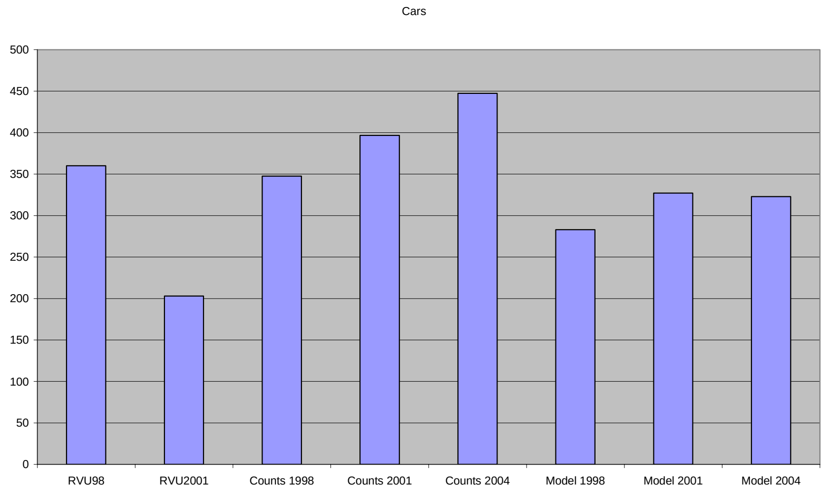


Figure 15 Trips by bus over borderline 3, Survey data, and model results

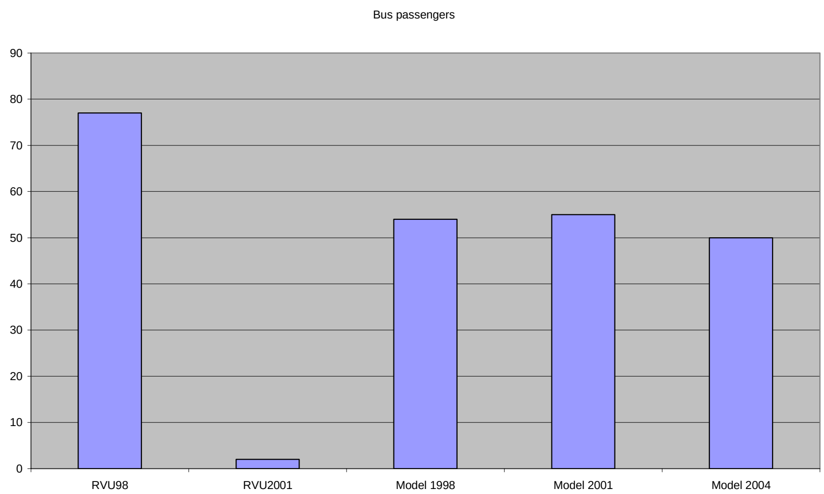


Figure 16 Trips by air over borderline 3, Survey data (national and for air passengers), and model results

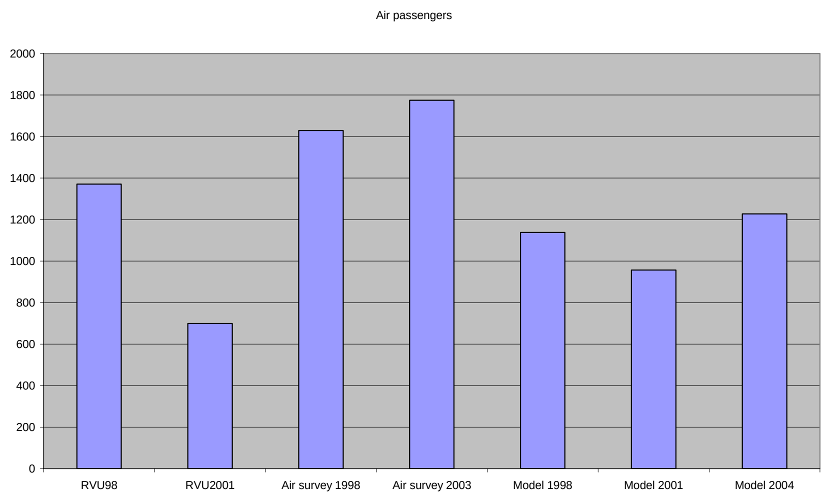
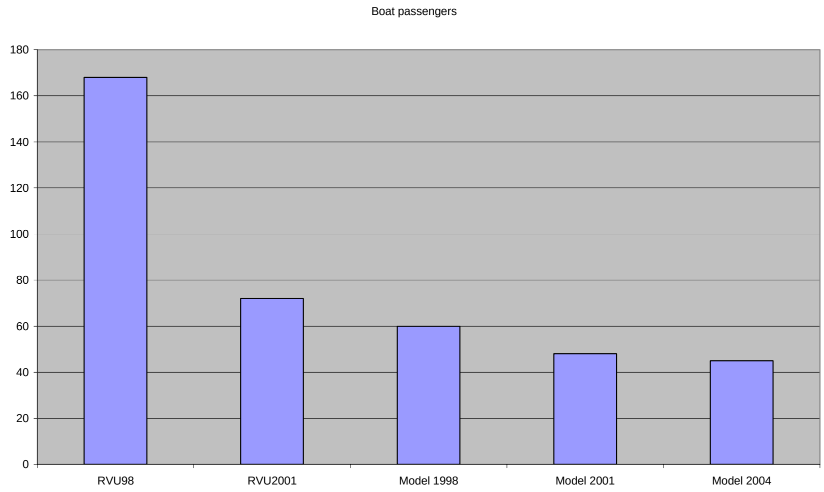


Figure 17 Trips by boat over borderline 3, Survey data, and model results



3.3 Evaluation of the geographical dimension

In this section the models performance in the geographical dimension is evaluated. The trip distribution of each mode form the model runs for each base year by counties, are compared with the corresponding distributions from the national travel surveys and mode specific travel surveys of air passengers. It is important to note that the information from the travel surveys, are encumbered with statistical uncertainty and various types of measurement errors, simply because it is a sampled material. This also affects the reliability of the distributions from the surveys presented in this section. The data from the surveys can therefore be inaccurate, and sometimes also completely misguiding, especially in situations where the sample size is small.

There are 19 counties in Norway, and the population in the counties varies between 73000 (Finnmark) and 520000 (Oslo). It is important to notice that the data that we study in this section reflect both generation and attraction of trips (i.e. the total number of long distance trips to and/from the counties). Because of this, the population distribution on the counties is not as relevant as a source of comparison, as if only trip generation was studied.

Figure 18 Distribution of trips to and from counties, all modes, 1998. NTM5 and RVU98, distribution of population on counties in 1998.

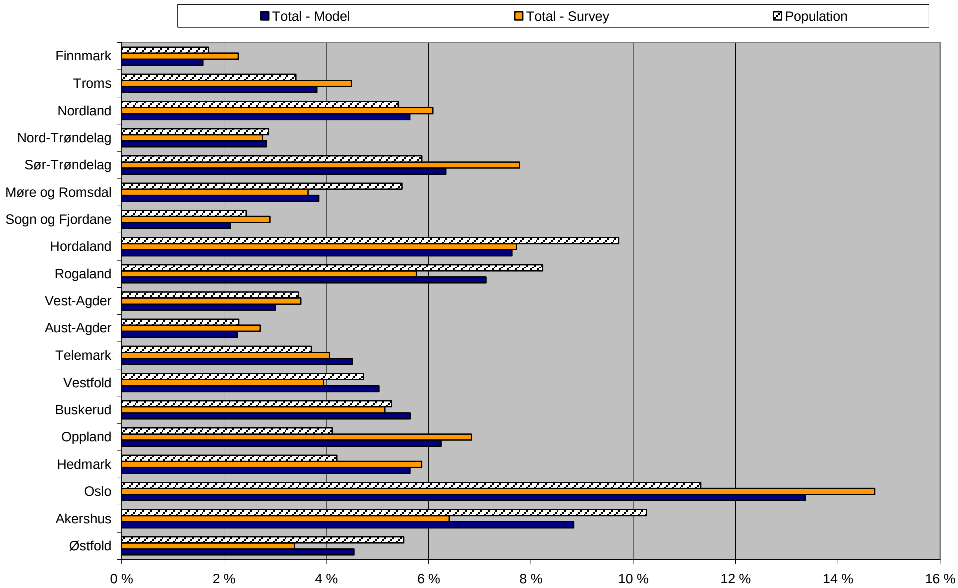
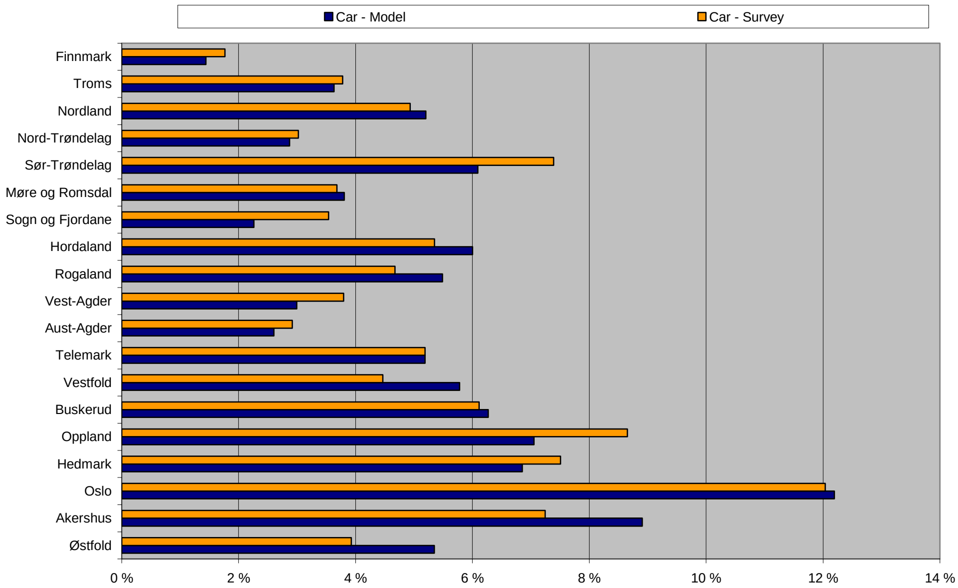


Figure 18 shows the trip distribution on counties for all trips from the base run for 1998 and in the national survey for 1998. The population distribution on counties in 1998 is also indicated. Some of the counties have a proportion of the trips that roughly corresponds with their proportion of the population. Oslo, being the capital of Norway, has a larger proportion of the trips than its proportion of the population. Hedmark and Oppland, being the most popular recreation areas for the population in the area around Oslo, also have larger proportions of trips than their population should indicate. Østfold and Akershus are located close (below the 100 km boundary) to the capital with its attractions for different types of trips, and therefore have a smaller proportion of trips than their proportions of population. Rogaland and Hordaland, the counties of the two second largest city areas in Norway, also have smaller proportions of trips than their population.

Noting the scale in the figure, there are no large differences between the trip distribution of the model and the distribution in the national survey. The three northern counties (at the top of the figure) have somewhat smaller proportions of the trips in the model than in the survey. Sør-Trøndelag located between the north and south parts of the country have also have a smaller proportion in the model. Rogaland, in the south-western parts of Norway have a larger proportion in the model than in the survey, and this is also the case for Østfold and Akershus. The differences are not very large, and they can be the result several factors or phenomena. The overall impression is that the model and the national survey reflect mainly the same picture, with a few exceptions, as mentioned.

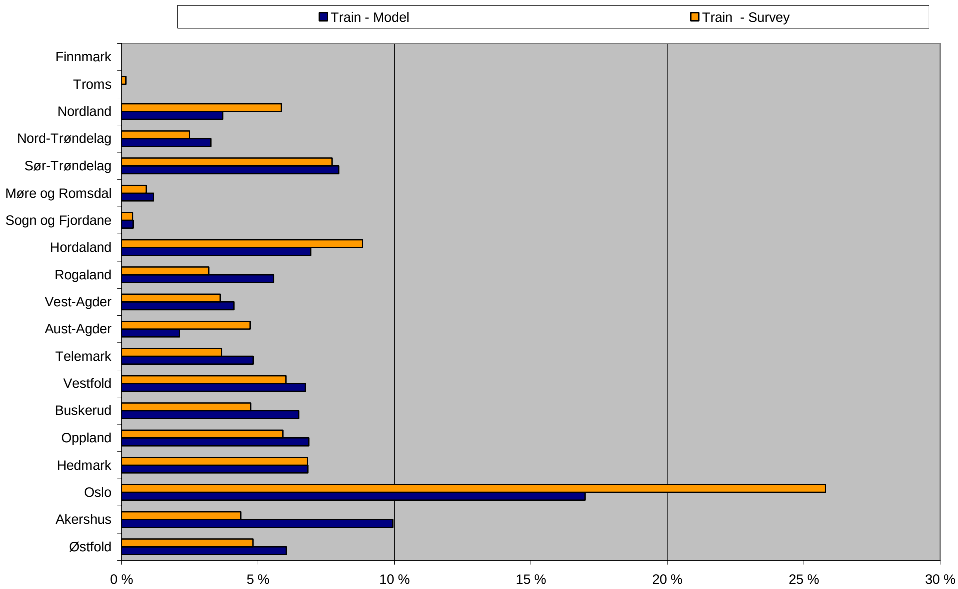
The distribution of car trips, shown in Figure 19, reflects almost the same tendencies as we found for the distribution of the total number of trips. This is perhaps naturally, car being the dominant mode in long distance travel.

Figure 19 Distribution of trips to and from counties, car, 1998. NTM5 and RVU98



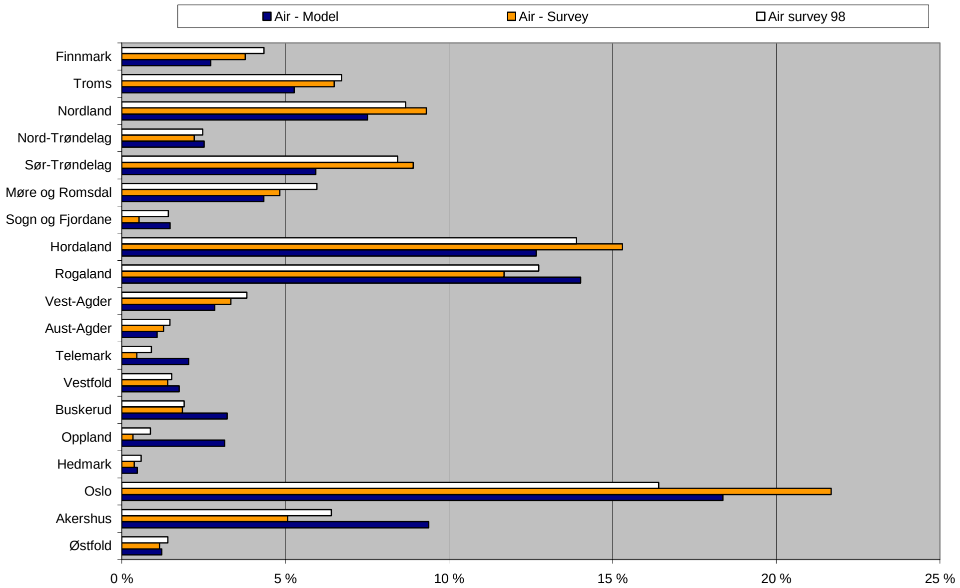
When we compare the distributions of trips by train (note the difference in scale from the two previous figures) there are a few main problems as shown in Figure 20. In the model result, Oslo has a proportion of only 17 % of the trips, while as its share in the survey is 26 %. For Akershus, the neighbour county of Oslo, the situation is reversed. For the rest of the counties the situation is satisfactory, even if some differences can be observed.

Figure 20 Distribution of trips to and from counties, train, 1998. NTM5 and RVU98



For the distribution of trips on the counties by air, we also have the mode specific air passenger survey in the comparison. There is a tendency that the model predicts low on the proportion of trips by air in the three northern counties, Sør-Trøndelag and Møre og Romsdal. For the south eastern counties, from Telemark to Akershus (except Oslo), the proportion in the model is high. The difference is largest for Buskerud, Oppland and Akershus. The model's proportion of the trips by air in Oslo, lies in the between of the proportions form the national and the mode specific survey.

Figure 21 Distribution of trips to and from counties, air, 1998. NTM5, air survey 1998 and RVU98



When it comes to the two remaining modes the sample in RVU98 is quite small (300 for bus and less than 200 for boat). The information that can be drawn from the survey with respect to the distribution on the counties is therefore limited. However, the results for these two modes are shown in Figure 22 and Figure 23.

Figure 22 Distribution of trips to and from counties, bus, 1998. NTM5 and RVU98

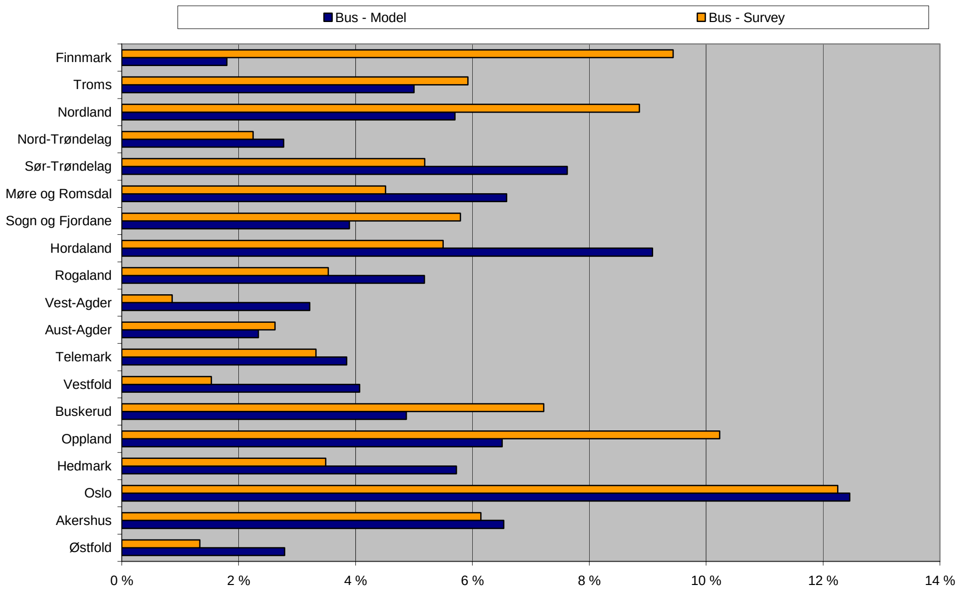
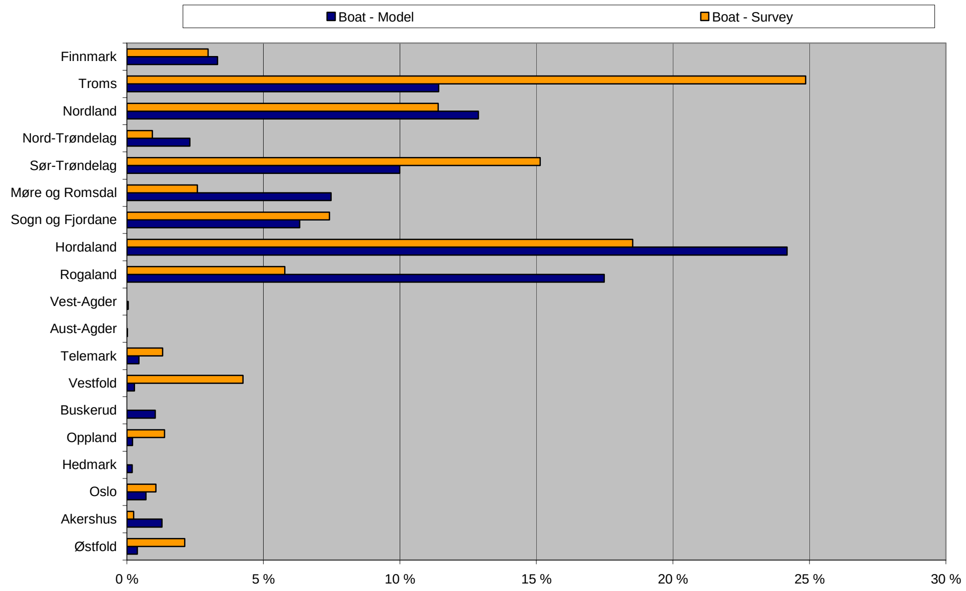


Figure 23 Distribution of trips to and from counties, boat, 1998. NTM5 and RVU98



The overall situation for the distribution of trips on counties in 2001 is shown in Figure 24. As shown some of the same differences that we had in 1998 situation, can also be observed in 2001. The model proportion of trips is low in Sør-Trøndelag, and high in Rogaland and Østfold. The impression is that the distributions from the model runs for 2001 seems to fit better with RVU2001, as compared to the model runs performance for 1998. This could be due to the fact that the sample in RVU2001 is almost 3 times larger than the sample in RVU98.

Figure 24 Distribution of trips to and from counties, all modes, 2001. NTM5 and RVU2001, distribution of population on counties in 2001.

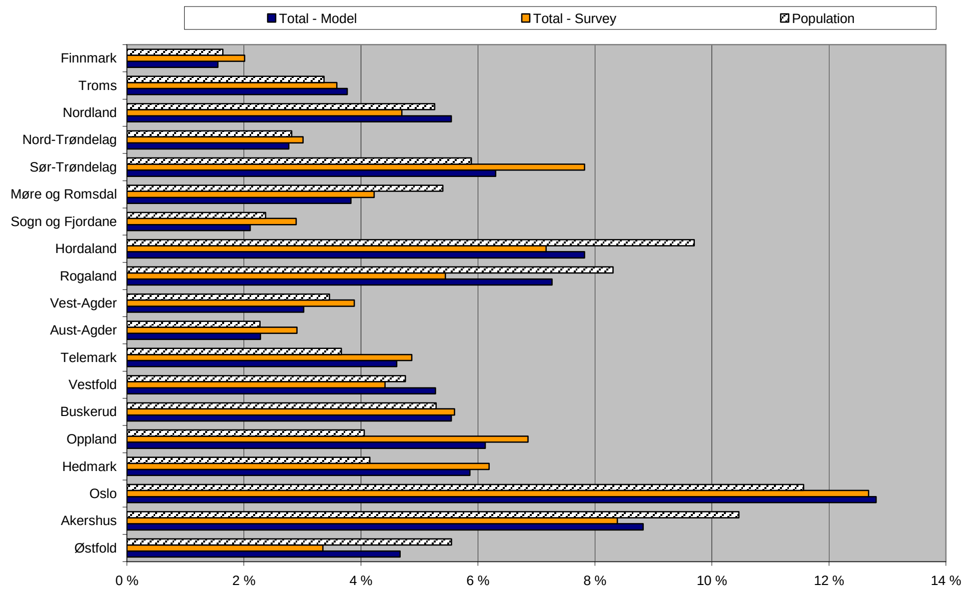
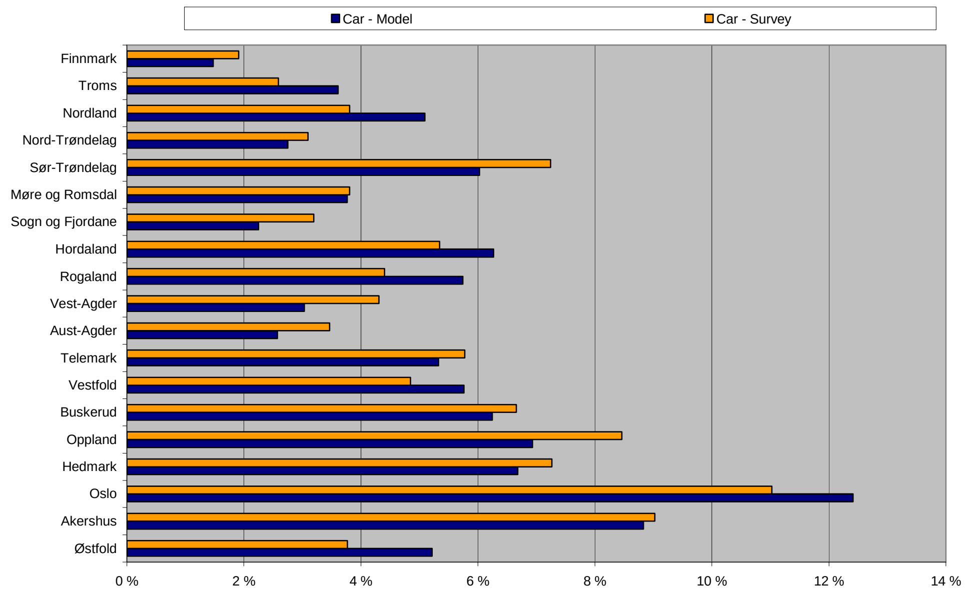


Figure 25 Distribution of trips to and from counties, car, 2001. NTM5 and RVU2001



The situation for long distance trips by train in 2001 also shows some of the same differences as could be observed in the 1998 data. The proportion of trips to and from Oslo in the model is significantly lower than the proportion in the survey, and the reverse situation is observed in Akershus and Østfold. This indicates that there are some problems in the model predicting the correct mode distribution in this area. It is however not clear if these problems are connected to the attraction of trips or the generation of trips by train. The proportion of trips to and from Hordaland seems also to be low in the model. The other trip proportions on the counties appear to be satisfactory accurate.

Figure 26 Distribution of trips to and from counties, train, 2001. NTM5 and RVU2001

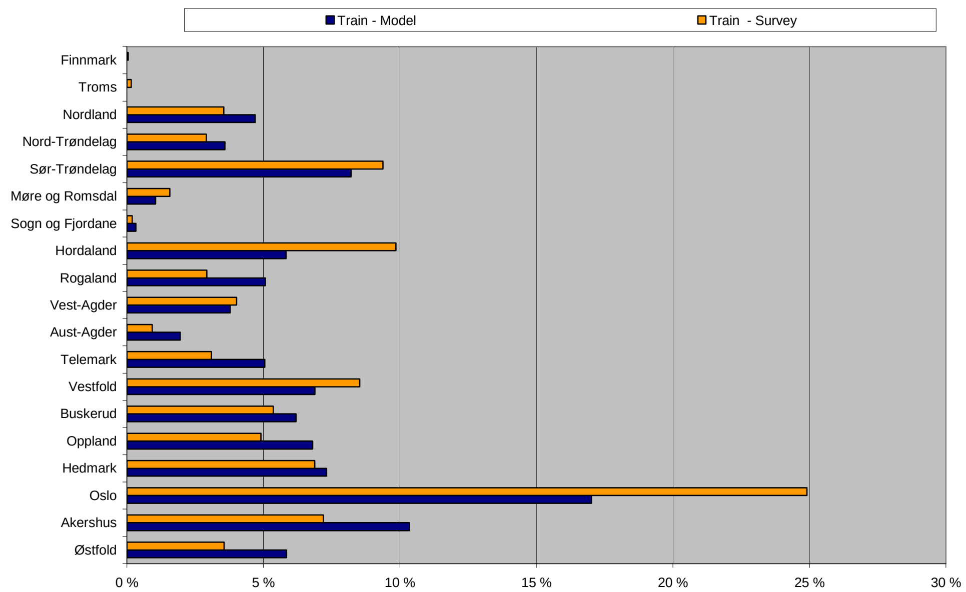
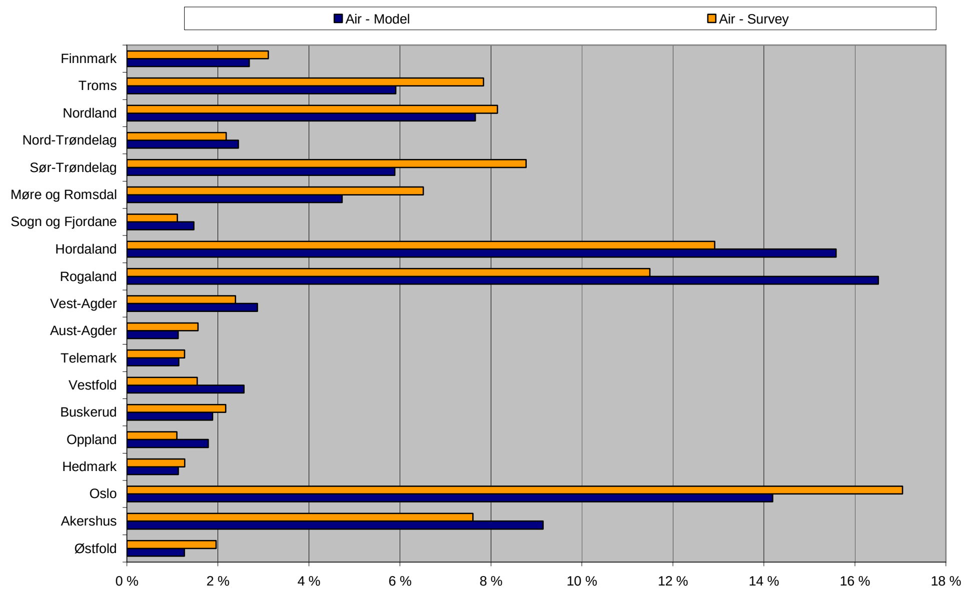


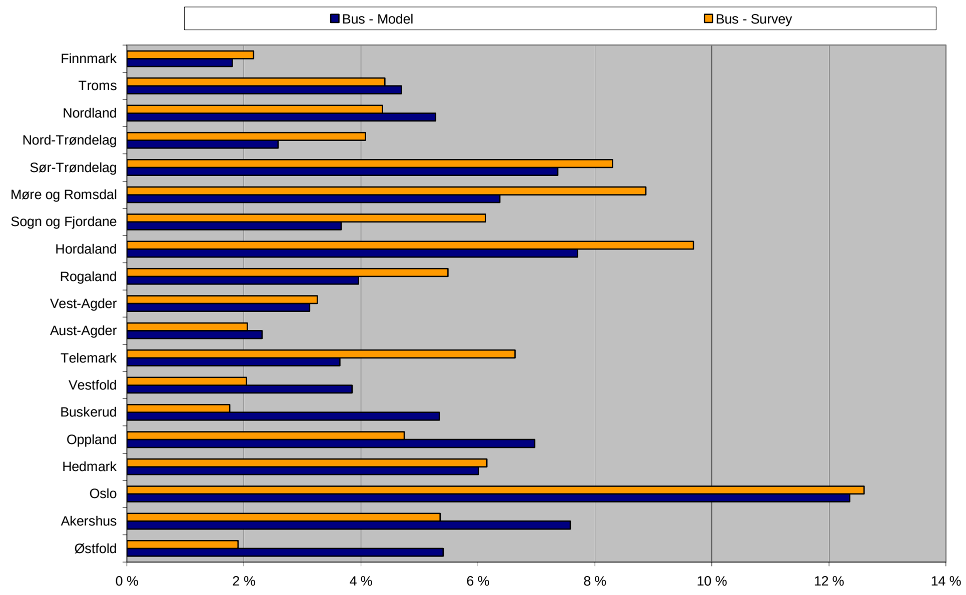
Figure 27 Distribution of trips to and from counties, air, 2001. NTM5 and RVU2001



When it comes to air travel the model still seems low in the three northern counties, and in Sør-Trøndelag and Møre og Romsdal. Compared to data from the survey, the model gives high results in Hordaland and Rogaland. This is also the case when we compare the model runs for 2004 with the mode specific travel survey for air passengers conducted in 2003 (se Figure 30). In the network data for the three base years there is a considerable increase in the frequencies between the airports in Bergen and Stavanger (main cities and county capitals of the two counties). In 1998, the number of departures is 26 (13 in each direction). In 2001 the departures is almost tripled to 68. In 2004 the number of departures is down to 34, still 30 % more than in 1998. It is possible that the model is too sensitive to these changes. As in 1998, the proportion of trips to and from Oslo is lower in the model than in the survey, while the situation for Akershus is reverse. However, in the mode specific air survey from 1998, the proportion of trips by air to and from Oslo was lower than the proportion from the model run.

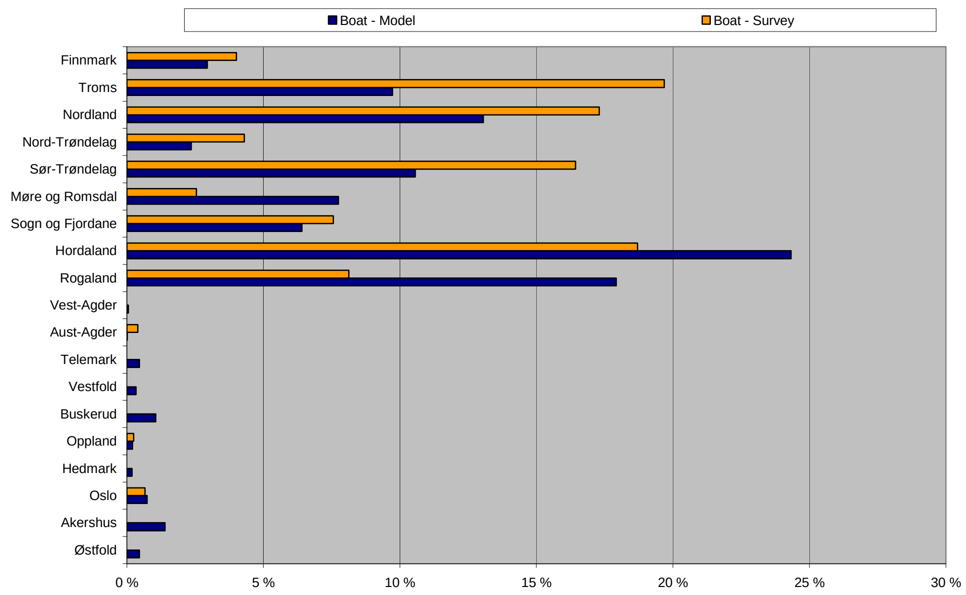
In RVU2001, the number of observations for bus and boat is higher than in RVU98 (600 for bus and 300 for boat). This gives a slightly better basis for discussions of the results of the model for 2001. Figure 28 gives a very different picture of the situation for bus travel than the corresponding material for 1998, shown in Figure 22. The model seem however to be low on the trip proportions along the west coast (from Sør-Trøndelag and down to Rogaland), and correspondingly high on proportions in the central eastern territories, except for Oslo and Hedmark where the model gives an almost exact fit to the survey data.

Figure 28 Distribution of trips to and from counties, bus, 2001. NTM5 and RVU2001



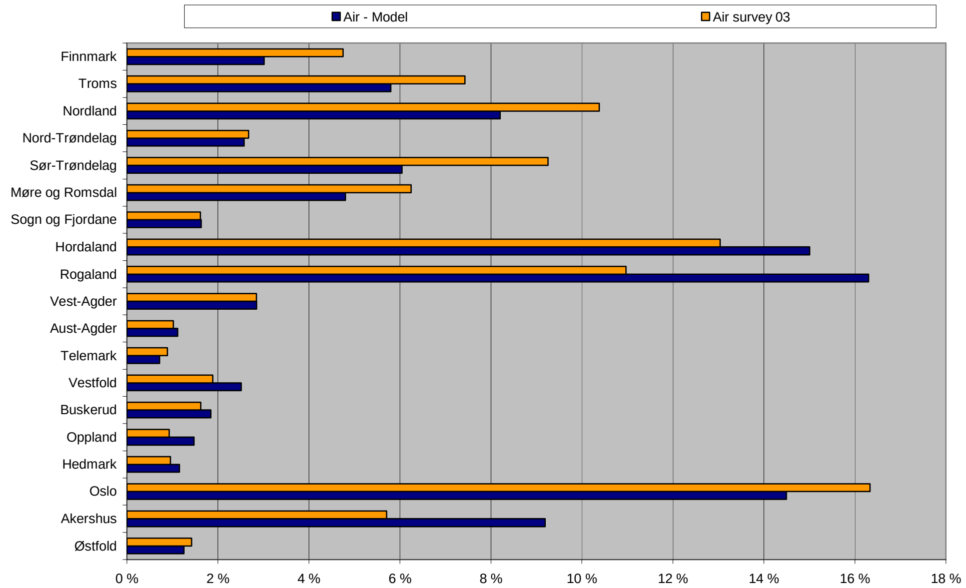
According to the travel survey, Troms, Nordland, Sør-Trøndelag and Hordaland counties is the origin and/or destination of over 70 % of the long distance boat trips in Norway. The model however, points at Hordaland and Rogaland as the largest boat counties with 42 % of the trips. The model is considerable lower on trip proportions in the north. This seems natural, since the main high speed coaster lines are located in the southern part of the west coast. In the north, the main mode of passenger transport by sea is the Hurtigruten, which has daily departures from Kirkenes in the far northeast, to Bergen which is the largest city on the west coast. It is however probable that Hurtigruten is more frequently used in long distance travel in the north than at the west coast.

Figure 29 Distribution of trips to and from counties, boat, 2001. NTM5 and RVU2001



For 2004, the mode specific air survey conducted in 2003 is the only source of information about the geographical pattern of travel. Compared to this data, the model seems low when it comes to trip proportions in the three northern counties, in Sør-Trøndelag, Møre og Romsdal and Oslo, and high in Hordaland, Rogaland and Akershus. This is roughly the same situation as reported for the two previous base years, so there may be some systematic problems associated to the geographical distribution in the model.

Figure 30 Distribution of trips to and from counties, air, 2004. NTM5 and air survey 2003.



The following figures presents the data discussed above in a different way. The figures below provide a more comprehensive picture of the distribution on transport modes when it comes to long distance travel to and from the 19 counties in Norway. Travel by car as passenger are excluded from the figures because of the difference between the travel surveys and model runs (see chapter 3.1)

Figure 31 Mode distribution by county, national survey 1998 (except car passengers)

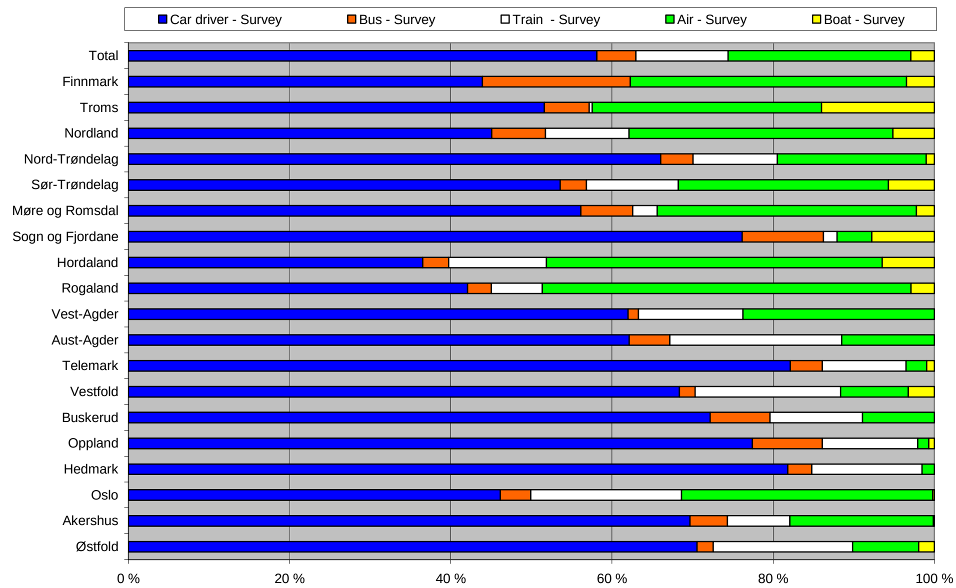


Figure 32 Mode distribution by county, NTM5 1998 (except car passengers)

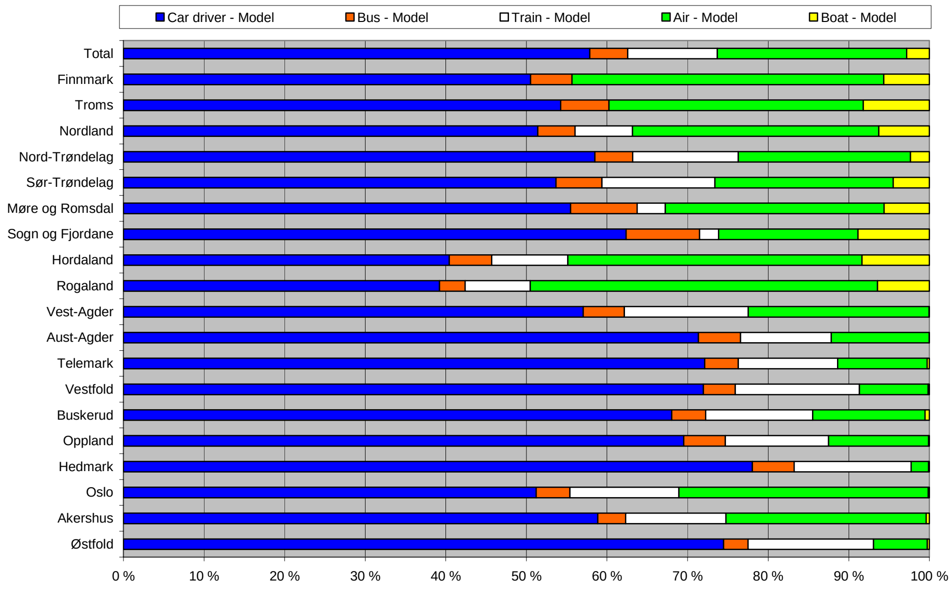


Figure 33 Mode distribution by county, national survey 2001 (except car passengers)

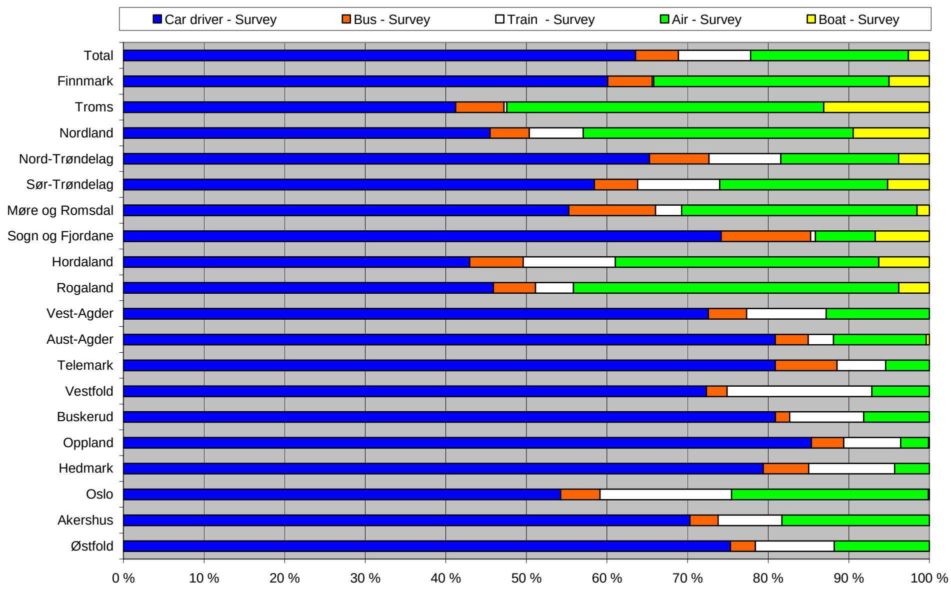


Figure 34 Mode distribution by county, NTM5 2001 (except car passengers)

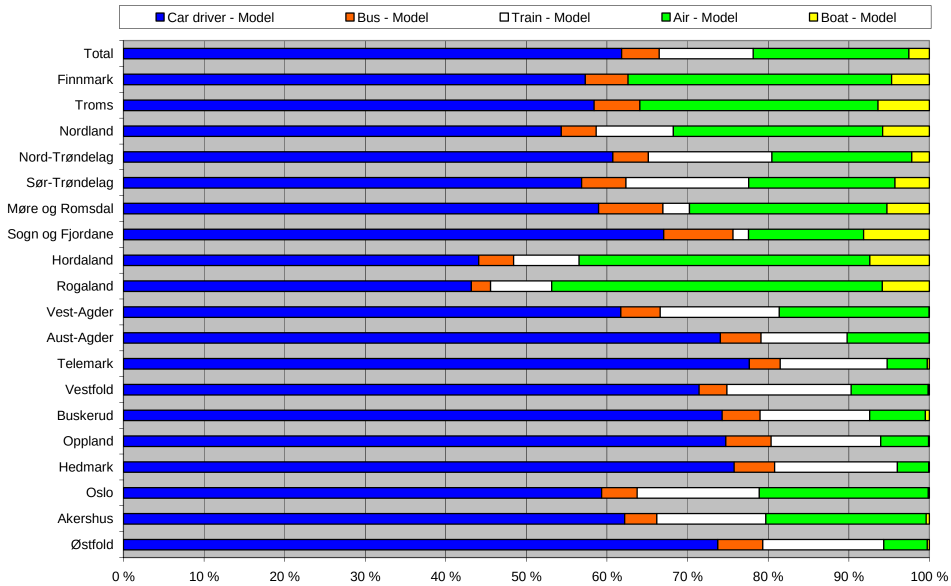
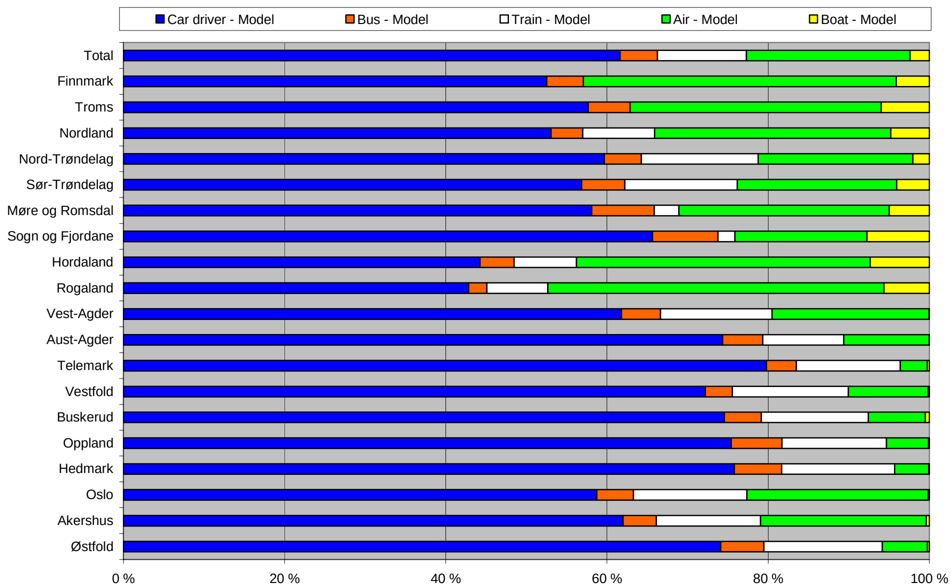


Figure 35 Mode distribution by county, NTM5 2004 (except car passengers)



3.4 Trip length distributions

In this section the models performance when it comes to trip lengths is studied. The trip length distribution for the different transport modes calculated by the model is compared with corresponding data from the travel national surveys conducted in 1998 and 2001. The overall situation is presented in Figure 36. The trip length distributions from the two surveys are quite similar apart from the short distance interval, and the medium length interval. In the most recent survey there are more trips in the shortest interval (100 – 200 km) and fewer trips in the medium distance interval (400 – 500 km). The differences are however quite small, so it is hard to say if this is a real tendency or just statistical noise[7]. The model predicts approximately the same trip length distribution for the three base years. As compared to the survey data there is a tendency that the model is somewhat low for the short trips (100 – 200 km), high for the medium length trips (300 – 500 km) and low for the long trips (>1000 km).

Figure 36 Trip length distribution, all trips, Model calculations for base years 1998, 2001 and 2004, and in the national travel surveys RVU98 and RVU2001

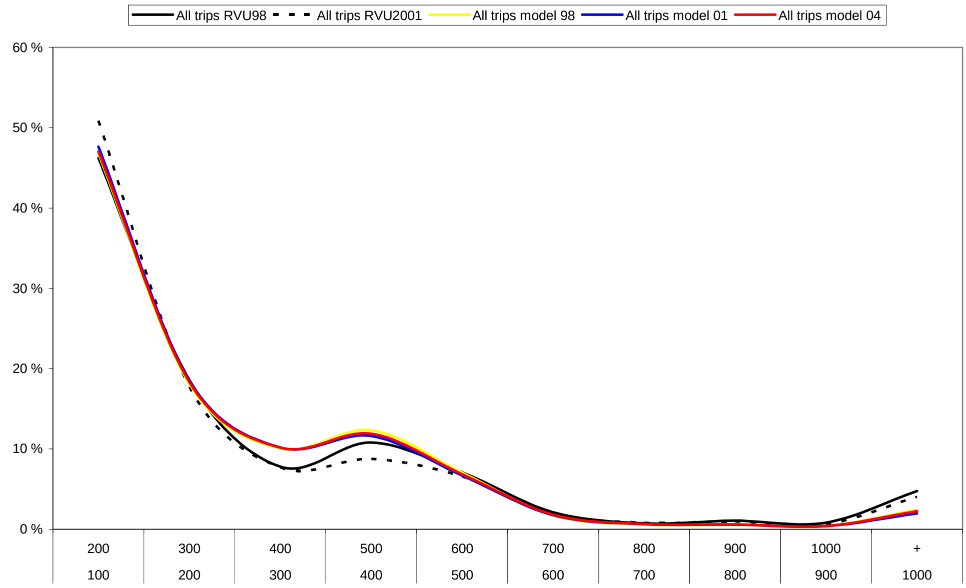
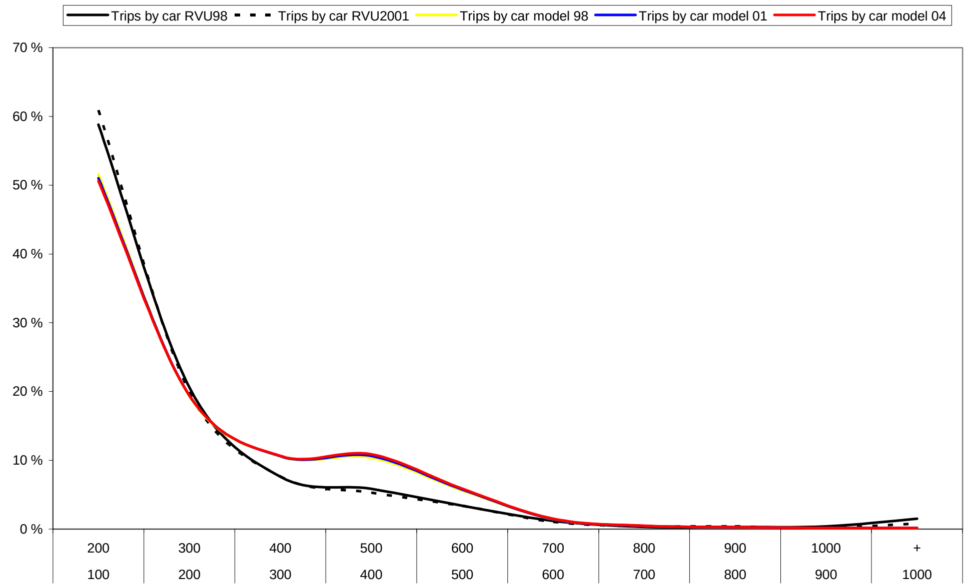


Figure 37 shows that we have the same problem for car trips, and that the problem here is more severe. Compared to the surveys, which have a quite similar distribution for car trips, the model is 8 – 10 % units low in the short interval, 4 – 5 % units high in the medium length interval (300 – 600 km), and low for the longest trips.

[7] A rough 95 % confidence interval test indicate that there are significant tendencies towards more short distance trips and fewer medium distance trips.

Figure 37 Trip length distribution, trips by car, Model calculations for base years 1998, 2001 and 2004, and in the national travel surveys RVU98 and RVU2001



In Figure 38 and Figure 39, the trips by car are divided into trips as driver and passengers[8]. The problems are more severe for trips as passengers than for trips as drivers. For car passenger the distributions produced by the model have a distinct accumulation around 400 – 500 km, an interval that covers trips between the largest cities in Norway. In the distribution from the surveys these accumulations are almost absent.

[8] The model does not distinct between drivers and passengers for car trips. This distinction is done by a procedure after the model calculations. The latest version however is segmented by travel party size, i.e. travel alone and travel in a party of two and more persons. In the latter segment the distinction between drivers and passengers is necessary, and the car occupancy rate (by travel distance) is entered exogenously as input to this procedure. It is important to point out that the assumptions of car occupancy were made as a rough calibration of the model was necessary. These assumptions are important when it comes to the models performance on trip lengths, and they therefore should be further investigated further.

Figure 38 Trip length distribution, trips by car as driver, Model calculations for base years 1998, 2001 and 2004, and in the national travel surveys RVU98 and RVU2001

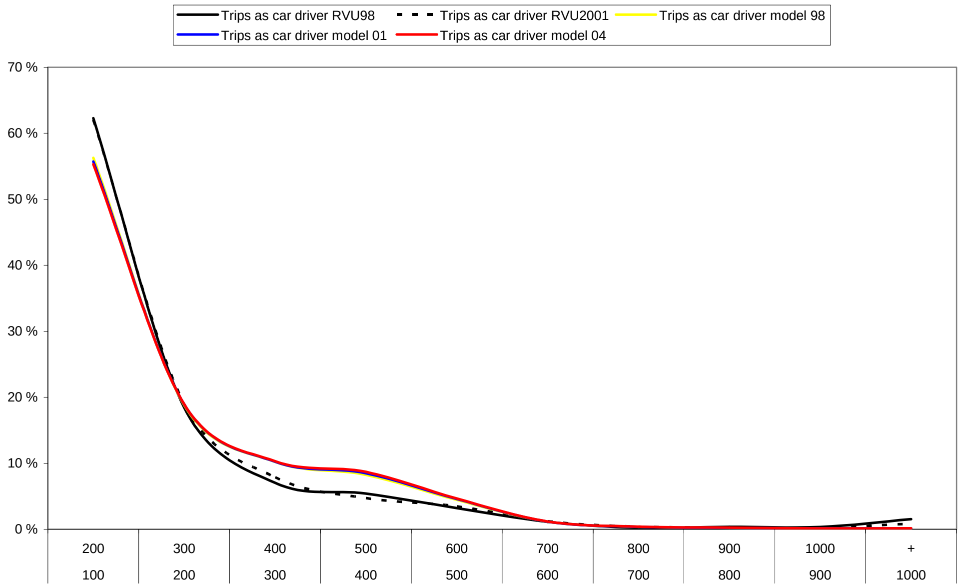
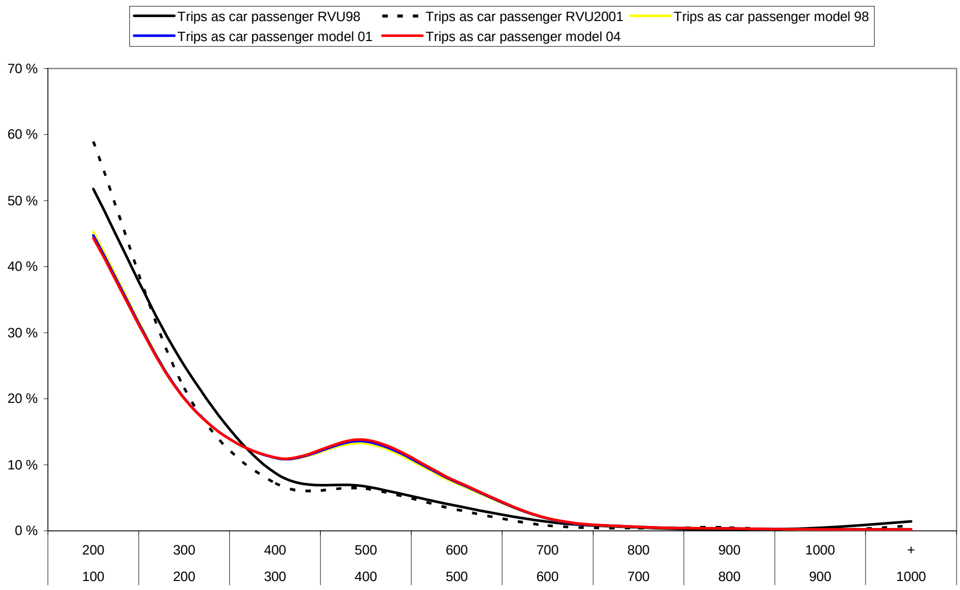


Figure 39 Trip length distribution, trips by car as passenger, Model calculations for base years 1998, 2001 and 2004, and in the national travel surveys RVU98 and RVU2001



The trip distributions for trips by train are shown in Figure 40. The differences between the distributions of the two surveys are not quite as similar as observed in the previous figures. This is probably mostly due to statistical noise caused by a smaller amount of observations (750 in RVU98), and do not reflect true changes in behaviour. The distributions from the model fit better with the distribution from RVU98 than with the distribution from RVU2001, at least for the shorter trips.

Figure 40 Trip length distribution, trips by train, Model calculations for base years 1998, 2001 and 2004, and in the national travel surveys RVU98 and RVU2001

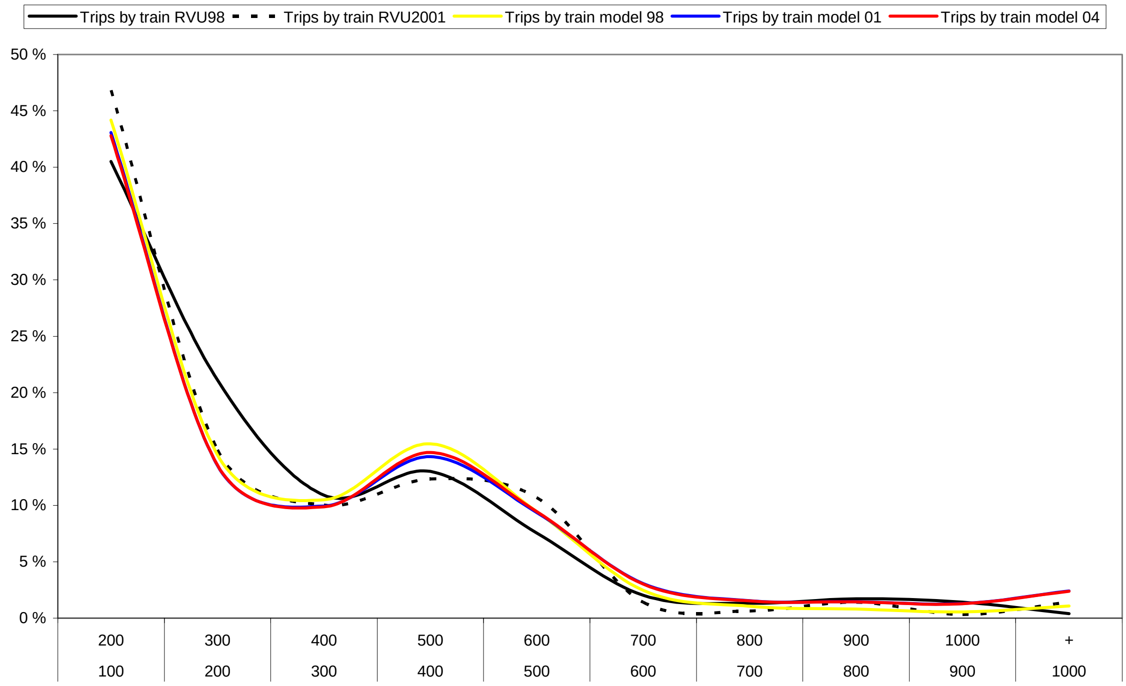
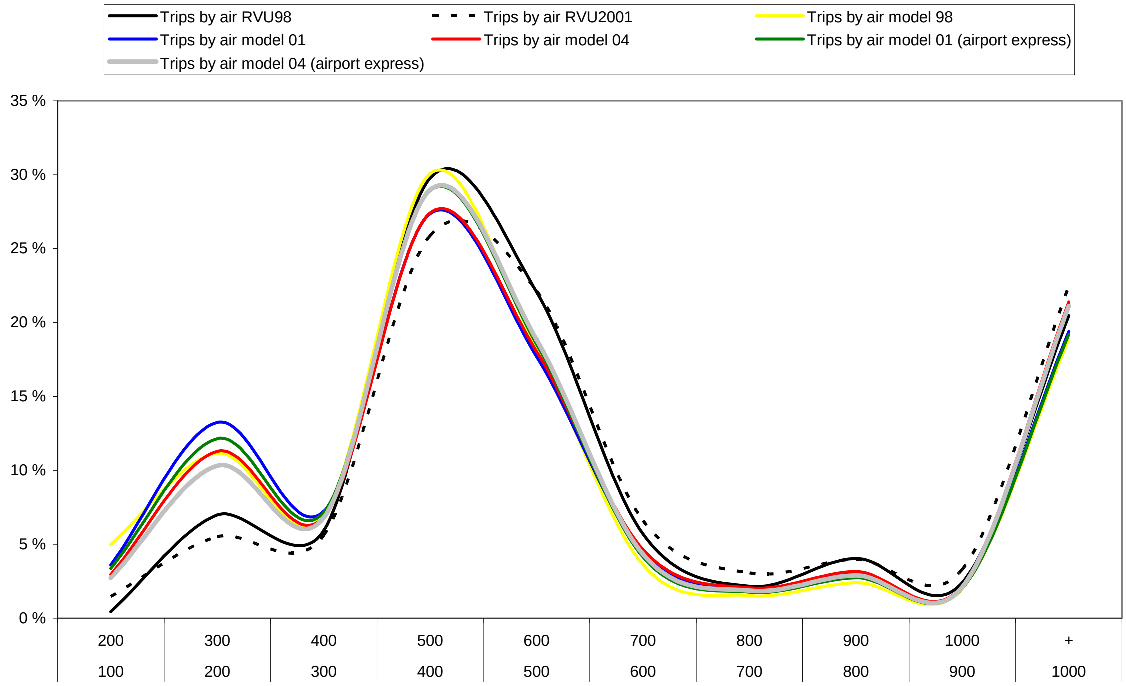


Figure 41 reveals big problems connected to the trip length distribution for trips by air. First, there are differences between the distributions from the two surveys, but its hard to conclude whether this differences reflects changes in travel behaviour, or statistical noise (the number of observations in RVU98 is 1600, and in RVU2001 2300)[9]. The problems with the distributions from the different model runs are largest for trips shorter than 400 km where the trips are heavily overestimated, and for trips longer than 500 km, where the trips are underestimated, especially in the interval between 500 and 800 km.

[9] A rough 95 % confidence interval test on the peak of the two distributions (400 – 500 km), with 470 observations in RVU98 and 620 observations in RVU2001, shows that they slightly overlap.

Figure 41 Trip length distribution, trips by air, Model calculations for base years 1998, 2001 and 2004 (with and without airport express train as access mode to OSL), and in the national travel surveys RVU98 and RVU2001



The trip length distributions for bus and boat are shown in Figure 42 and Figure 43. As pointed out earlier, the number of observations for these two modes is quite small, and their trip length distributions in the travel surveys are surrounded by broad confidence intervals. The figures indicate some of the same problems for trips by bus as observed for trips by car, i.e. underestimation of shorter trips and overestimation of medium length trips. The trip lengths distributions from the model for trips by boat seem to roughly fit the data from the two surveys.

Figure 42 Trip length distribution, trips by bus, Model calculations for base years 1998, 2001 and 2004, and in the national travel surveys RVU98 and RVU2001

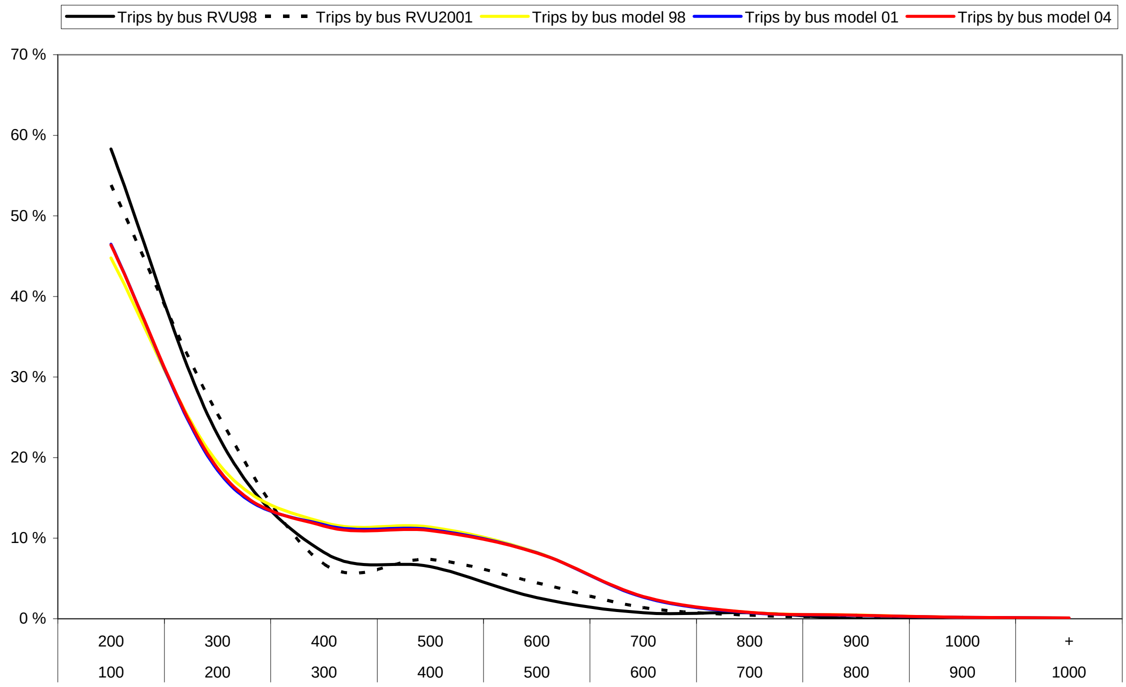
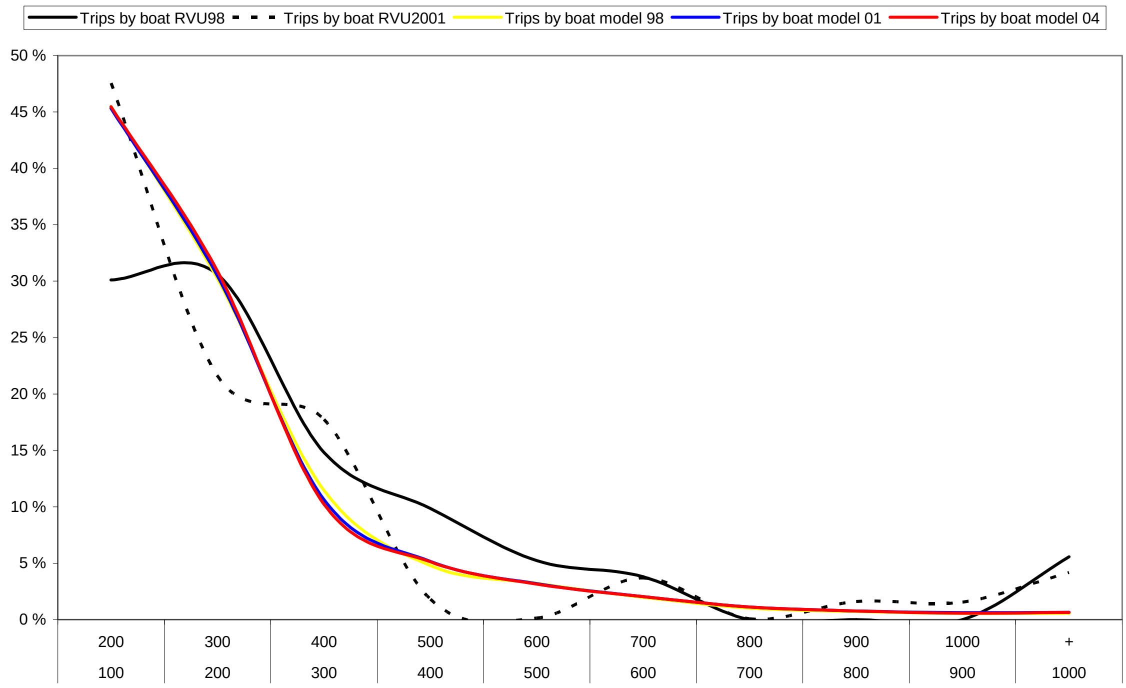


Figure 43 Trip length distribution, trips by boat, Model calculations for base years 1998, 2001 and 2004, and in the national travel surveys RVU98 and RVU2001



For a model of this type, a fairly reliable performance related to the distribution of trips by length, is quite important. It could be argued that this is a necessary condition to get a fairly reliable distribution on destinations (a dimension of which is far more difficult to evaluate, see section 3.2). Even though the data from the national travel surveys also can be biased in different ways, there are some evidence of problems with the trip length distribution, at least for trips by car and by air (perhaps also by bus). Problems like this are not unique for this model. Similar problems are reported in the estimation of regional transport models in Norway (Madslien et al 2005). In NTM5 the problems of course gets more apparent as the model cover trips in the distance interval of 100 – 2000 kilometres.

A part of the problem could be a phenomenon known in the literature as heteroscedasticity. This problem can occur when important unobserved variables are left out as explanatory variables in the estimation of the different sub models. In our case, costs and other aspects connected to the need to stay overnight at the destination when choosing other modes than air, can be argued to be important variables that are left out in the estimation of the mode and destination choice models. The extent of this problem could be tested by estimation of similar models with different types of segmentation with respect to overnight stays at the destination, or simply by introducing different types of (mode specific) dummy variables by trip length. The first suggestion is more difficult to test than the latter, as it raises many issues connected to both of data requirement and model implementation. The latter is less theoretically feasible, but far easier to test.

It should however be worthwhile to investigate what effect different assumptions with respect to travel party sizes and car occupancy can entail with respect to the trip length distribution, especially on the distribution of trips as car passengers. As will be discussed in the next section, it may also be worthwhile to investigate how reliable the air fares are for short distance air travel.

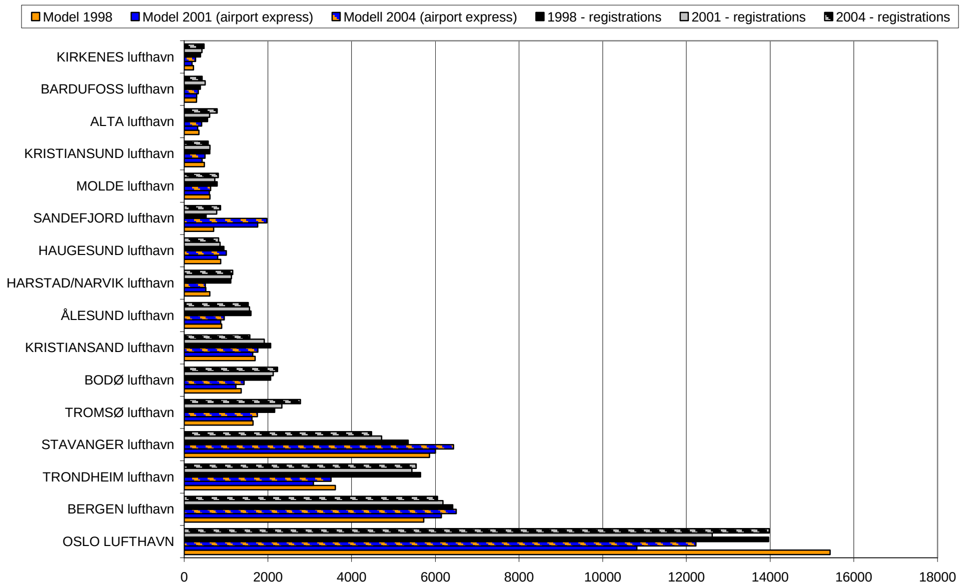
3.5 Passenger volumes at airports

Avinor, www.avinor.no, publishes information on passenger volumes at Norwegian airports. The material, which originates from ticket sales and boarding registrations, shows domestic and international departures, arrivals, transit and transfer for scheduled flights and charter flights. We have processed this material to fit with the markets that NTM5 cover[10]. The material is compared with the model's performance with respect to assigned air travel demand on airports in the network.

The passenger volumes at the largest airports (sorted by traffic registrations in 2001) are shown in Figure 44. The overall impression is that the model results coincide convincingly with the registered passenger volumes. However, when we dive into the details, some problems occur. We have already discussed the problems in the model of separating between the effects of changed location of the national airport in Oslo from the effects from the new coding principle for air transit lines in the national network. These two changes added up seem to give a higher reduction on air passengers in the model than actual observed. The model is a little bit too high on passenger volumes at Oslo Airport (the old location) in 1998 and too low in 2001 and 2004 (new location). On some of the airports, the level of passenger volumes is inaccurate, but the model seems to reflect the changes relatively good (Trondheim, Tromsø, and Bodø). On some of the other airports, the level of the volumes are more accurate, but the changes seem to be wrong (Bergen, Stavanger and Kristiansand).

[10] Domestic travel (both origin and destination in Norway) longer than 100 km one way, by private car or scheduled public transport, conducted by Norwegian residents (13 years or older).

Figure 44 Passenger volumes (not transit and transfer) at airports (16 largest), registrations and volumes calculated by NTM5, for 1998, 2001 and 2004.



The first of these two problems is also reflected in some of the data discussed earlier. It seem to be quite clear that the model is somewhat low when it comes to generation and/or attraction of trips by air in the northern and middle parts of Norway (including airports in Trondheim, Tromsø, Bodø, Harstad/Narvik, Alta, Bardufoss and Kirkenes). It is also indicated that the level of air passenger volumes generated and/or attracted to the less central counties in the east of the country, is high (including Sandefjord in the figure above and Skien and Fagernes in Figure 46). The problem of wrong signs of the changes at some of the airports can be related to a somewhat unfortunate formulation of the departure frequency variable in the different models. We will return to this issue in the discussions of the elasticities in the model.

When it comes to the model's ability to assign trips on the networks, there is a wide range of problems. However, network assignment problems are not the main focus in this project. One particular problem that could be mentioned is not due to shortcomings in the different algorithms used, but rather to the way we collect and process data to the networks, and the relevance of these actions with respect to model evaluation against other data sources. The transit lines for the air mode represent the actual movements of aircrafts during one representative day. On the smallest airports however (in terms of passenger volumes) the level of service can vary considerably both during the week and by different seasons. The data for passenger volumes on airports (and most of the other data sources involved in this evaluation) reflects the accumulation of traffic during one year. This can leave us with quite extensive differences when the model results are compared to registrations, as shown for some of the airports in the next two figures.

Figure 45 Passenger volumes (not transit and transfer) at airports (17 medium size), registrations and volumes calculated by NTM5, for 1998, 2001 and 2004.

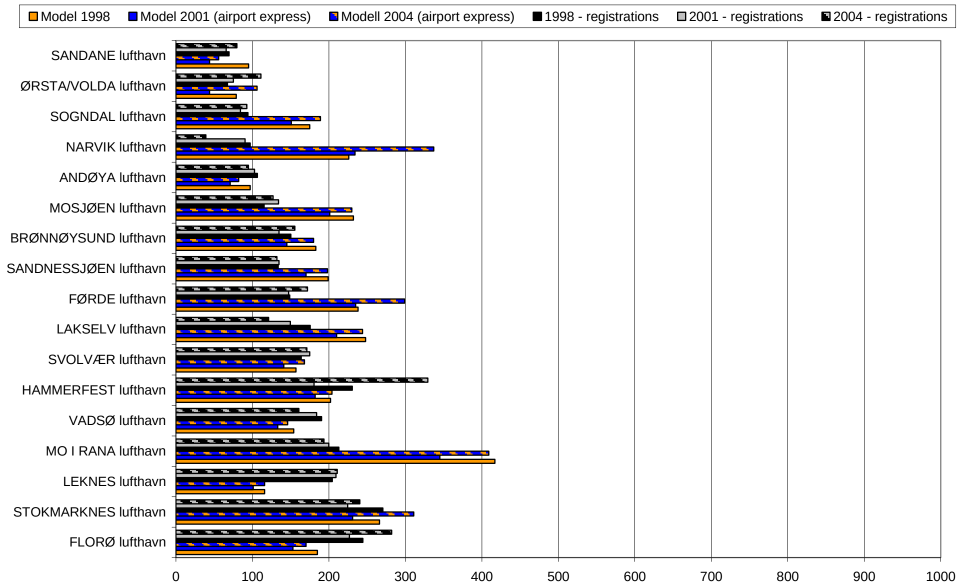
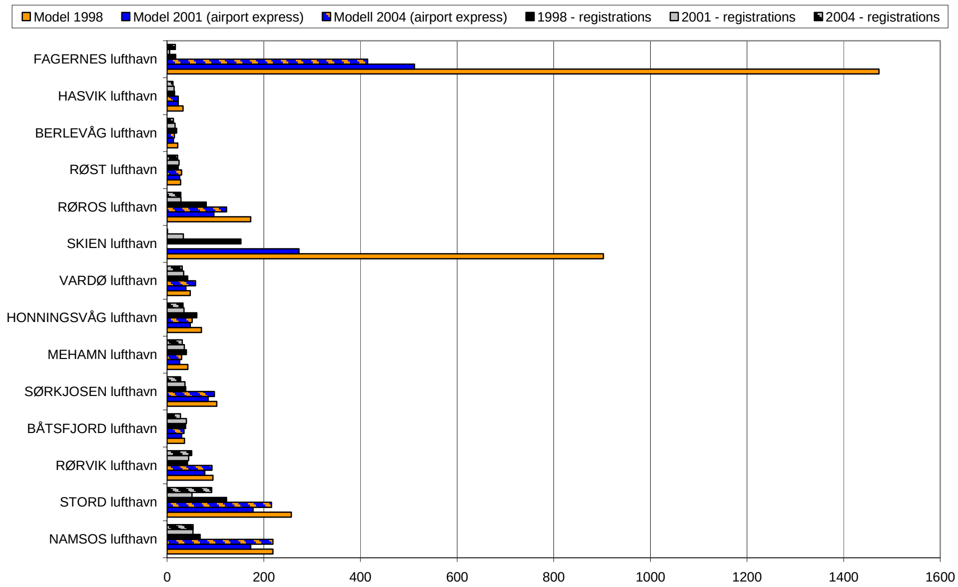


Figure 46 shows that this definitely is the case for the airports in Fagernes and Skien. In addition we have detected problems with the level of ticket fares for short distance air traffic. Between Fagernes and Oslo airport, the actual average air fare is twice the size of the amount represented as input to the model. Minor quality controls of the airfares on different legs in the data material of the model system, indicate that the airfares for the short distance air traffic are too low in general. The problem is mostly connected to the smaller airports and especially in situations where the short distance air network is used as access mode to the long distance network.

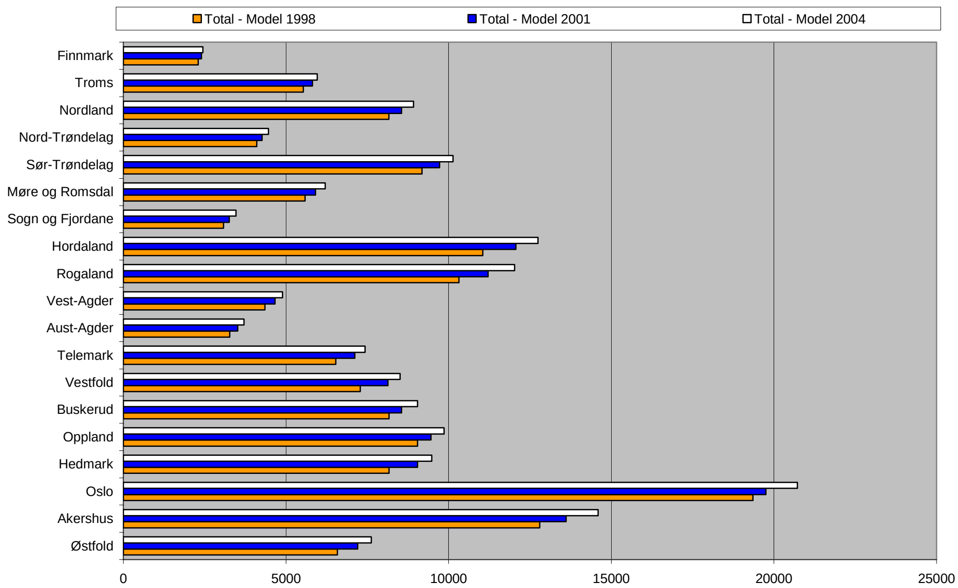
Figure 46 Passenger volumes (not transit and transfer) at airports (14 smallest), registrations and volumes calculated by NTM5, for 1998, 2001 and 2004.



3.6 Model predictions by counties

The last figures in this section shows the number of trips to and from counties in Norway calculated with NTM5. Figure 47 shows the overall dynamics in the process. The increase in long distance travel is a result of many more or less realistic changes between the base years along a wide range of dimensions, including changes in the population size, the demographics of the population, changes in income, minor and major mode specific changes in infrastructure, and level of transport service, changes in mode specific costs and fares, etc.

Figure 47 The number of long distance trips by counties and base year, all modes



The dynamics in the process are to a large extent mode specific. This is one of the main points stated by the figures below. However, the dynamics are not isolated to each mode of transport. The changes in attributes of one mode may inflict on changes in travel by other modes. The reduction in Figure 50 between 1998 and 2001 in long distance air travel found for Oslo is mainly caused by high prices and the relocation of the airport. These factors can partly explain the increase in travel by car and train for Oslo found in Figure 48 and Figure 49. These system effects make models like NTM5 very useful tools in transport planning.

Figure 48 The number of long distance trips by counties and base year, car

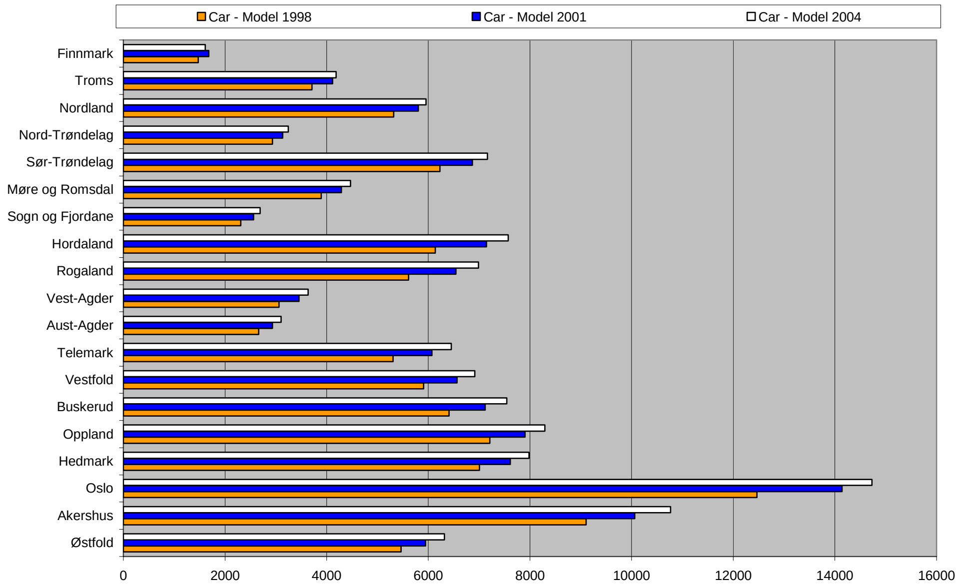


Figure 49 The number of long distance trips by counties and base year, train

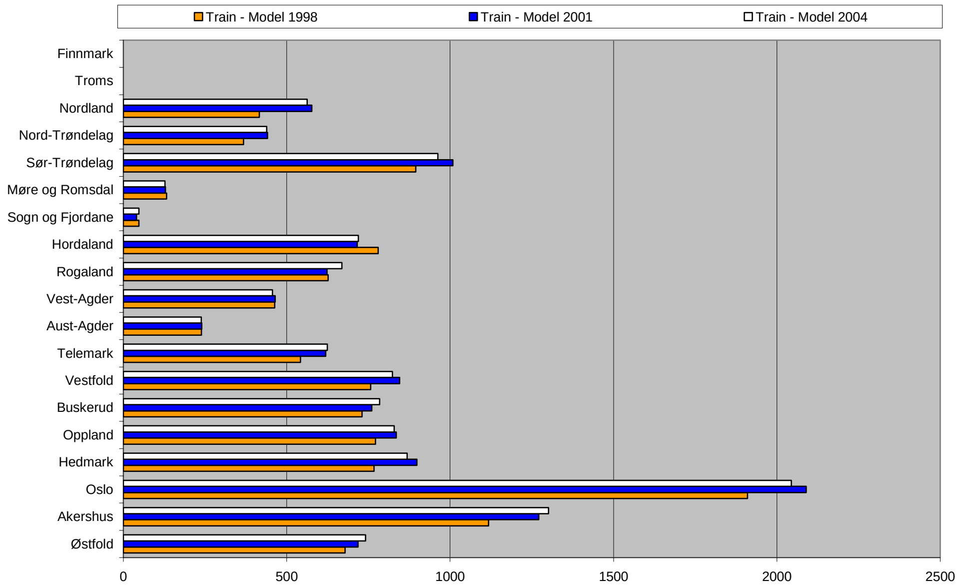


Figure 50 The number of long distance trips by counties and base year, air

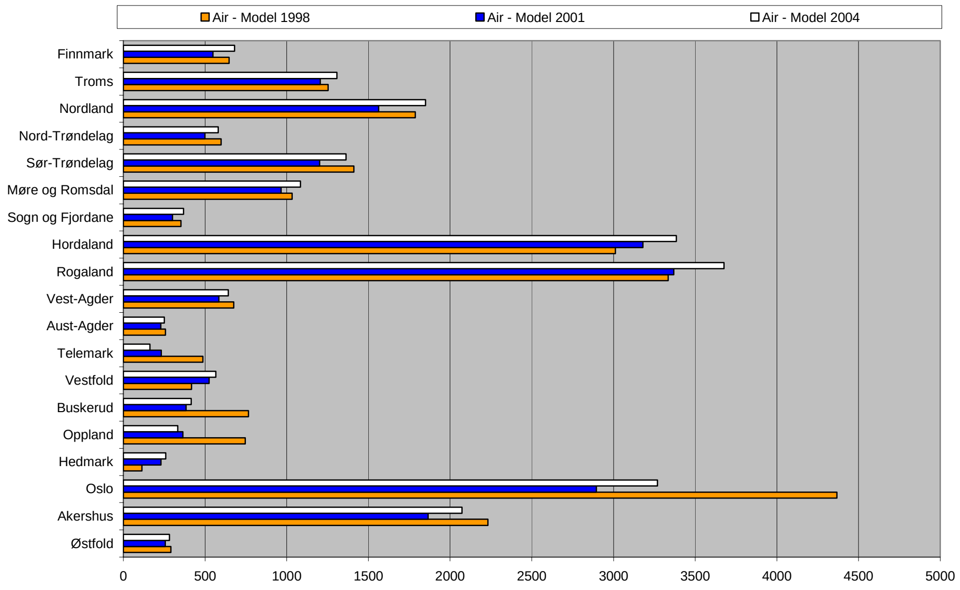


Figure 51 The number of long distance trips by counties and base year, bus

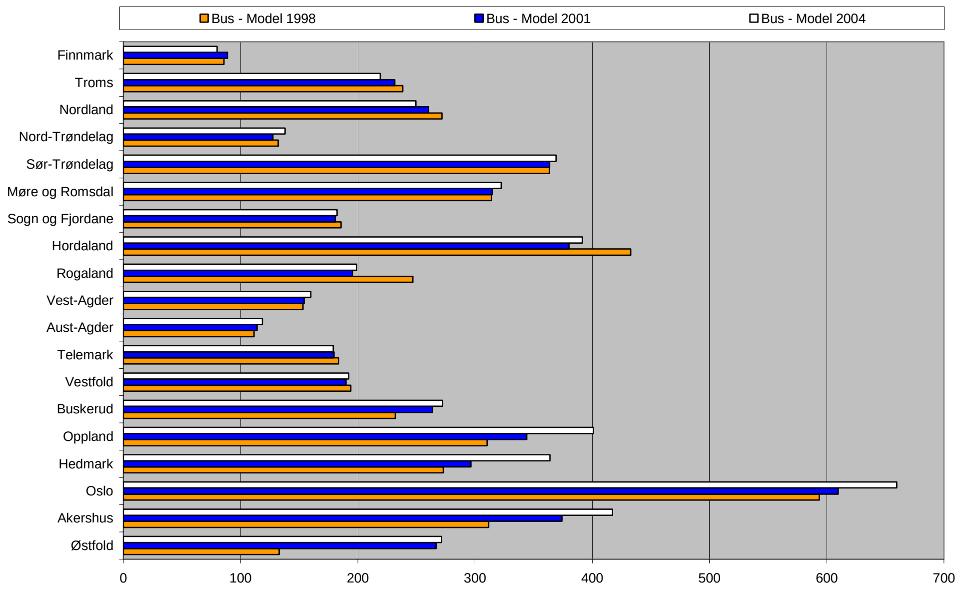
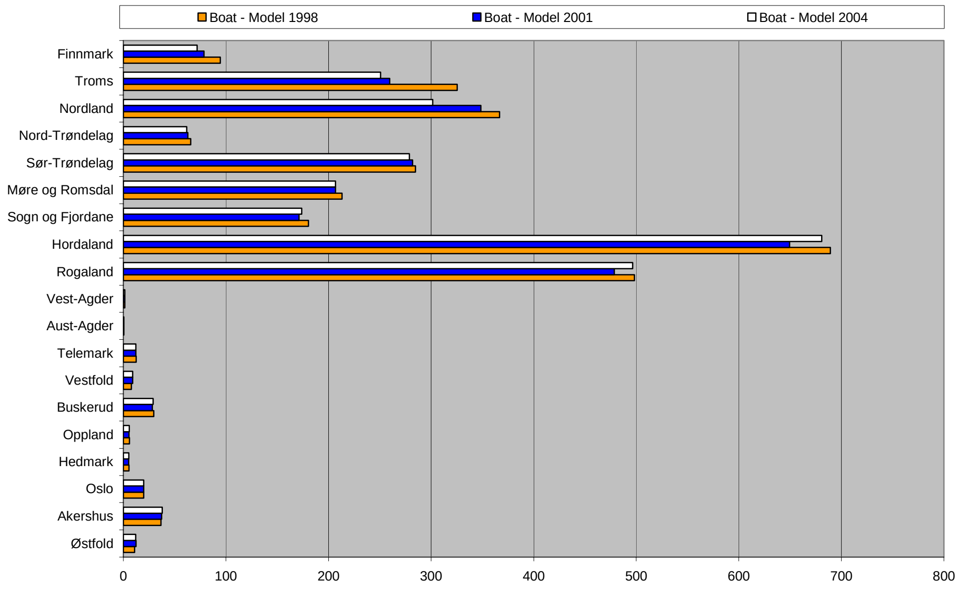


Figure 52 The number of long distance trips by counties and base year, boat



4 Elasticities in NTM5

In model systems like NTM5 elasticities for the different variables are implicitly defined by the different models included. The calculation of different elasticities from the model system helps us to understand and discuss the behaviour of the model, and the elasticities can sometimes be quite helpful as tools in different studies and calculations connected to the different markets covered by the model system. However, one of our main statements from this section of the evaluation of the model system is that any study or calculation using elasticity estimates from the model system should also discuss the relevance of the elasticity estimate used. Elasticity estimates from NTM5, or any similar model, varies by a wide range of factors which are included as components in different parts of the model systems. Different estimates of elasticities can also be calculated under different assumptions, reflecting different types of policies or actions taken by different agents that operate in the transport system.

It can be appropriate to distinct between aggregated national elasticities and more disaggregated elasticities reflecting the situation in different sub markets. National elasticities reflect the situation of general nationwide changes in variables, such as different national taxation schemes (petrol tax, tax on fares, etc.), changes in income and taxation of income, etc. Elasticities reflecting such policies can easily be calculated at an aggregate level, or at a more disaggregate level , such as regions or counties, showing that national policies can have different effects in different parts of the country. These elasticities however reflect the effect of nationwide changes in different variables, and they should not be used in studies or calculations where the changes are more specific, geographically restricted or defined as taking place in different submarkets.

The state owned company for airports and air traffic control, ownership and operations, Avinor, could as an example be interested in studying the changes in passenger volumes by air on one particular airport as a result of changed departure frequencies on this particular airport, or the changes in passenger volumes on a particular leg as a result changes in airfares. A traffic company or different public authorities could be interested in studying the changes in passenger volumes on boat as a result of changes in price or other level of service components offered by other modes. Elasticities reflecting these types of changes may differ from the national elasticities quite substantially. In such situations, the use of national elasticities, even at a disaggregated level, can lead to biased conclusions.

In this project, we have calculated a wide range of elasticities (direct and cross) including the national level, transport corridors, and between areas surrounding the main airports in Norway. As a tool to calculate elasticities between geographical areas, an application is developed adapt the data needed to calculate changes in demand by means of NTM5. Input to this application is a level of service data set for one mode, a specification of the particular variable in the data set of interest (i.e. price, frequency, etc), and a definition of the relevant geographical division of the study (i.e. a transport corridor divided into different sub areas, or any other geographical division at interest). Output from the application is new data sets for level of service input to the model system, corresponding to a specific change in the specified variable, between all the geographical sub areas defined in the geographical division.

4.1 Elasticities in NTM5

In a simple mode choice logit model the formula for the direct elasticity of a variable is:

(1) $El_{ii} = (1\text{-}P_i)\, a_{ix}\, X_i$,

where P_i is the probability of using mode "i" (the market share of mode "i"), a_{ix} is the coefficient of variable X for mode "i" and X_i is the value of variable X for mode "i". As we can see from the formula the size of the elasticity depends on the market share of the mode we are studying (a high market share gives low elasticity) the size and sign of the coefficient and the size of the variable itself.

In the same simple mode choice logit model the formula for the cross elasticity of a variable is:

(2) $El_{ij} = -P_i\, a_{ix}\, X_i$,

While the direct elasticity tells what happens with the demand of a mode when one of the variables for the same mode changes, the cross elasticity gives the resulting demand of other modes when the same variable changes. The size of the cross elasticity depends on the market share of the transport mode of the variable in question, the size and sign of the coefficient of that mode, and the size of the variable itself. As we can see the cross elasticity has the opposite sign of the direct elasticity. The absolute value of the cross elasticity increases with increased market share of the transport mode of the variable in question, and it also increases with increased value of the variable itself.

In NTM5, like in many other similar model systems, some of the variables are transformed. Transforming certain variables is some times necessary because of problems with covariation between variables (travel time and travel costs). When variables are transformed the formulas of the elasticities gets slightly more complicated:

(3) $El_{ii} = (1\text{-}P_i)\, a_{ix}\, f'(X_i)\, X_i$, and
(4) $El_{ij} = -P_i\, a_{ix}\, f'(X_i)\, X_i$,

In NTM5, the travel cost variables are generic for all modes and transformed by taking the logarithm of the actual cost. When it comes to effects of changes in the cost variable, this transformation leaves no effect directly by the actual level of the variable[11]. The effect of the level of the variable in a simple mode choice logit model will then enter through the market share only (higher prices => lower market share). Since NTM5 also include models of destination choice and choice of travel frequency the effects becomes even more complicated, but the elasticities will still reflect the effect of this transformation to some degree.

In NTM5, the frequency variables are also transformed, and specified as generic variables for the transit modes in all four models. The variables are specified as the square root of the number of departures per day. With this specification, the direct elasticity will have the following formula (in a simple mode choice model):

(5) $El_{ii} = (1\text{-}P_i)\, a_{ix}\, f'(X_i)\, X_i = (1\text{-}P_i)\, a_{ix}\, X_i /(2\sqrt{X_i}) = (1\text{-}P_i)\, a_{ix}\, (\sqrt{X_i})/2$

[11] $Ln(X_i)' = 1/X_i$, and the term $f'(X_i)X_i$, drops out of the equations (3) and (4).

This causes a positive isolated effect form the variable itself (i.e. the elasticity will be higher with 20 departures a day, than with 5). However, a high variable value will also influence the market share (higher market share with 20 departures than with 5), and therefore indirectly give a lower elasticity. Table 12 and Table 13 give an indication of the extent of these aspects. The first table shows the isolated effect of changed departure frequency on elasticity of departure frequency between Bergen and Stavanger[12], holding the market share constant (the coefficient a_{ix} taken from the business model in NTM5, X_i is the number of departures). The elasticity decreases when the departure frequency decreases, which is not a very realistic effect.

The second table shows the situation when also the market share is assumed to change as a result of changed departure frequency. We assume that the market share for air decreases from 39 % to 26 % as the departure frequency decreases from 34 to 10 per day. The elasticities decrease but not to the same extent as for the situation with constant market shares.

Table 12. Example of elasticity calculations for travel between Stavanger and Bergen by air. Increased number of departures (work related trips).

El_{ii}	$(1-P_i)$	a_{ix}	$F'(X_i)$	X_i
0.44	0.61	0.25	0.09	34
0.43	0.61	0.25	0.09	32
0.42	0.61	0.25	0.09	30
0.40	0.61	0.25	0.09	28
0.39	0.61	0.25	0.10	26
0.37	0.61	0.25	0.10	24
0.36	0.61	0.25	0.11	22
0.34	0.61	0.25	0.11	20
0.32	0.61	0.25	0.12	18
0.31	0.61	0.25	0.13	16
0.29	0.61	0.25	0.13	14
0.26	0.61	0.25	0.14	12
0.24	0.61	0.25	0.16	10

Table 13 Example of elasticity calculations for travel between Stavanger and Bergen by air. Increased number of departures and increased market share (work related trips).

El_{ii}	$(1-P_i)$	a_{ix}	$f'(X_i)$	X_i
0.44	0.61	0.25	0.09	34
0.44	0.62	0.25	0.09	32
0.43	0.63	0.25	0.09	30
0.42	0.64	0.25	0.09	28
0.41	0.65	0.25	0.10	26
0.40	0.66	0.25	0.10	24
0.39	0.67	0.25	0.11	22
0.38	0.68	0.25	0.11	20
0.37	0.69	0.25	0.12	18
0.35	0.70	0.25	0.13	16
0.33	0.71	0.25	0.13	14
0.31	0.72	0.25	0.14	12
0.29	0.73	0.25	0.16	10

However, changes in the number of departures are not the only factor influencing the market share. In Table 14, the actual situation from model results for the three base years is reflected. The market shares for air in 1998, 2001 and 2004 between Stavanger and Bergen, are quite similar, 34 %, 39 % and 36 % respectively. The relatively stable market share these years is

[12] The data in the tables reflect market shares from NTM5 defined by a relative broad area around the airports in the two cities.

partly due to a peak in airfares in 2001 that coincides with the frequency peak this year, resulting in a fairly high elasticity for departure frequency in 2001 and lower elasticities in 1998 and 2004. This effect is due to the formulation of this variable in the model specification, and it is from our point of view highly questionable.

Table 14 Example of elasticity calculations for travel between Stavanger and Bergen by air, NTM5 model results by base year.

Year	El_{ii}	$(1-P_i)$	a_{ix}	$f'(X_i)$	X_i
1998	0.30	0.66	0.25	0.14	13
2001	0.44	0.61	0.25	0.09	34
2004	0.33	0.64	0.25	0.12	17

Given the complexity of the model system the elasticities are calculated by running the NTM5 model system, and not by using the simplistic formulas above, reflecting the elasticities in a simple mode choice model. First the model is applied for the base situation, and thereafter with a marginal change (usually 10 %) in one of the variables. Geographically disaggregated elasticities are calculated by changing the variables of interest between geographical sub areas. The elasticities are then calculated using the following formula:

(6) $El_x = \ln(T^1/T^0)/\ln(X^1/X^0)$,

where (T^1/T^0) is the relative change in demand, and (X^1/X^0) is the relative change in the variable. When the geographical elasticities are calculated, the subscript "ij" (origin and destination sub group) is attached to X and T in the formula.

4.2 National elasticities

National elasticities are calculated for work related trips (business and long distance commuting trips paid by the firm), for private trips (all other trips), and for the average total. We have focused on price (fare and cost) elasticities for all modes, travel time elasticities for car, elasticities for departure frequency for scheduled modes, and income elasticities for all modes. All elasticities are calculated for the three base years 1998, 2001 and 2004. The two following figures show the national total marked shares for work related trips and for private trips by base year. Car trips dominate the market completely at the aggregate level, with the exception of work related trips by air. The changes in market shares shown in the figures will to some extent influence the elasticities presented in this section.

Figure 53 National market shares for work related trips (< 100 km) by base year (Markedsandeler for arbeidsrelaterte reiser etter årstall).

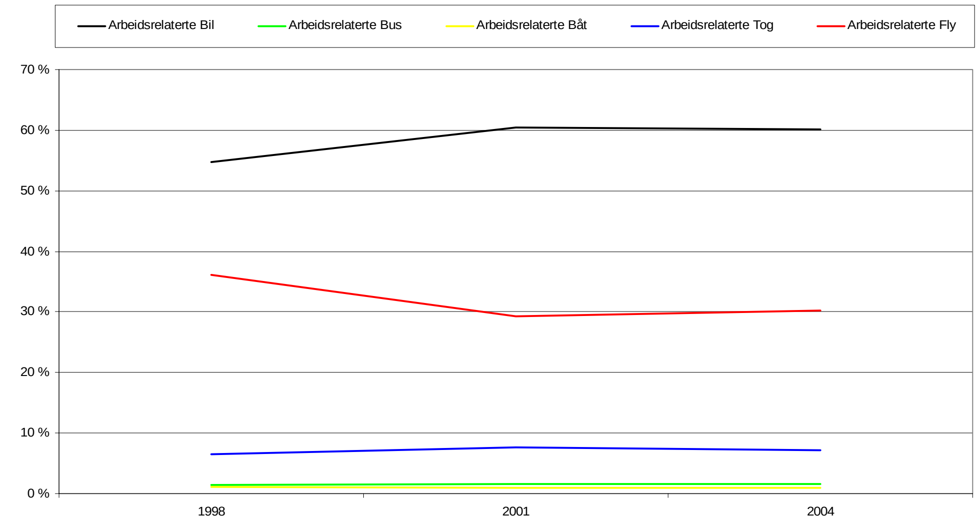


Figure 54 National market shares for private trips (< 100 km) by base year (Markedsandeler for private reiser etter årstall)

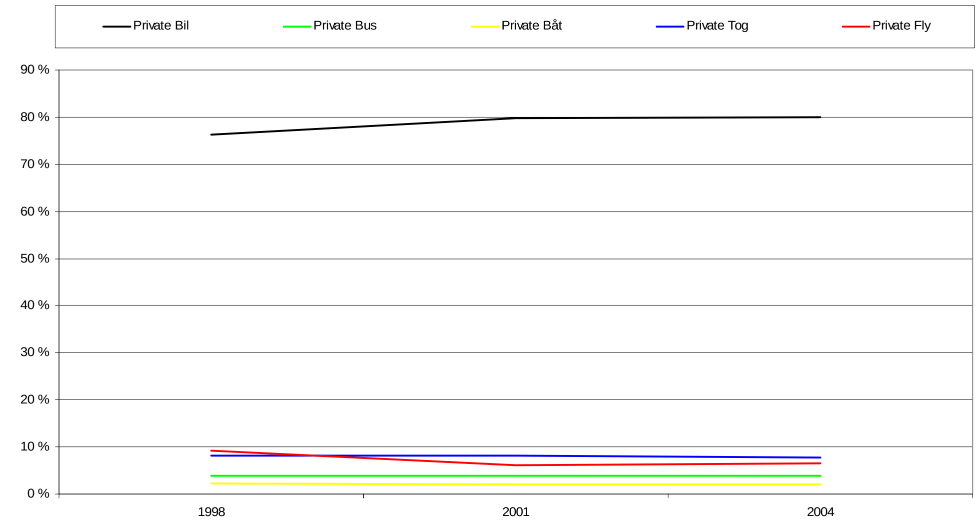
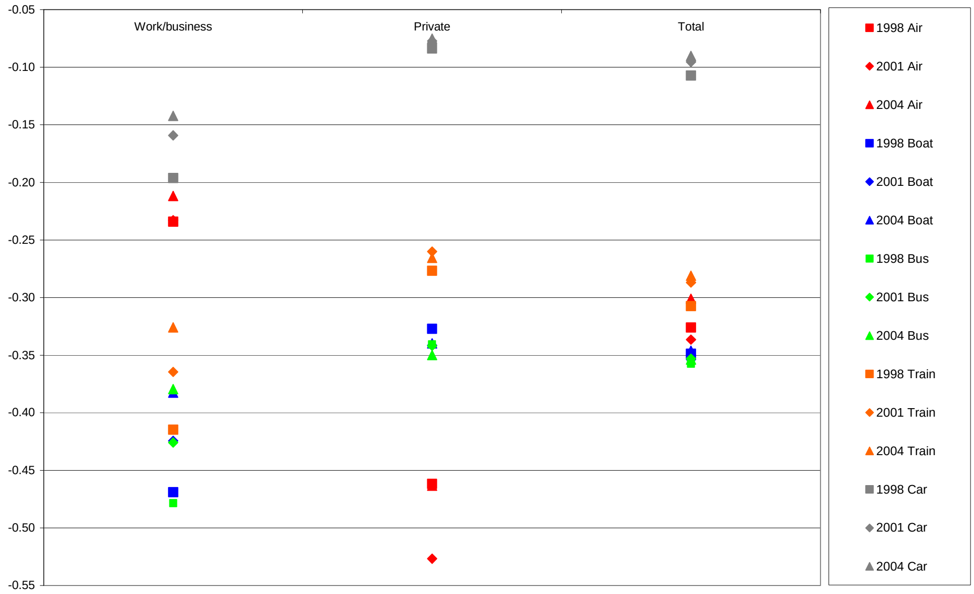


Figure 55 summarizes our findings when it comes to aggregated national elasticities for fares and driving cost (fuel costs for car). It is important to point out that these are average total elasticities, and as will be commented later, vary significantly at the geographical level. The reasons for these variations are geographical mode specific variations in level of service and in market shares, which plays a vital role in the elasticity formulas, as shown above.

The direct price elasticities for air (all purposes) are found to be -0.33 in 1998, -0.34 in 2001 and -0.30 in 2004. They are significantly lower for business trips than for private trips, which is natural when we consider the market share for travel by air for work related and private trips. It has been claimed that the elasticity for air travel in NTM5 are low in absolute values. In fact, the elasticity for private trips in NTM5 is higher than the similar elasticity in the Swedish sister model SAMPERS (Sika, 2005). For business trips the elasticity is much higher in SAMPERS than in NTM5. For the Norwegian situation, a lower elasticity for business travel than for private travel is in accordance with the theory (significantly higher market share for air for business trips than for private trips in Norway).

Figure 56 shows to which extent the national price elasticities for air travel vary by the geographical level (between the 19 counties of Norway). The elasticities in the figure are based on general price changes for the whole country, but the changes in demand are calculated in a 19 x 19 matrix level (i.e. 361 different elasticities). There is a large variation around the aggregated national total elasticities, reflecting the variation in price levels and market shares at the geographical level.

Figure 55 National direct price elasticities by travel purpose, mode and base year.



The national aggregated direct price elasticity for boat travel is -0.35 for all base years. Figure 55 shows that the elasticity for work related trips are higher (in absolute level) than for private trips. The national market share for travel by boat is 1 % for work related trips and 2 % for private trips. The national aggregate price elasticity for travel by boat however, does not give a representative picture of the models elasticity. This is because travel by boat is restricted to the areas in the country where boat is an available transport mode, along the western and northern coast line. The distribution of the elasticities between counties where the boat mode is available is shown in Figure 57. As we can see the national aggregated elasticity of -0.35 is on the lower side of the geographical ones. The mean value of the elasticities reported in the figure is -0.75.

Figure 56 The distribution of direct aggregated price elasticities for air travel between counties (19 x 19) by base year.

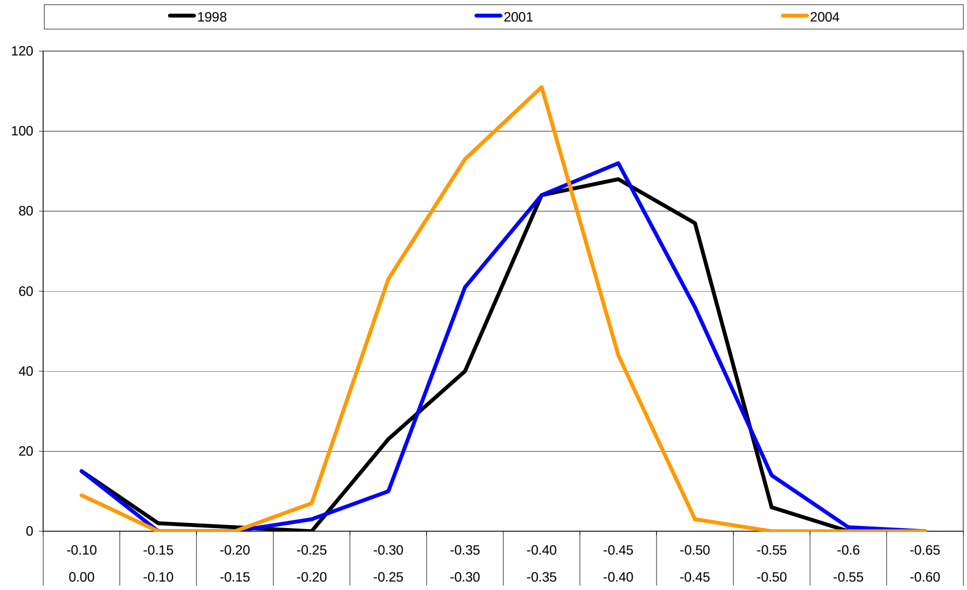
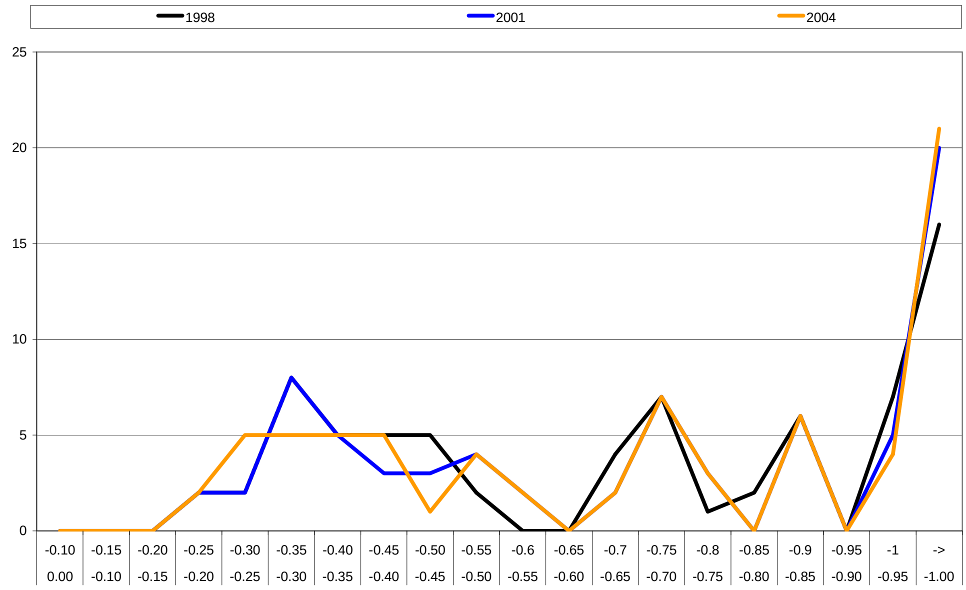


Figure 57 The distribution of direct aggregated price elasticities for travel by boat between counties located on the west and northern coast of Norway (9 x 9), by base year.



The national aggregated elasticity for travel by bus is -0.35. The elasticities for work related trips are lower (in absolute values) than those for private trips, mostly because of lower market share for work related trips (2 %) than for private trips (4 %). Figure 58 shows that there is a large geographical variation in the price elasticity for bus as well.

The national aggregate direct price elasticity for travel by train is -0.3. The distribution of the elasticities between counties is shown in Figure 59. The price elasticities for travel reflect the fuel cost component only (80 % of the total driving cost, except for toll and ferry cost). This aggregate elasticity is -0.1, and the work related elasticity is higher than the private one, partly because the market share for work related trips is lower for work related trips. The distri-butions of the price elasticity for long distance car travel are shown in Figure 60. Although the direct elasticities for travel by car are smaller in terms of absolute values, there is a large variation in these elasticities as well.

Figure 58 The distribution of direct aggregated price elasticities for travel by bus between counties (19 x 19), by base year.

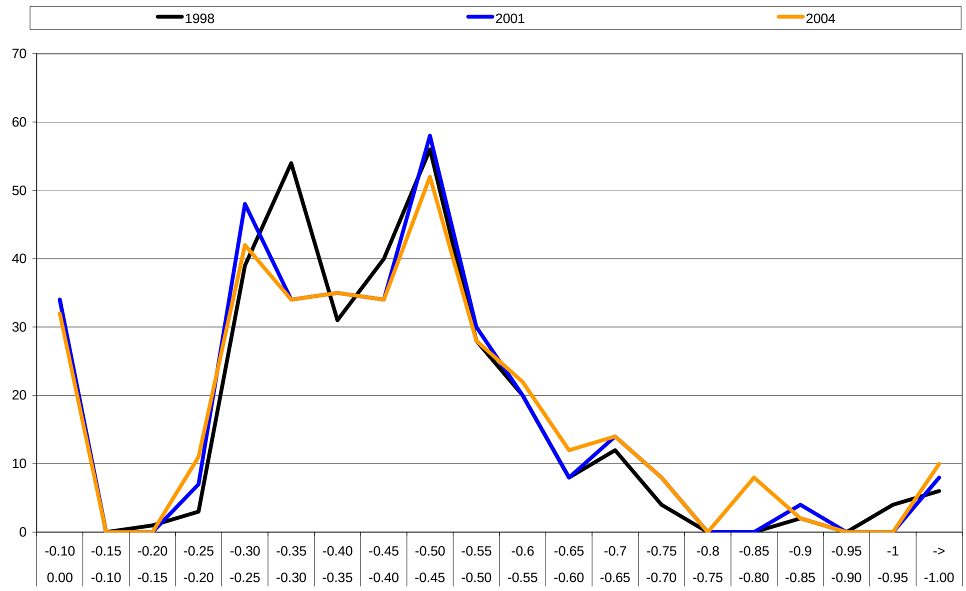


Figure 59 The distribution of direct aggregated price elasticities for travel by bus between counties (19 x19), by base year.

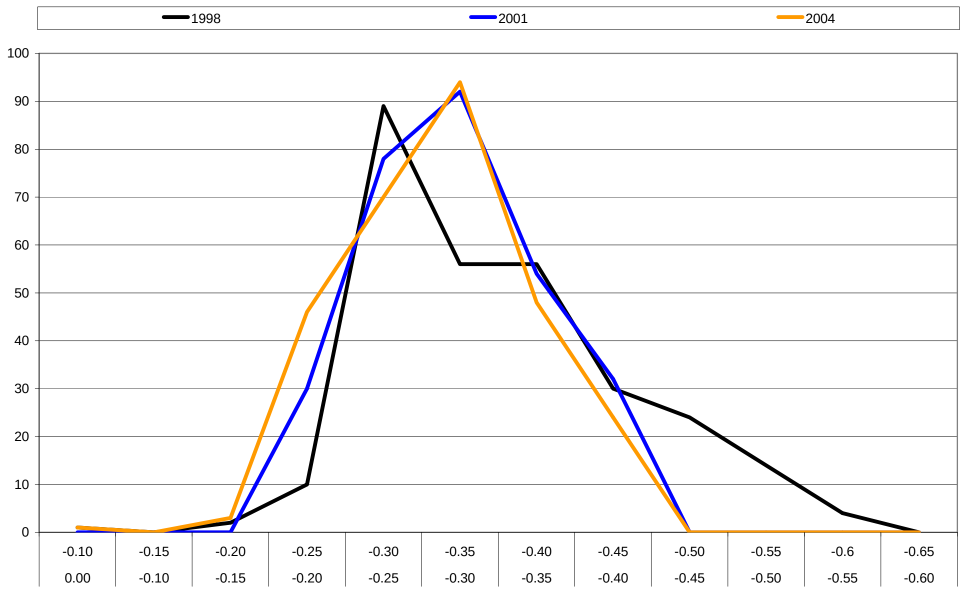
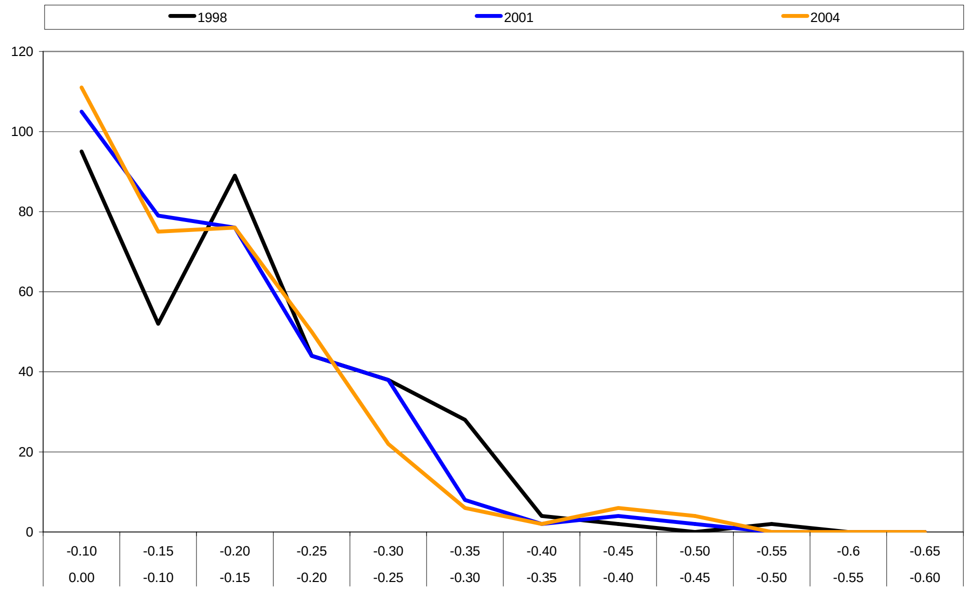
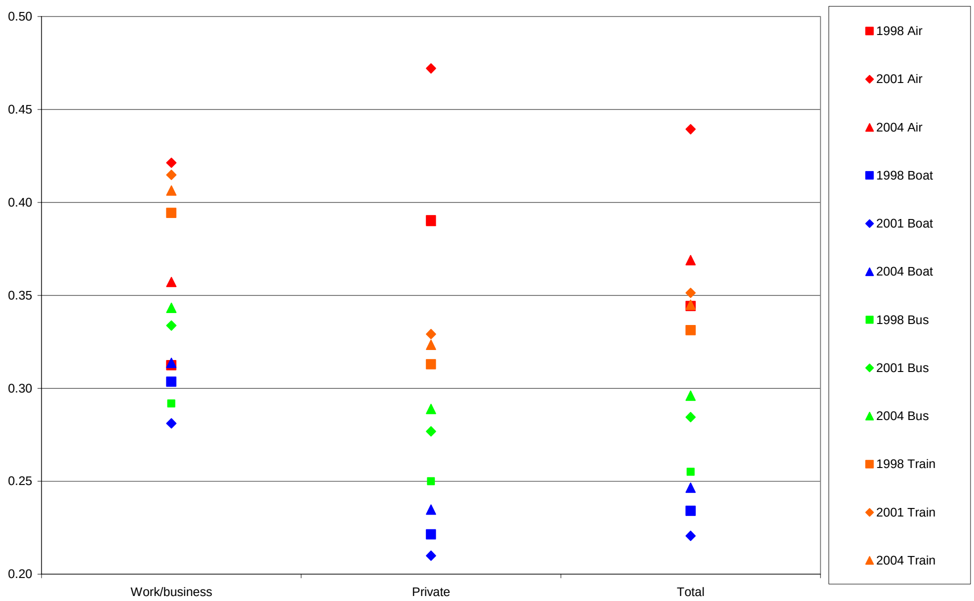


Figure 60 The distribution of direct aggregated price elasticities for travel by car between counties (19 x 19), by base year.



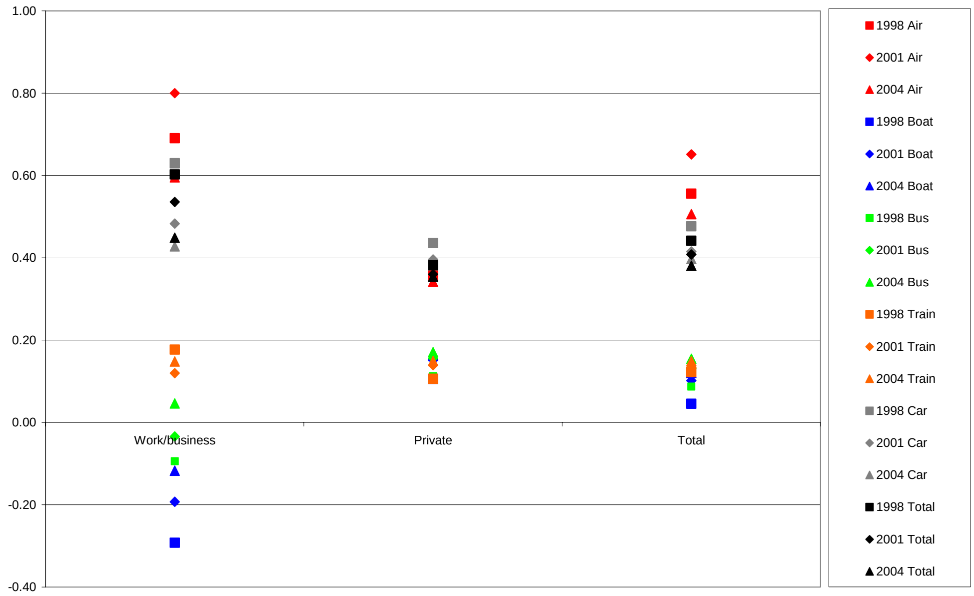
Departure frequency elasticities for the scheduled modes are shown in Figure 61. The elasticities seem to be higher for the most frequent modes and lower for the modes with lower departure frequencies. This is not a very realistic feature of the current version of NTM5, and it is due to the problems discussed in section 4.1. This can also be one of the reasons why the model on some of the airports give the opposite effect as compared to the observed volumes in the registrations of airport passenger volumes in 1998, 2001 and 2004. Correcting for this problem will give a far more reliable model system.

Figure 61 National direct departure frequency elasticities by travel purpose, mode, and base year.



The income elasticities presented in Figure 62 seems to be far more realistic than the elasticities of departure frequency. The overall total income elasticity declines as income increase, from 0.44 in 1998, to 0.41 in 2001 and 0.38 in 2004. In this period income in Norway has increased by 15 % in real prices.

Figure 62 National income elasticities by travel purpose, mode, and base year.



The income elasticities are higher for work related trips than for private trips, a questionable feature of the model. General changes in income hardly influences work related travel to any extent. The cashier in a convenient store, for instance, can hardly be assumed to conduct more business trips in 2004 than in 1998 because of increased income by 15 % in the period. Changes in private income however, can also indicate the changes in the level of activity (or growth) in business in general, so this effect is perhaps not so problematic after all.

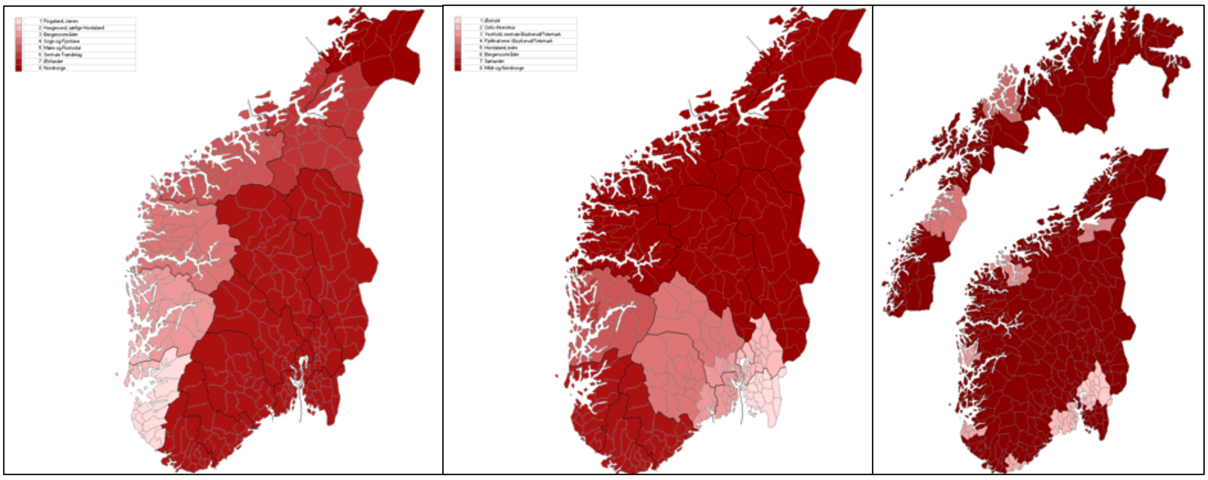
Most of the national aggregated elasticities presented in this section falls comfortably into the relatively wide range reported in different studies and models (Sika, 2005). The only questionable issues, as far as we can see, are connected to the logarithmic transformation of the cost variable (a quadratic transformation for instance, could give somewhat higher elasticities for costs components), and the formulation of departure frequency variable for scheduled modes where alternative formulations like the inverse departure frequency may give slightly more realistic elasticities and effects from changes.

4.3 Elasticities in transport corridors

As we have seen in the previous section, even elasticities reflecting general national changes in variables vary significantly in the geographical dimension. The source of this variation is related to the variation in mode specific level of service, and market shares. In this section we study elasticities that reflect more specific changes. To illustrate the extent of variation we have defined 2 different corridors, and one geographical division reflecting areas surrounding the largest airports in Norway. The geographical demarcations are illustrated in Figure 63. Elasticities are calculated to reflect changes between all the sub areas in each. There are 6 sub areas in each of the two corridors and 9 different airport areas.

Figure 63 Definition of geographical demarcations of corridors 1 and 2 and areas surrounding main airports in Norway.

Corridor 1, West Coast **Corridor 2, Central East - West** **Airport areas**

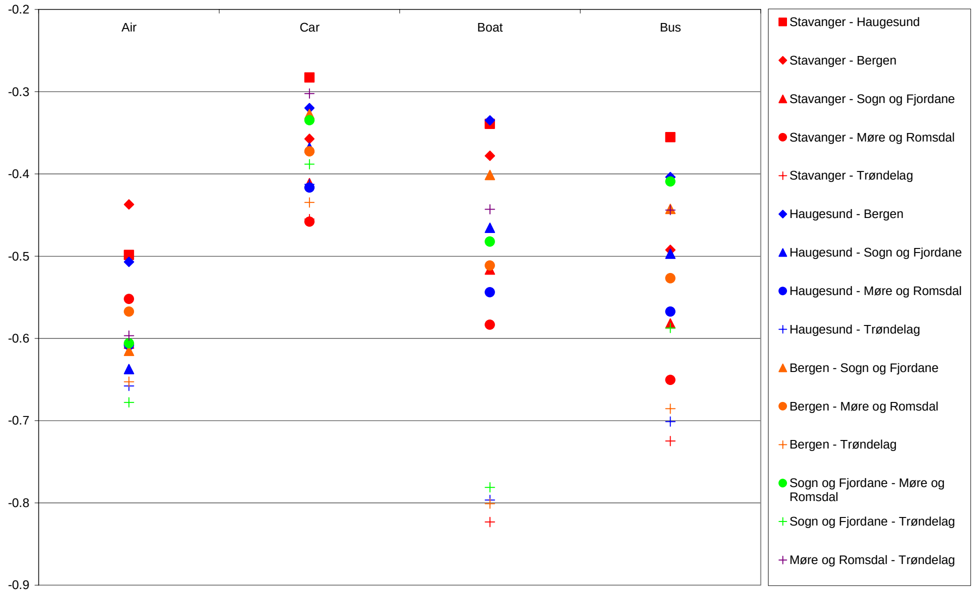


The elasticities in the corridors and between airport areas are calculated under the assumption that the variable is changed between pairs of geographical sub groups, one at the time, reflecting geographical changes in variables. One could, as an example, be interested in the isolated effect on demand of a change in airfare between Rogaland (Stavanger) and Trøndelag (Trondheim), leaving airfares in the rest of the country unaffected. This type of change can give completely different results on demand than overall national changes, as the affected population can adjust to the change by choosing other destinations.

Direct price elasticities in the first corridor (West Coast) are shown in Figure 64. The direct price elasticities for air vary between -0.4 and -0.7. The national elasticity was -0.34, with geographical variations from -0.2 to -0.6. It is mainly the effect from destination choice that makes the elasticities for specific changes in the corridor higher than the national elasticity even at a disaggregate level. Most of the elasticities for the boat mode in the corridor are also significant higher than the national price elasticity. The price elasticities travel between the most distance sub areas by boat are especially high (marked with the sign + in the figure). The same tendencies are found for travel by bus. The direct price elasticities increase by distance.

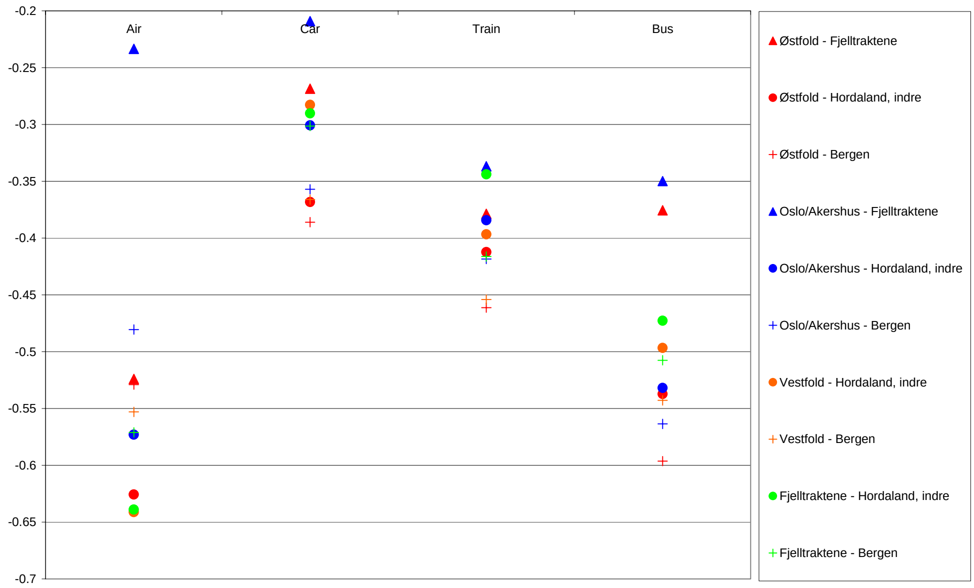
The price elasticities calculated for travel by car, reflects the change in total driving costs, and not just fuel costs as assumed in the calculations of the national elasticities. For car travel the elasticities in the corridor are not particular relevant, as it is difficult to change the costs between two particular geographical sub areas without changing them between other areas as well. The variation is however evident for car travel as well.

Figure 64 Price elasticities in corridor 1, West Coast, by mode and geographical sub group



The direct price elasticities in corridor 2 (Central East – West) are shown in Figure 65. The figure reflects some of the same tendencies as where observed in the previous figure. Except for the air mode, the highest elasticities are found for the longest trips (marked with the sign + in the figure).

Figure 65 Price elasticities in corridor 2, Central East - West, by mode and geographical sub group



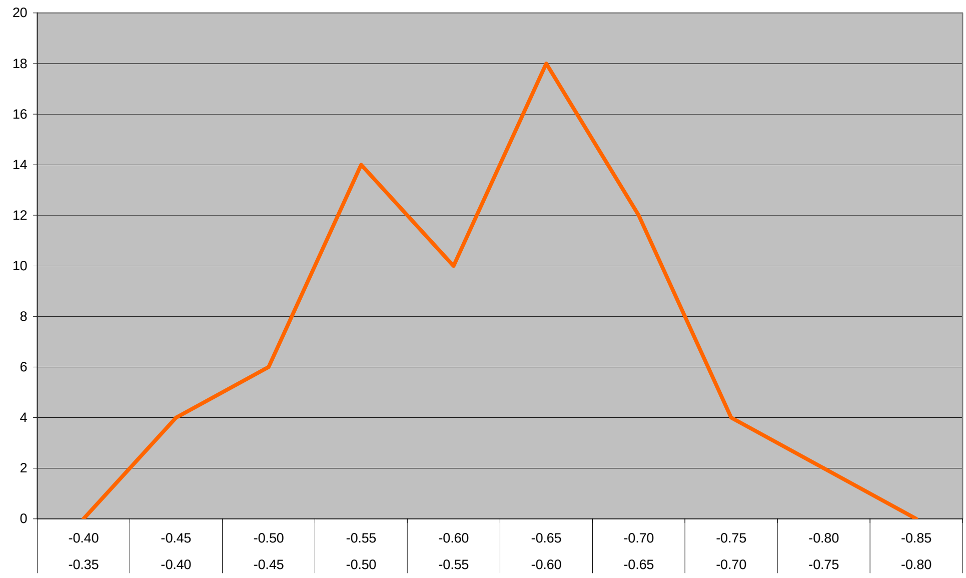
The direct elasticities for air travel between the 9 regions surrounding the main airports in Norway are shown in Table 15. As we can se, most of them are significantly higher in terms of absolute values than the national elasticity of -0.34. They reflect the change in demand (in percent) of air travel between a particular pair of airports of a 1 % change in price between the same airports only.

Table 15 Direct price elasticities for air travel between 9 main airports in Norway.

		1	2	3	4	5	6	7	8	9
1	Oslo			-0.53	-0.41	-0.48	-0.49	-0.51	-0.62	-0.52
2	Grenland/Vestfold			-0.59	-0.48	-0.55	-0.57	-0.61	-0.73	-0.68
3	Kristiansand	-0.53	-0.59		-0.53	-0.62	-0.63	-0.68	-0.76	-0.70
4	Nord - Jæren	-0.41	-0.48	-0.53		-0.43	-0.51	-0.56	-0.65	-0.53
5	Bergen	-0.48	-0.55	-0.62	-0.43		-0.53	-0.62	-0.70	-0.61
6	Ålesund	-0.49	-0.57	-0.63	-0.51	-0.53		-0.58	-0.69	-0.65
7	Trondheim	-0.51	-0.61	-0.68	-0.56	-0.62	-0.58		-0.70	-0.65
8	Bodø	-0.62	-0.73	-0.76	-0.65	-0.70	-0.69	-0.70		-0.67
9	Tromsø	-0.52	-0.68	-0.70	-0.53	-0.61	-0.65	-0.65	-0.67	

Figure 66 shows the frequency distribution of the elasticities in Table 15. As we se there are observations in the interval between -0.4 and -0.8, and the mean value is -0.6, which is close to 80 % higher than the national direct elasticity for air travel.

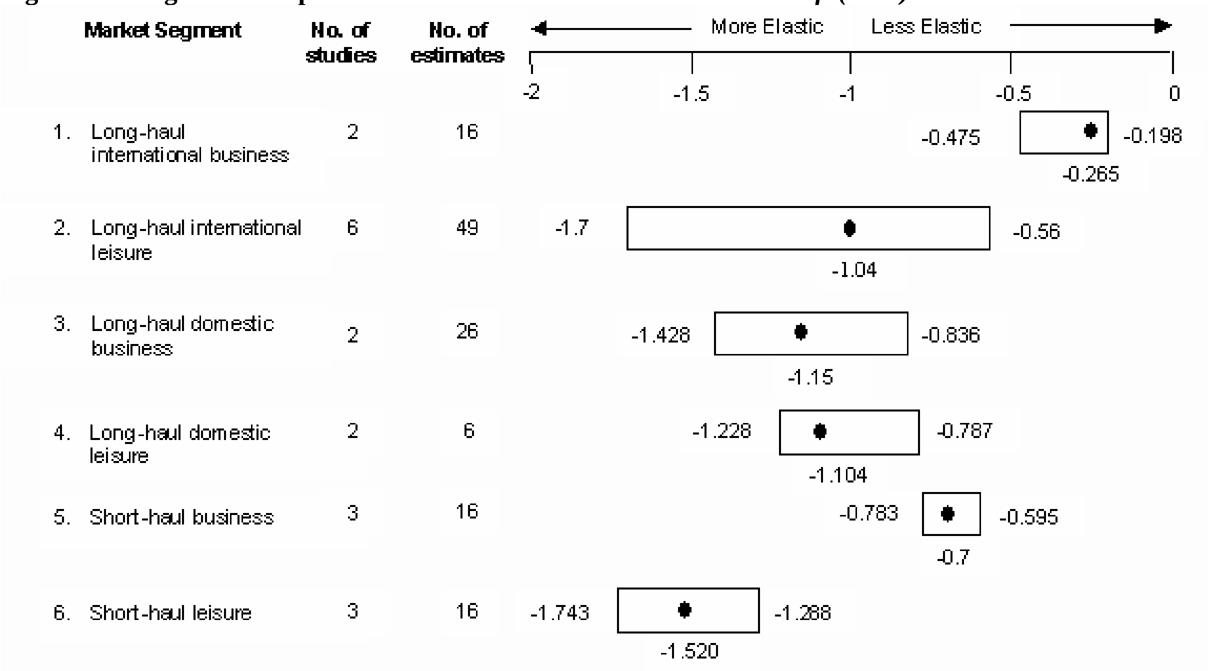
Figure 66 Frequency distribution of direct price elasticities for travel by air between main airports (N=9x9-9-2=70, y-axis)



The literature reports a wide range of elasticities. Most of the elasticities in the Swedish long distance transport model are quite similar to the elasticities in NTM5 (SIKA, 2005). Njegovan (2006) reports elasticities for air travel within a relatively wide range. Dargay and Hanly (2001) estimated a price elasticity for air travel of -0.6 for UK tourism abroad on a time series from 1989-1998. Njegovan (2006) finds a elasticity for the same market segment of -0.7 on a time series from 1993-2003.

One of the most referenced studies is Gillen et al (2003), reporting results form 21 different studies of price elasticities in different segments of the aviation market, mainly based on time series. This study is also the main source of information in EC (2005) which deals with the consequences of taxation of fuel in the EEA-area. Figure 67summarizes the findings of Gillen et al (2003).

Figure 67 Range of direct price elasticities in aviation. ***Source: Gillen m fl (2003).***



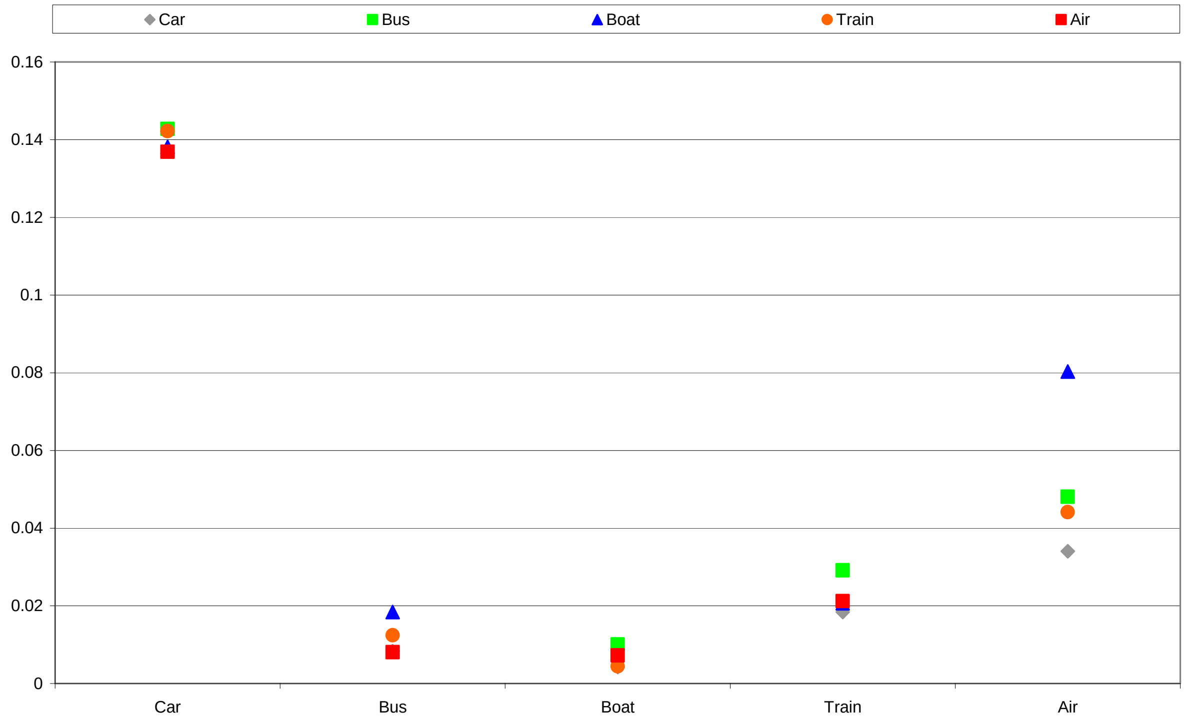
Even though the range of variation is quite wide, it seems that the direct elasticities reported in Gillen are higher than the corresponding elasticities calculated from NTM5 for the market segments covered by the model (segment 5 and 6). Short-haul business trips (a substantial share of the Norwegian domestic market) have a median of -0.7. Short-haul leisure trips in this have a median of -1.5. A Norwegian study (Helgheim 2002) find direct price elasticities between -0.6 og -1.0, with one of the leisure segments as high as -1.4. This study covered the markets Molde-Oslo and Kristiansund-Oslo.

It is important to point out that all the studies referred above are based on time series data, while NTM5 and Sampers are based on cross sectional data. The elasticities derived from these two methodologies are based on quite separate "mechanisms". In time series data the variation over time gives the estimates, while the individual variation, the geographical variation and variation between modes gives the estimates in cross sectional data used to estimate the model systems. Most of the studies referred above also reflect the situation in other countries where income and the market conditions might be quite different from the situation in Norway.

4.4 Cross elasticities

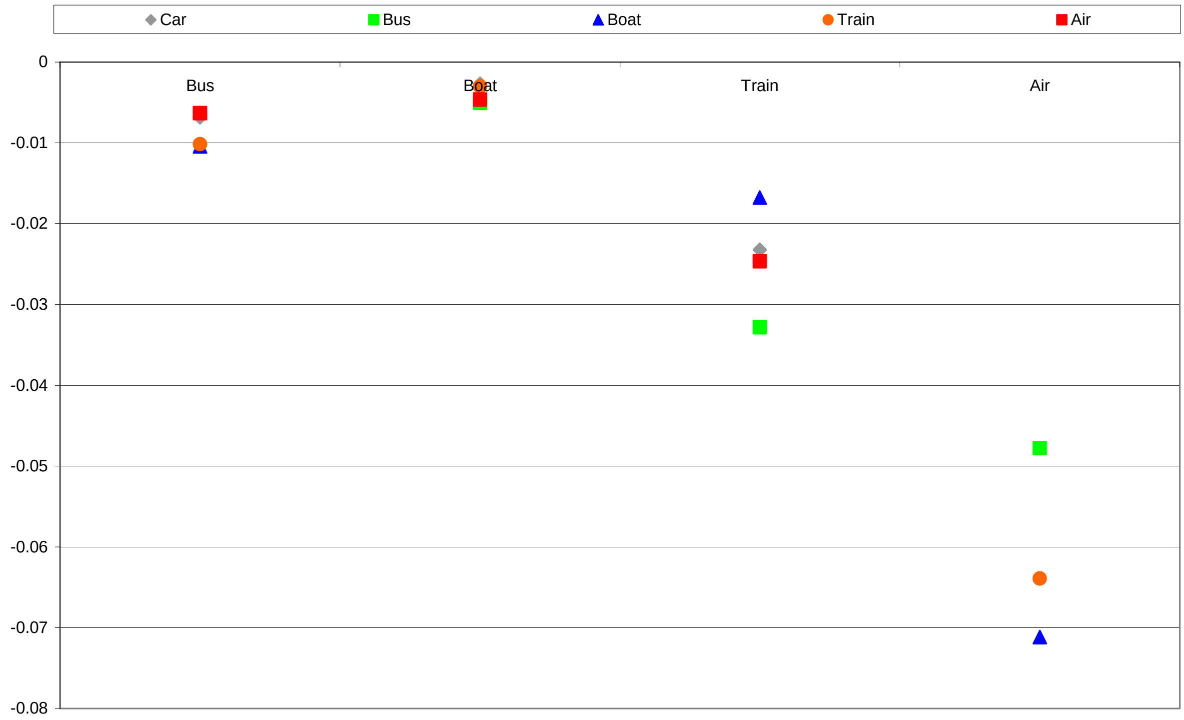
The cross elasticities give the effect of a change in a variable for one mode on the demand for all the other modes included in the context. Figure 68 and Figure 69 shows the levels of these elasticities in NTM5 at the national aggregated level for changes in price and departure frequencies. Changes in travel costs for car give the highest cross elasticities for the other modes (0.14). The high cross elasticities for changes in car costs is due to the fact that car is the dominant transport mode for long distance travel in Norway. When it comes to changes in travel cost for bus and boat, the highest cross elasticity can be observed for boat and bus respectively. The elasticities are however quite low, partly because of a low market share for these modes at the national level. Changes in travel costs for travel by train influences travel by bus to the largest degree (0.03). Changes in travel costs for travel by air have the largest effect on the demand for travel by boat. This is perhaps quite surprisingly as we are studying the national aggregated level. One of the reasons can be that the long distance boat mode in Norway operates in areas where air traffic is the dominant mode of transport (Bergen – Stavanger, and at the coast of northern Norway). When it comes to changes in travel costs the cross elasticities for air is significantly higher than they are for the other scheduled modes.

Figure 68 Cross elasticities for price at the overall national aggregated level



The same tendency can be observed for changes in departure frequencies at the national level. The demand for travel boat are mostly influenced by changes in departure frequency for air, and the demand for travel by bus are influenced by changes in departure frequency for air and train. The demand for travel by train is also influenced by changes in departure frequency for air. The absolute level of the cross elasticities for both travel costs and departure frequency are however quite low, but similar to the level reported from other model systems, like the Sampers model in Sweden (SIKA 2005).

Figure 69 Cross elasticities for departure frequencies at the overall national aggregated level



Cross elasticities are also calculated in the two transport corridors studied in this project. The area covered by each of the corridors is divided into 6 sub areas, and the elasticities are calculated by changing the variable between each pair of sub area sequentially. These calculations thus also give effects on destination choice. If the price for the air mode is changed, say increased, between Trondheim and Bergen, the variable in question has the same level as before between Trondheim and Stavanger. The traffic by air can therefore be reduced between Trondheim and Bergen chances are that the traffic will be observed to increase on other important airport pairs, such as Trondheim – Stavanger. This means that the cross elasticities can be expected to be lower in the calculations for the corridors, which indeed is the case as can be observed in the four following tables. The tables below (Table 16, Table 17, Table 18 and Table 19) shows the number of zone (sub area) pairs (N) in the corridor, the number of zone pairs with a cross elasticity greater than zero (N>0), the maximum, minimum and average value of the cross elasticity, and the standard deviation of the different cross elasticities.

Table 16 Cross elasticities for price in corridor 1, West Coast

Price change for:	Effect on:	N	N>0	Max	Min	Ave	STD
Air	Car	30	30	0.032	0.001	0.006	0.008
Air	Boat	30	28	0.030	0.000	0.006	0.007
Air	Bus	30	20	0.023	0.000	0.005	0.006
Car	Air	30	28	0.104	0.000	0.018	0.029
Car	Boat	30	24	0.040	0.000	0.012	0.014
Car	Bus	30	20	0.023	0.000	0.005	0.006
Boat	Air	30	26	0.012	0.000	0.003	0.004
Boat	Car	30	24	0.008	0.000	0.002	0.003
Boat	Bus	30	18	0.023	0.000	0.005	0.007
Bus	Air	30	22	0.005	0.000	0.001	0.002
Bus	Car	30	22	0.004	0.000	0.001	0.001
Bus	Boat	30	22	0.006	0.000	0.002	0.002

Table 17 Cross elasticities for price in corridor 2, Central East - West

Price change for:	Effect on:	N	N>0	Max	Min	Ave	STD
Air	Car	20	20	0.016	0.000	0.003	0.005
Air	Train	20	16	0.021	0.000	0.005	0.006
Air	Bus	20	14	0.016	0.000	0.003	0.005
Car	Air	20	12	0.068	0.000	0.010	0.021
Car	Train	20	20	0.044	0.002	0.011	0.012
Car	Bus	20	18	0.035	0.000	0.009	0.010
Train	Air	20	14	0.014	0.000	0.003	0.004
Train	Car	20	20	0.005	0.000	0.002	0.002
Train	Bus	20	16	0.008	0.000	0.003	0.002
Bus	Air	20	12	0.004	0.000	0.001	0.001
Bus	Car	20	20	0.002	0.000	0.001	0.001
Bus	Train	20	18	0.004	0.000	0.001	0.001

Table 18 Cross elasticities for departure frequency in corridor 1, West Coast

Change in # of departures for:	Effect on:	N	N>0	Max	Min	Ave	STD
Air	Car	30	26	-0.037	0.000	-0.004	-0.009
Air	Boat	30	24	-0.027	0.000	-0.003	-0.006
Air	Bus	30	18	-0.021	0.000	-0.002	-0.005
Boat	Air	n/a	n/a	n/a	n/a	n/a	n/a
Boat	Car	n/a	n/a	n/a	n/a	n/a	n/a
Boat	Bus	n/a	n/a	n/a	n/a	n/a	n/a
Bus	Air	30	16	-0.002	0.000	0.000	-0.001
Bus	Car	30	18	-0.001	0.000	0.000	0.000
Bus	Boat	30	14	-0.002	0.000	-0.001	-0.001

Table 19 Cross elasticities for departure frequency in corridor 2, Central East - West

Change in # of departures for:	Effect on:	N	N>0	Max	Min	Ave	STD
Air	Car	20	20	-0.020	0.000	-0.003	-0.006
Air	Train	20	16	-0.020	0.000	-0.004	-0.006
Air	Bus	20	10	-0.012	0.000	-0.002	-0.004
Train	Air	20	14	-0.014	0.000	-0.003	-0.004
Train	Car	20	20	-0.002	0.000	-0.001	-0.001
Train	Bus	20	12	-0.004	0.000	-0.001	-0.001
Bus	Air	20	8	-0.001	0.000	0.000	0.000
Bus	Car	20	16	-0.001	0.000	0.000	0.000
Bus	Train	20	14	-0.002	0.000	0.000	-0.001

When the cross elasticities in the tables are compared with the corresponding national aggregated cross elasticities in Figure 68 and Figure 69, we find that the aggregated cross elasticities are significantly larger than the ones calculated for the transport corridors. To explain this result further we will have to dive into the details of the effects summarized in the tables. As an example we will study the effect of changing the price for the air mode between Stavanger and Bergen (zone 1 and 3 in the west coast corridor).

Table 20 shows the direct elasticities for air transport as a result of a change in the price by air between Stavanger and Bergen. The direct elasticity is -0.437. The table shows however that there are smaller elasticities with an opposite sign between the two areas and all of the other areas defined in the corridor. These elasticities must be interpreted as cross elasticities with respect to destination choice for the air mode of travel. We can observe that the highest destination choice cross elasticity is 0.047, between Bergen and East Norway (including Oslo), and between Bergen and the north of Rogaland (Haugesund).

Table 21, Table 22 and Table 23 shows the cross elasticities for travel by other modes by a change in airfares between Stavanger and Bergen. We observe that all of these elasticities are lower in absolute values than the highest elasticity for destination choice for air. These results imply to some extent that when changes in the level of service for various reasons are planned and implemented at a local level, the different transport sectors (i.e. aviation, sea transport, bus transport and train transport), in some situations will be their own largest competitor. In NTM5 we observe these types of effects for all the five transport modes, but to a varying extent (indicated by the difference between the cross elasticities in the four previous and their corresponding national aggregated cross elasticity). It is not easy to verify the extent of these results.

Table 20 Direct elasticity for price by air between zone 1 and 3 (Stavanger – Bergen), cross elasticities with respect to other destinations.

		1	2	3	4	5	6	7	8
1	***Stavanger, Jæren and inner Rogaland***		***0.014***	***-0.437***	***0.016***	***0.014***	***0.015***	***0.029***	***0.005***
2	North Rogaland and south Hordaland	**0.014**		**0.047**	0.000	0.000	0.000	0.000	0.000
3	***Bergen, north of Hordaland***	**-0.437**	***0.047***		***0.027***	***0.027***	***0.032***	***0.047***	***0.008***
4	Sogn og Fjordane county	**0.016**	0.000	**0.027**		0.000	0.000	0.000	0.000
5	Møre og Romsdal county	**0.014**	0.000	**0.027**	0.000		0.000	0.000	0.000
6	Trøndelag counties	**0.015**	0.000	**0.032**	0.000	0.000		0.000	0.000
7	Eastern Norway	**0.029**	0.000	**0.047**	0.000	0.000	0.000		0.000
8	Northern Norway	**0.005**	0.000	**0.008**	0.000	0.000	0.000	0.000	

Table 21 Cross elasticities for price by air between zone 1 and 3 (Stavanger – Bergen), with respect to travel by car.

		1	2	3	4	5	6	7	8
1	***Stavanger, Jæren and inner Rogaland***		**0.009**	**0.032**	**0.006**	**0.004**	**0.005**	**0.009**	**0.004**
2	North Rogaland and South Hordaland	**0.009**		**0.012**	0.000	0.000	0.000	0.000	0.000
3	***Bergen, North of Hordaland***	**0.032**	**0.012**		**0.008**	**0.006**	**0.006**	**0.010**	**0.002**
4	Sogn og Fjordane county	**0.006**	0.000	**0.008**		0.000	0.000	0.000	0.000
5	Møre og Romsdal county	**0.004**	0.000	**0.006**	0.000		0.000	0.000	0.000
6	Trøndelag counties	**0.005**	0.000	**0.006**	0.000	0.000		0.000	0.000
7	Eastern Norway	**0.009**	0.000	**0.010**	0.000	0.000	0.000		0.000
8	Northern Norway	**0.004**	0.000	**0.002**	0.000	0.000	0.000	0.000	

Table 22 Cross elasticities for price by air between zone 1 and 3 (Stavanger – Bergen), with respect to travel by boat.

		1	2	3	4	5	6	7	8
1	***Stavanger, Jæren and inner Rogaland***		**0.011**	**0.030**	**0.008**	**0.006**	**0.007**	**0.017**	**0.000**
2	North Rogaland and South Hordaland	**0.011**		**0.013**	0.000	0.000	0.000	0.000	0.000
3	***Bergen, North of Hordaland***	**0.030**	**0.013**		**0.008**	**0.006**	**0.006**	**0.006**	**0.005**
4	Sogn og Fjordane county	**0.008**	0.000	**0.008**		0.000	0.000	0.000	0.000
5	Møre og Romsdal county	**0.006**	0.000	**0.006**	0.000		0.000	0.000	0.000
6	Trøndelag counties	**0.007**	0.000	**0.006**	0.000	0.000		0.000	0.000
7	Eastern Norway	**0.017**	0.000	**0.006**	0.000	0.000	0.000		0.000
8	Northern Norway	**0.000**	0.000	**0.005**	0.000	0.000	0.000	0.000	

Table 23 Cross elasticities for price by air between zone 1 and 3 (Stavanger – Bergen), with respect to travel by bus.

		1	2	3	4	5	6	7	8
1	***Stavanger, Jæren and inner Rogaland***		**0.013**	**0.023**	**0.008**	**0.008**	**0.006**	**0.011**	**0.000**
2	North Rogaland and South Hordaland	**0.013**		**0.011**	0.000	0.000	0.000	0.000	0.000
3	***Bergen, North of Hordaland***	**0.023**	**0.011**		**0.009**	**0.008**	**0.009**	**0.007**	**0.000**
4	Sogn og Fjordane county	**0.008**	0.000	**0.009**		0.000	0.000	0.000	0.000
5	Møre og Romsdal county	**0.008**	0.000	**0.008**	0.000		0.000	0.000	0.000
6	Trøndelag counties	**0.006**	0.000	**0.009**	0.000	0.000		0.000	0.000
7	Eastern Norway	**0.011**	0.000	**0.007**	0.000	0.000	0.000		0.000
8	Northern Norway	**0.000**	0.000	**0.000**	0.000	0.000	0.000	0.000	

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