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ECONOMIC IMPACT ASSESSMENT OF THE NEW ICAO STANDARD FOR CONTAMINATED RUNWAYS

A case study of four Norwegian airports

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SHORT SUMMARY

This is a summary of a case study of four Norwegian airports that are likely to be exposed to the impacts of ICAO State letter AN 4/1.2.26-16/19 regulations of minimum friction on contaminated runways, in terms of reduced regularity. The report assesses the economic effects for passengers and operators, in terms of additional costs. The new ICAO standard is suggested to maintain the existing high level of safety within aviation. This study does not discuss any economic benefits from imposing the new standard.

The study assesses five scenarios: Scenario P1 and P2 assess an increase in airfares of 20 % and 50% respectively and the use of smaller aircraft to maintain regularity on today's level. Scenario P3 deals with a winter (November–March) closure of the airports and transfer of traffic to nearest airport, whereas scenario P4 and U1 deal with planned or unforeseen transfers of *affected flights* to the nearest airport, respectively.

The economic costs turn out to be significant, particularly in cases where reduced regularity happens without notice and where there are long travel distances to the nearest alternative airport. Unforeseen cancellations or transfers to the nearest relevant airport give the highest economic costs per passenger, spanning from NOK 750 to NOK 5000 per return flight, depending on the airport and destination in question.

If scenario U1 is generalized to comprise all *affected flights* (around 500 landings in the regional and around 3,800 landings in the local airport network during an average winter season), we get an estimate of NOK 400-450 million per year for the passenger costs only. This aggregated estimate may be on the higher side due to the fact that we have not been able to isolate the landings where the flight is on time, but with a reduced number of passengers.

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PREFACE

This report contains an economic impact assessment of implementing ICAO State letter AN 4/1.2.26-16/19 regulations of minimum friction on contaminated runways. In particular, the report deals with the economic costs of reduced regularity for the passengers. It also indicates the effects for the airlines. The impacts for the airport operator, Avinor, are not assessed here.

The work has been undertaken in February-March 2018. Karoline L. Hoff, Lage Lyche, Hilde J. Svendsen and Svein Bråthen (project leader), Møreforsking Molde AS has been the project team.

The Client has been Avinor AS, Division for Strategic Affairs. The Senior Advisors Jon I. Lian and Hans J. Bugge, Avinor has been the Client's contact persons.

Associate Professor Alex Klein-Paste, NTNU, department for Civil and Environmental Engineering has carried out the assessment of the new standard on the number of affected landings on Norwegian airports, as a basis for quantifying the number of aircraft movements and passengers affected. Senior Advisor Lars Draagen, Avinor has provided information about the number of passengers affected by reduced payloads on affected landings.

We would like to thank Director of Strategic Affairs Terje Skram, Widerøes Flyveselskap, and Captain (B-737) Stig Patey, Manager, Flight Support, Documentation and Fuel Savings, Norwegian for valuable information about flight operations.

The views and conclusions are the authors' sole responsibility.

Molde, 28 March 2018

The authors

CONTENT

SUMMARY

ICAO State letter AN 4/1.2.26-16/19 regulations of minimum friction on contaminated runways are likely to affect aircraft operations under specific weather conditions. Without any countermeasures, this may entail a larger number of cancelled or diverted flights because of reduced aircraft maximum landing weight (MLW). The severity of delays and cancellations will depend upon the weather conditions (in terms of duration and severity) and the affected traffic volumes.

This case study will assess the consequences of lower allowed friction coefficients for four Norwegian airports severely exposed to snow and ice, with particular attention towards the costs of reduced regularity for the passengers. The new ICAO standard is suggested to maintain the existing high level of safety within aviation. This study does not discuss any economic benefits from imposing the new standard.

The four airports are (percentage and number of affected landings during a normal winter season November-March in brackets):

- Kirkenes (KKN), regional airport, 2055 m runway. (34.0%, 108 landings)
- Alta (ALF), regional airport, 2177 m runway. (6.1%, 19 landings)
- Vadsø (VDS), local airport, 870 m runway (19.4%, 75 landings)
- Honningsvåg airport (HVG), 860 m runway (15.7%, 197 landings)

The data does not allow for any differentiation between the types of possible actions for the affected landings. These actions could span from reduced MLW in terms of reduced passengers and/or luggage, cancellation or diversion to an adjacent airport. In some cases, the number of affected landings could give a regularity of much less than 90 %. This is likely to cause a seasonal closure of the airport or use of smaller aircraft where practically possible. Because of the available data, we have assessed the following scenarios for airports with expected regularity of less than 90%, for all affected landings:

- Scenario P1: The airport remains open during winter, but with smaller aircraft that can serve under the new ICAO friction regulations. 20% fare increase.
- Scenario P2: As scenario P1, but with 50% fare increase.
- Scenario P3: The airport is closed during winter[1], and all traffic is transferred to the nearest relevant airport, i.e. an airport can serve today's types of aircraft
- Scenario P4: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations are published well ahead.
- Scenario U1: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations occur without notice.

We have calculated the increased costs per passenger. This information can be used if more disaggregated data on possible actions becomes available.

Table A.1 summarizes the main findings.

[1] The "closure" affects only the routes that are highly likely to become affected by the new ICAO regulations. Routes served by aircraft that are unaffected by these regulations at the actual airport are not included in the study.

Table A.1 Main findings, economic impacts, 5 scenarios (in millions NOK)

Scenario	Airport			
	KKN	ALF	HVG	VDS
Scenario P1: The airport remains open during winter, but with smaller aircraft that can serve under the new ICAO friction regulations. 20% fare increase.				
Costs for passengers	-18.0	-25.1	-1.0	-4.9
Revenue loss(-) or gain, airlines	11.4	15.5	0.6	3.3
Operating costs, airlines (reduced (+) or increased)	-16.0	-15.8	-2.4	-8.5
SUM economic effects	-22.6	-25.4	-2.8	-10.1
Scenario P2: As scenario P1, but with 50% fare increase.				
Costs for passengers	-42.7	-59.5	-2.3	-11.8
Revenue loss(-) or gain, airlines	24.2	32.3	1.2	7.2
Operating costs, airlines (reduced (+) or increased)	-16.0	-15.8	-2.4	-8.5
SUM economic effects	-34.5	-43.0	-3.5	-13.1
Scenario P3: The airport is closed during winter, and all traffic is transferred to the nearest relevant airport, i.e. an airport can serve today’s types of aircraft				
Costs for passengers	-89.1	-76.0	-4.1	-9.5
Revenue loss(-) or gain, airlines	-37.1	-30.1	-1.6	-2.3
Operating costs, airlines (reduced (+) or increased)	4.7	-2.3	-0.5	-7.1
SUM economic effects	-121.4	-108.4	-6.2	-19.5
Scenario P4: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations are published well ahead.				
Costs for passengers	-30.3	-4.5	-0.8	-1.5
Revenue loss(-) or gain, airlines	-12.6	-1.8	-0.3	-0.5
Operating costs, airlines (reduced (+) or increased)	1.5	-0.1	0.5	-1.1
SUM economic effects	-41.4	-6.4	-0.6	-3.1
Scenario U1: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations occur without notice.				
Costs for passengers	-57.2	-10.9	-2.1	-6.4
Revenue loss(-) or gain, airlines	-3.6	-0.1	-0.1	-0.2
Operating costs, airlines (reduced (+) or increased)	-5.0	-0.7	-1.5	-3.9
SUM economic effects	-65.8	-11.7	-3.7	-10.5

The orange/yellow-marked scenarios P3 and U1 appear to be the most relevant ones. P3 (winter closure and transfer to an adjacent airport) seems relevant because the regularity will either end close to 90% (Alta) or even way below (the three others). This raises the question of whether the winter services will remain sustainable under the new regulations. U1 (unexpected delays for the affected passengers) is the situation that the passengers and airlines normally face in cases of disrupted services. The passengers face additional waiting time and shuttle costs as well as inconveniences connected to their planned activities. The airlines face additional flight time and holding costs. The economic impacts of these scenarios are clearly the highest both in total and per passenger.

The other scenarios are included to show e.g. possible impacts of using smaller aircraft. These scenarios (P1 and P2) are likely to cause significant alterations in the market structure on the supply side. The results indicate that there is a potential for a better match between the size of the market and the capacity offered, but a thorough assessment of operational changes is beyond the scope of this study.

Please note that the aggregated effects will be smaller if the planned aircraft movements take place, but with reduced payload. This means that lesser passengers will become affected. Therefore, we recommend to using the costs per passenger as the most reliable estimates, and consider the aggregated passenger costs in Table A.1 as upper estimates.

Table A.2 shows the costs per passenger and the share of deterred traffic per scenario.

Table A.2 Costs per passenger in NOK per one-way trip, and share of deterred traffic (in %).

Differences in passengers' cost from today's services, per passenger, one way. **Costs for all affected passengers (*ex ante*) in bold,** *remaining travelling passengers (ex post) in Italics* (% deterred passengers from the affected flights)	**KKN**	**ALF**	**HVG**	**VDS**
P1	**276**/*281* (7%)	**276**/*286* (7%)	**157**/*190* (5%)	**177**/*193* (5%)
P2	**647**/*703* (16%)	**655**/*715* (17%)	**392**/*450* (12%)	**443**/*463* (12%)
P3	**1,350**/*1,741* (39%)	**837**/*972* (23%)	**816**/*822* (23%)	**363**/*371* (9%)
P4	**1,352**/*1,741* (39%)	**833**/*972* (23%)	**816**/*821* (23%)	**363**/*371* (9%)
U1	**2,554**/*2,798* *(12%)*	**2,019**/*2,126* (8%)	**1,926**/*2,178* (8%)	**1,556**/*1,561* (5%)

Scenario U1 has much lower traffic deterrence than the comparable scenario P4 (a hypothetical but not very realistic situation where the delays could be announced well in advance). The reason is that we have used a much lower demand elasticity of -0.2 for U1 as compared to -0.8 for the others. In scenario U1 many trips will have already started (e g. the affected return trips) and hence the passengers are less sensitive because they on average are likely to be significantly more reluctant to cancelling their trip. The common denominator for the "P" scenarios is that the passengers are informed in advance about delays, cancellations and/or diversions and hence they will on average have much more flexibility.

Table A.2 shows that the passenger inconveniences are potentially high. Passengers at Kirkenes in particular, with a long shuttle distance to the alternative airport in Lakselv (Figure 1.1), gets more than NOK 5,000 in extra costs for a return trip if diversions on short notice occur. Even those with only around 70 kilometers to the nearest alternative airport get additional costs of around NOK 3,000 for a return trip under such conditions. For a planned diversion (P3) the costs are between approximately NOK 750 and NOK 2,700, respectively.

If we generalize scenario U1 to comprise all affected landings (around 500 landings in the regional and around 3,800 landings in the local airport network during an average winter season), we get an estimate of NOK 400-450 million per year for the passenger costs only. This aggregated estimate may be on the higher side due to the fact that we have not been able to isolate the landings where the flight is on time, but with a reduced number of passengers.

The rest of the report is structured as follows: Section 1 gives an introduction, whereas Section 2 presents the method for assessing the passengers' costs. Section 3 describes the scenarios. Section 4 discusses data, assumptions and uncertainties. Section 5 presents briefly the airline cost model. Section 6 and 7 give aggregated and detailed results, respectively.

1 INTRODUCTION

ICAO State letter AN 4/1.2.26-16/19 regulations of minimum friction on contaminated runways are likely to affect aircraft operations under specific weather conditions. Without any countermeasures, this may entail a larger number of cancelled or diverted flights because of reduced aircraft maximum landing weight (MLW). The severity of delays and cancellations will depend upon the weather conditions (in terms of duration and severity) and the affected traffic volumes.

This case study will assess the consequences of lower allowed friction coefficients for four Norwegian airports severely exposed to snow and ice, with particular attention towards the costs of reduced regularity for the passengers. The four airports are (percentage and number of landings affected during a normal winter season November-March in brackets):

- Kirkenes (KKN), regional airport, 2055 m runway. (34.0%, 108 landings)
- Alta (ALF), regional airport, 2177 m runway. (6.1%, 19 landings)
- Vadsø (VDS), local airport, 870 m runway (19.4%, 75 landings)
- Honningsvåg airport (HVG), 860 m runway (15.7%, 197 landings)

Figure 1.1 shows these airports, located in the northernmost county in Norway (Finnmark), along with the airports' catchment areas.

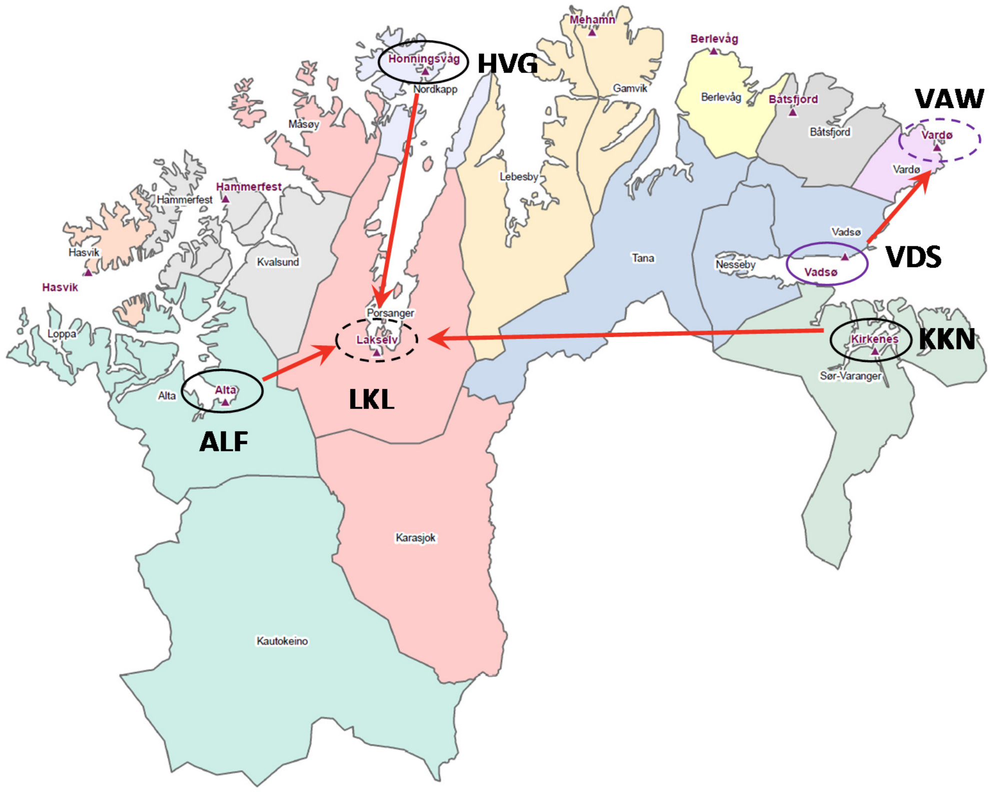

Figure 1.1 Airports included in the study (dotted ellipsoids shows alternative airports)

Other airports, like Svalbard/Longyearbyen, Kristiansand/Kjevik (regional airports), and Harstad/Narvik Sogndal, Mosjøen, Svolvær and Berlevåg (local short track airports) are affected to a varying extent as well. This study assesses the two most exposed airports in each of these airport groups.

Kirkenes (KKN) and Alta (ALF) airports are served by Boeing 737-700 and 737-800 in addition to Bombardier DHC8-100/200, for KKN also DHC8-300. The nearest relevant airports for these, are Lakselv (LKL) that has a longer runway and no contamination issues. The two short-track airports Honningsvåg (HVG) and Vadsø (VDS) uses Lakselv (LKL) and Vardø (VAW), respectively.

2 METHOD FOR ASSESSING THE PASSENGERS' COSTS

2.1 CHANGE IN PASSENGER COSTS – AN OVERVIEW

When the effects of changes in regularity are considered, there are reasons to believe that a large share of the passengers will have the use of an adjacent airport as the second-best alternative. Some will avoid undertaking the trip because of the increase in total travel costs (because of longer distance to/from the airport, increased travel time and perhaps other costs like having to pass through tolled roads or use ferries).

Figure 2.1 shows the change in consumer surplus (CS) from a general increase in travel costs (Bråthen and Eriksen 2007). The difference in generalized travel costs (time costs +payable travel costs like fares and vehicle operating costs) together with the deterred traffic ($X_0 - X_1$ in the figure) and the traffic that will use the adjacent airport (X_1), here taken as the best alternative transport, is used to calculate the black and crosshatched area. The black area is the loss in consumer surplus for those who will still go from the adjacent airport even if it is more expensive, while the crosshatched area is the loss for those who will abstain from travelling because of the higher travel costs. The figure shows a composite average. In reality, the black + crosshatched trapezoid are calculated for different market segments, depending on e.g. the passengers' travel purpose and place of visit or residence.

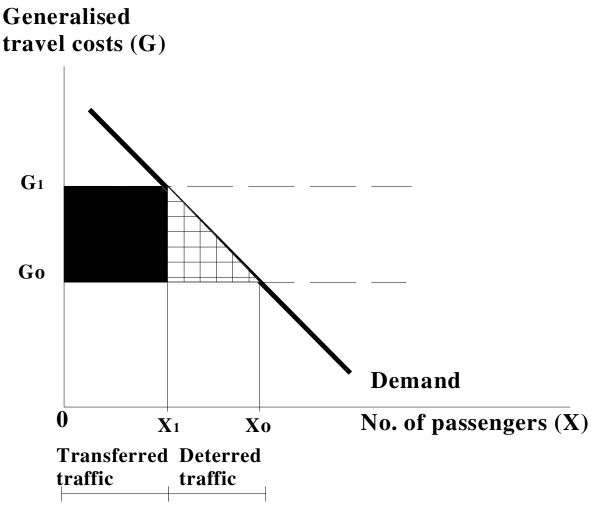

Figure 2.1 Economic loss for air passengers from airport closure.

A general specification of value of the reduction in CS discounted over *n* years is:

$$N_T = \sum_{i=1}^{40} \frac{X_{1i} + X_{0i}}{2} (G_1 - G_0)(1+r)^i$$

where:

N_T = Net present value of the CS loss, here 40 years;
X_{1i} = Traffic that will use adjacent airport, year *i*;
X_{0i} = Traffic at the existing airport, year *i*;
G_1 = Generalized travel costs by travelling from an adjacent airport;
G_0 = Generalized travel costs by going from the airport that is assessed with respect to possible winter closure or diversion;
r = Social discount rate (currently 4 per cent).

In this case study, we assess the effects for an average year only, based on annual data for the winter season from 2011/2012. Discounting to net present value can be made by means of traffic forecasts and real growth in factor prices for future years. This can be relevant if assessments of measures like runway extensions are considered.

However, this framework does not allow for separating between planned and unforeseen delays from changes in runway friction requirements. At the outset, it is likely that the changes in ICAO regulations could result in both increased stochasticity and seasonal MLW restrictions. In order to account for this, we will use an approach where we differ between planned and unforeseen cancellations or diversions, discussed by means of two figures that build upon Figure 2.1. As commented below, the data does not allow for fine-tuned calculations of a reduced passenger number from reduced MLW.

2.2 PASSENGERS' COSTS OF CHANGES IN REGULARITY

As an example, a given airport could have a regularity of 98 per cent during winter. The new runway friction requirements could reduce the regularity to 88 %. If this had been stochastic events only, we could have considered it as an ordinary regularity issue with a probability of 0.88 for serving a scheduled aircraft movement over the year.

In this case, however, it is convenient to use two main kinds of impacts, (1) planned, and (2) unpredictable accessibility to scheduled aircraft capacity with reduced MLW. Hence, three types of situations may occur from stricter friction requirements:

a) Scheduled reduced aircraft capacity due to runway friction conditions, where the passengers get information well ahead of the departure. Then they are able to reschedule their plans in order to use an alternative transport or to do something else. This could be an announced reduction in seat capacity, but with departure according to the schedule, cancellation of specific flights, diversions to an adjacent airport or a seasonal closure in cases of a severe reduction in winter regularity.
b) A sudden severe reduction in runway friction, which causes a need for immediate abatement plans like alternative surface transport, a full cancellation of the trip or attempts to use an adjacent airport.
c) An in-between situation of a. and b., where a sudden reduction in MLW takes place but the flight completes according to the schedule. In this case, a limited number of passengers are affected.

In this study, we have data about the average number of affected landings, i.e. the average number during the last 6 winter seasons. Given the new ICAO State letter AN 4/1.2.26-16/19 regulations, actions would have to be taken due to lower runway friction combined mainly with aircraft landing weights and wind conditions. In addition, a number of Other landings with Braking Actions report ("restricted landings") are identified where braking action reports have been issued. These landings can presumably be made under the new friction regulations, but there are reasons to believe that some of them may become marginal. This category of landings is not further assessed in this study.

A reduction in regularity will result in a certain number of passengers affected. As an example, if the traffic is 100,000 during winter and the regularity drops from 98 to 88 per cent, then (100,000/0.98)*0.88, approximately 90,000 passengers will be served, a drop of around 10,000 passengers. Ideally, this number must be split into each of the three groups above when we are carrying out the economic impact assessment.

For the passengers that are exposed to a pre-known reduced number of seats available, there are reasons to assume that the economic loss corresponds to the additional costs of using the best alternative transport (i.e. the cheapest alternative, with time costs and payable costs taken into consideration). This could be to travel from the nearest airport or by any surface transport mode to the destination. The passengers for whom the utility of the planned trip is less than the costs of using alternative transport will not travel.

Figure 2.2 below illustrates the passenger costs of constrained airport capacity in the case of a seasonal airport closure. The distance *c-d* corresponds to the number of passengers that are exposed to a pre-known capacity reduction (situation a) in the list above) that causes the closure. Using the best alternative transport gives an economic cost *a-d* for the passengers from having to use a more expensive transport. In total, this entails an economic cost for the passengers equal to the area *abcd*. The distance *c-f* corresponds to the number of passengers who abstain from travelling with more expensive alternatives, whereas the distance *f-d* are those who are willing to pay the extra costs and stick to their travel plans by using alternative transport, like an adjacent airport. The slope of the demand curve is fairly well known from recent studies of price sensitivity, and the costs of the best alternative transport is calculated after some data gathering.

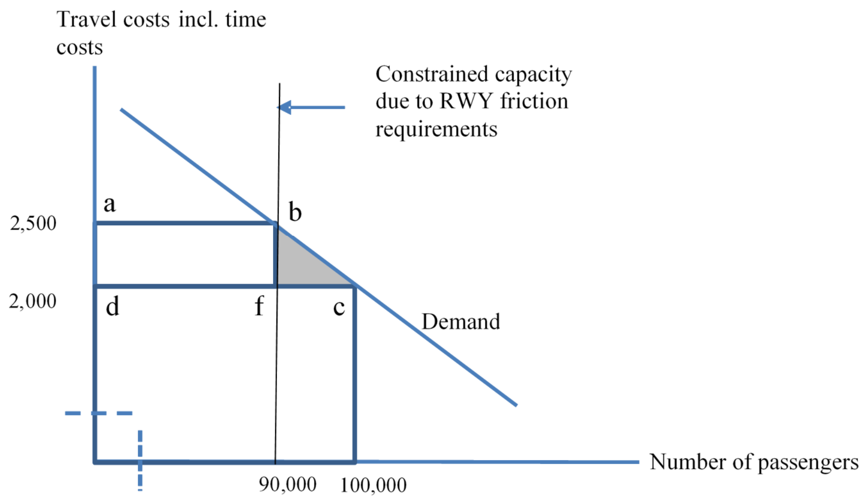

Figure 2.2 Passenger costs of constrained capacity – planned seasonal airport closure.

Figure 2.3 illustrates the costs for the affected 10,000 passengers in our example if the services continue, but with reduced seat capacity for given affected flights. If there is a segment of the market where the change in friction coefficient requirements causes unexpected disruptions in terms of reduced regularity in a more classical sense (situation b) or c) in the list above), a higher economic cost *h-d* per affected trip is the likely result. The economic costs for this group of passengers will correspond to the area *hgcd*. The reason why the costs are higher for situation b) and c) is mainly due to the higher time costs when unexpected delays and/or disruptions occur. Of this subset, 2,000 passengers will abstain from travelling in this example whereas the remaining passengers will use alternative transport.

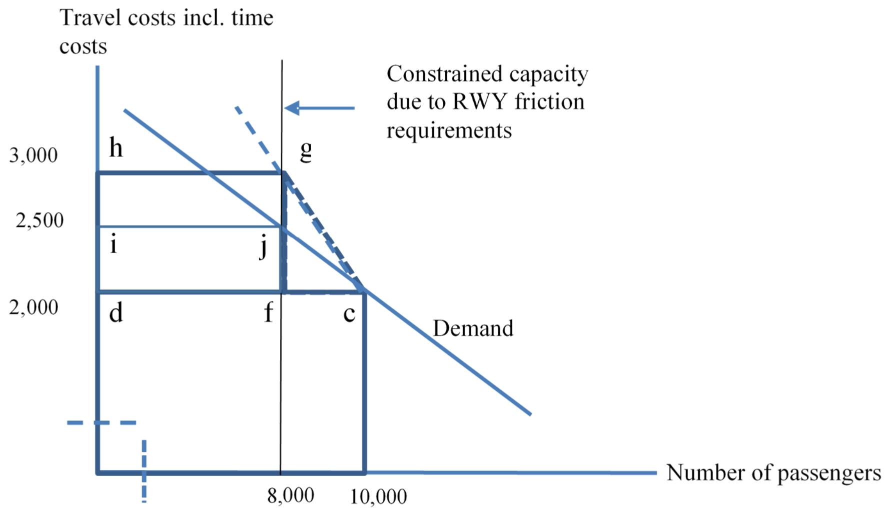

Figure 2.3 Passenger costs of constrained capacity – stochastic seat capacity reduction

The kinked demand stems from the fact that a sudden reduction may take place at a time where a) the trip has started or b) return trips are affected and the passengers have to get back home. Because of this, the elasticity of demand is highly likely to become reduced, hence the demand curve becomes steeper. The same reasoning can be applied to a planned seat capacity reduction. The additional passenger travel costs will then be lower (area *ijcd)* because the inconveniences of a planned reduction is less. In addition, the elasticity of demand is likely to be on approximately the same level as in the case with a planned seasonal closure. In both situations, around 2000 passengers will not travel in this example because of the higher travel costs (deterred passengers).

For the economic impact assessment, it will be necessary to quantify the changes in predictable and sudden changes in the air transport services as consequences of a change in runway friction regulations. This is carried out by means of assumptions, building upon the number of affected landings and the total number of landings during the winter season. If a planned seasonal closure is made, then the passengers throughout the entire season will become affected. The costs are calculated as illustrated in Figure 2.1. The same procedure is followed if we assume that smaller aircraft with somewhat higher fares can be used instead of having to close because of poor regularity with larger aircraft. Then the change in travel costs are related to the higher airfares only.

Furthermore, we assume that the affected landings diverts the corresponding number of passengers to the nearest relevant airport, and that the corresponding *departure* is made from this same airport. The costs are calculated as illustrated in Figure 2.3 above.

A couple of comments need to be made with respect to the value of time (VOT) and the consumer surplus/travel costs calculations. Firstly, there are reasons to expect that the value of time is higher when delays happen without notice. Such events are likely to cause inconveniences for many passengers. We are not aware of any studies that deal with the value of delays in air transport. One has to take into account that delays may entail new equilibria in a transport network (e.g. selection of alternative routes), perhaps with only marginal inconveniences. However, when alternative solutions are expensive, time-consuming and perhaps even non-existent and disruptions happen without notice, significant inconveniences is a likely result. Extra time costs of delays are supported in e.g. Jelenius et al (2011). A recent, unpublished study of Norwegian delay costs in road transport indicates a twofold value of time of avoiding such situations. A study by Cook and Tanner (2015) suggest a non-linear VOT function with a steep increase between 30 and 90 minutes, with values for a 60-90 minutes delay approximately equal to a twofold VOT value. We have applied a doubling of the value of time in scenarios where we assume that the affected landings happens without notice, in order to include the inconvenience for the passengers per hour of extra waiting and time under way to the airport. Arguably, we have not doubled the VOT for ordinary aircraft on-board time or shuttle time at destination.

Secondly, we would like to add that both a seasonal closure, transferring passengers to the nearest airport leading to presumably higher departure frequency there, and smaller aircraft used at the original airport with higher airfares but also with higher departure frequency are likely to result in some benefits from higher frequencies. These benefits are not taken into account. Departure tends to cluster around peak hours and hence without a uniform distribution during the day, we do not believe that significant additional benefits occur as long as necessary capacity is supplied.

Ideally, we would like to gain a thorough understanding of how the market actually responds to a sudden cancellation, and what the economic costs are likely to be. This reaction could mainly be one out of three:

- Rebook to a later departure.
- Travel with the best alternative option.
- Cancel the trip or postpone it for a longer period.

It turned out to be demanding to get a very high level of precision with respect to how the market will respond. Instead, we have assumed that the passengers will use an alternative mode in case of cancellations or sudden reductions in MLW. In case of poor regularity leading to expected seasonal closures, we have assumed that the passengers transfer to the nearest airport. Some will abstain from travelling, as discussed above.

3 THE SCENARIOS

As discussed above, the data does not allow for any differentiation between the types of possible actions for the affected landings. These actions could span from reduced MLW in terms of reduced passengers and/or luggage, cancellation or diversion to an adjacent airport. In some cases, the number of affected landings could give a regularity of much less than 90 %. This is likely to cause a seasonal closure of the airport or use of smaller aircraft where practically possible. Because of the available data, we have assessed the following scenarios for airports with expected regularity of less than 90%, for all affected landings:

- Scenario P1: The airport remains open during winter, but with smaller aircraft that can serve under the new ICAO friction regulations. 20% fare increase.
- Scenario P2: As scenario P1, but with 50% fare increase.

- Scenario P3: The airport is closed during winter[2], and all traffic is transferred to the nearest relevant airport, i.e. an airport can serve today's types of aircraft
- Scenario P4: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations are published well ahead.
- Scenario U1: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations occur without notice.

Hence, we do not assess situation a) in case of seat reductions only, or situation c), the effects of transferring a limited number of passengers on affected landings (the situations are described in the beginning of Section 2.2). However, we have calculated the increased costs per passenger. This information can be used if more disaggregated data becomes available.

4 MAIN DATA, OMITTED ELEMENTS AND UNCERTAINTIES

4.1 MAIN DATA

We use the following main data and elements to quantify the areas in the figures above:

1. Value of time (VOT) (numbers from the Norwegian VOT study), with 2 x VOT when there are unexpected delays or cancellations calculated for waiting time and in-vehicle time to or from the adjacent airport. VOT is NOK 572 for business travels and NOK 252 for other travels.
2. The demand elasticity is set to -0.8 (meaning that a 10% increase in travel costs deter 8% of the passengers) for planned changes. For unplanned changes, the price elasticity is set to -0.2 (Figure 2.3).
3. Time and costs by using the best alternative transport. Data is available from e.g. Google Maps and handbook values for operating costs for various modes. Underlying information from Avinor's National Air Travel Survey and Avinor's traffic numbers for the winter season 2016/17 is used.
4. An estimate on the number of affected and total number of landings during an average winter season, based on 6 winter seasons. These data is from Klein-Paste (2018).
5. Costs of aircraft operations, based on a calibrated model derived from Janic (2000), together with load factors in the local air network and on the routes to/from Oslo.

4.2 INPUT VALUES

Table 4.1 shows the main input values that are used in the calculations, with sources of information.

Table 4.1 Input values

Assumptions		Unit	Value	Source
Business travels	ALF	%	37,8	
	KKN	%	32,9	

[2] The "closure" affects only the routes that are highly likely to become affected by the new ICAO regulations. Routes served by aircraft that are unaffected by these regulations at the actual airport are not included in the study.

HVG VDS	% %	39,2 44,3	Avinor's National Air Travel Survey (2013)
Value of time, business travels	NOK 2017	572	The Norwegian Public Roads Administration Manual V712, 2014 Version 1.1 (Price adjusted)
Value of time, other travels	NOK 2017	252	
Vehicle operating costs (private cost)	NOK 2017	3,19	
Patronage, business travels	Number	1,57	
Patronage, other travels	Number	2,36	
Demand elasticity (planned change)		-0,8	Own assessment and prior studies
Demand elasticity (unexpected change)		-0,2	

The demand elasticities are discussed in Section 2, Figure 2.3.

4.3 MAIN ASSUMPTIONS

The main assumptions are:

- The passengers use their own vehicle for transport to the airport.
    - Parking fee of NOK 550, for two-three days on average, is included in the payable costs.
    - Distance and driving time from the given municipalities to the airports included in this study are provided by Avinor. The numbers are presented in chapters 7.1–7.4.
- The total time at the airport is set to 1 hour for all airports in this study.
- The flight time between airports is extracted from the airlines' websites. Calculations are based on a share of direct flights and transit/transfer (see appendix for more details).
- The air fares used in these calculations are based on Avinor's National Air Travel Survey (2013), prior studies, and searches on the airlines' websites.
- Travel time and cost from the destination airport to the center of Oslo, Tromsø and the smaller towns and places are assumed to differ between business and other travels.
    - Business travels to the center of Oslo is assumed to go via the Airport Express Train, while it is assumed that other travel purposes go by the NSB local train.
    - From TOS to Tromsø center it is assumed that the business travels use a taxi, and that other travel purposes go by bus transportation.
    - Travelling to the center of other local towns is assumed to be by taxi for both business and other travel purposes.
    - If a diverted return trip occurs, bus transport is assumed to be used to the airport where the outbound trip started.
- The additional flight time for a diverted trip is set to 1 hour from Kirkenes and 30 minutes for the other airports, where the distance to the nearest relevant airport is shorter.

- The aircraft costs per minute is set to NOK 500/minute for a B737-700/800 (data from Norwegian), NOK 350 for a 90-seater and NOK 200 for a 39-seater (the latter based on our cost model in Chapter 6).
- In cases where seasonal closure (winter) is considered, all aircraft movements during November-March are assumed to be affected.

4.4 SOME OMITTED ELEMENTS AND UNCERTAINTIES

This study includes economics costs for the passengers and the airlines. However, some elements are not included:

- Passenger costs: Elements connected to wider costs of delays (e.g. from chained activity patterns) are indirectly considered through higher time costs for the increased waiting and shuttle time. We believe that the passengers' inconveniences are calculated a bit on the lower rather than the higher side, per passengers. The aggregated impacts could be on the higher side if some of the aircraft movements are carried out according to schedule but with reduced payload. We have assumed that all affected landings are diverted to other airports (or serviced by smaller aircraft with higher airfares). As noted elsewhere in the report, the calculated costs per passenger can be of good use if more detailed information on the occurrence of reduced payload can be obtained.
- We have not included any costs of transfers/worsening of correspondence between flights. The data has not been available within the scope of this study. This effect causes both passenger and airline costs to be calculated on the lower side.
- Changes in departure frequency: Impacts from increased number of departures are not included. Reduced headway will, in theory, attract a certain amount of induced traffic and hence somewhat reduce the inconveniences of higher airfares when using smaller aircraft (scenario P1 and P2). This effect is considered as having a negligible impact on the results.
- Emissions to air: The impacts of changes in aircraft fleet, number of departures and actual routing and changes in shuttle services to/from the airports are not addressed. Previous studies, e.g. Tveter et al (2015) indicate that emissions to air have a smaller impact because most activities transfer between airports.
- Accidents: Increased shuttle surface transport has a higher risk per person km than air transport. Tveter et al (2015) indicates that this has some impact and it will increase the costs somewhat on scenario P3, P4 and U1. This contributes to calculations per passenger being slightly on the lower side.
- We have not assessed all different actions that could be performed if ICAO's regulations should be imposed because the data does not allow for this. The assessed actions are 1) to use smaller aircraft (scenario P1 and P2), 2) to close the airports during winter and transfer the activities to a nearby airport with better friction conditions (P3), inform ahead of the disruptions but otherwise keep today's schedule (P4), and 4) live with reduced regularity and handle the disruptions when they occur (U1). Other actions could e. g. be to leave passengers and/or luggage behind. This last option is highly relevant, but data is scarce. However, we have calculated the costs per affected passenger. Better data on this last issue could then give aggregated economic effects for this type of actions.

- We have used the present airport infrastructure and ATC/ATM systems in the study. Extension of the runway at KKN is planned, but no final decision on the timing is made. We have not carried out a sensitivity analysis on this runway extension or other abatement measures.
- A detailed assessment of aircraft capacity, aircraft types and routing is not made. We have only used aircraft *capacity* to investigate the effect of using smaller aircraft (90 seaters for KKN and ALF, 19 seaters for HVG and VDS) in scenario P1 and P2, but we have not undertaken a technical assessment of whether specific aircraft types are suitable under the actual friction and wind conditions, or not. For example, a commonly used 19 seater, Dornier-228, does not have a pressurized cabin which may put constraints on operations during adverse weather conditions.
- Rough assumptions are made with respect to aircraft size and departure frequencies on the specific routes. We have used the number of seats offered at present, and scaled up the departure frequency with smaller aircraft to meet this number. This is a rather complex matter in need of a careful assessment in order to design for actual operations. There is also uncertainty with respect to whether our cost model is able to represent all combinations of aircraft types and routes, even if tests have shown that they represent Boeing 737-800 and Bombardier Dash 8-100/200/300 fairly well. Network effects are however not considered. The aircraft cost calculations have the highest uncertainty in this study. Therefore, they must be considered as indicative only.
- Wider delay impacts are not considered (this is partly linked with bullet point 2 above). Such impacts occur when the delays happen unexpectedly, and contributes to that the costs in the U1 scenario are calculated on the lower side.
- Impacts on costs for Avinor and the ground handlers are not considered. In cases of winter closures in particular, this contributes to that the calculated effects of planned winter closures in particular are on the lower side.
- November and partly March has fewer days with contamination on average than the rest of the winter. This could contribute to an over-estimation of the total numbers in case of winter closure. On the other hand, there could be an increased number of unplanned delays, cancellations or diversions in these two months if the airports are open, given the new ICAO regulations. Chapter 6 and 7 indicates clearly that unforeseen disruptions have larger economic impacts.

5 THE COST MODEL

The cost structure of an airline can be considered in different time-scales such as day, week, month, year, which is dependent on the purpose. In this project, costs per one-way flight are considered, and they are aggregated over the number of trips.

As a practical approximation to these costs, Janic (2000) has estimated a regression model to quantify the average costs per flight, dependent on the aircraft size-capacity and non-stop route length as follows:

$$C(n,d) = 7.934n^{0.603}d^{0.656}$$

where $C(n, d)$ is average costs per flight; n is aircraft seating capacity and d is route length. The constant can be used for calibration.

The properties of the model seem appealing in the sense that it incorporates the scale effects of both flight length and aircraft size, and because it has proven to give a reasonable fit to the data for a selection of actual route costs. The model is therefore used in the calculations of changes in aircraft operating costs to get indications of the cost effects, when assessing changes in the number of flights, stage lengths and types of aircraft. However, this model is too crude to give detailed information for actual planning of commercial services. Here crew and fuel costs, age and characteristics of engines and fuselage, maintenance schedules etc. have to be considered.

6 MAIN RESULTS

This section presents the main findings. Section 7 presents and discusses more elaborated findings. As noted in Section 4.4, the operating costs for the airlines are probably the most uncertain part of the calculations. Table 6.1 summarizes the main findings.

Table 6.1 Main findings, economic impacts (in millions NOK)

Scenario	**Airport**			
	KKN	**ALF**	**HVG**	**VDS**
Scenario P1: The airport remains open during winter, but with smaller aircraft that can serve under the new ICAO friction regulations. 20% fare increase.				
Costs for passengers	-18.0	-25.1	-1.0	-4.9
Revenue loss(-) or gain, airlines	11.4	15.5	0.6	3.3
Operating costs, airlines (reduced (+) or increased)	-16.0	-15.8	-2.4	-8.5
SUM economic effects	-22.6	-25.4	-2.8	-10.1
Scenario P2: As scenario P1, but with 50% fare increase.				
Costs for passengers	-42.7	-59.5	-2.3	-11.8
Revenue loss(-) or gain, airlines	24.2	32.3	1.2	7.2
Operating costs, airlines (reduced (+) or increased)	-16.0	-15.8	-2.4	-8.5
SUM economic effects	-34.5	-43.0	-3.5	-13.1
Scenario P3: The airport is closed during winter, and all traffic is transferred to the nearest relevant airport, i.e. an airport can serve today's types of aircraft				
Costs for passengers	-89.1	-76.0	-4.1	-9.5

Scenario	Airport			
	KKN	ALF	HVG	VDS
Revenue loss(-) or gain, airlines	-37.1	-30.1	-1.6	-2.3
Operating costs, airlines (reduced (+) or increased)	4.7	-2.3	-0.5	-7.1
SUM economic effects	-121.4	-108.4	-6.2	-19.5
Scenario P4: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations are published well ahead.				
Costs for passengers	-30.3	-4.5	-0.8	-1.5
Revenue loss(-) or gain, airlines	-12.6	-1.8	-0.3	-0.5
Operating costs, airlines (reduced (+) or increased)	1.5	-0.1	0.5	-1.1
SUM economic effects	-41.4	-6.4	-0.6	-3.1
Scenario U1: Diversion of all affected landings to adjacent airports, under the assumption that the cancellations occur without notice.				
Costs for passengers	-57.2	-10.9	-2.1	-6.4
Revenue loss(-) or gain, airlines	-3.6	-0.1	-0.1	-0.2
Operating costs, airlines (reduced (+) or increased)	-5.0	-0.7	-1.5	-3.9
SUM economic effects	-65.8	-11.7	-3.7	-10.5

The orange/yellow-marked scenarios P3 and U1 appear to be the most relevant ones. P3 (winter closure and transfer to an adjacent airport) seems relevant because the regularity will either end close to 90% (Alta) or even way below (the three others). This raises the question of whether the winter services will remain sustainable under the new regulations. U1 (unexpected delays for the affected passengers) is the situation that the passengers and airlines normally face in cases of disrupted services. The passengers face additional waiting time and shuttle costs as well as inconveniences connected to their planned activities. The airlines face additional flight time and holding costs. The economic impacts of these scenarios are clearly the highest both in total and per passenger.

The other scenarios are included to show e.g. possible impacts of using smaller aircraft. These scenarios (P1 and P2) are likely to cause significant alterations in the market structure on the supply side. The results indicate that there is a potential for a better match between the size of the market and the capacity offered, but a thorough assessment of operational changes is beyond the scope of this study.

Please note that the aggregated effects will be smaller if the planned aircraft movements take place, but with reduced payload. This means that lesser passengers will become affected.

Therefore, we recommend to using the costs per passenger as the most reliable estimates, and consider the aggregated passenger costs in Table 6.1 as upper estimates.

Table 6.2 shows the costs per passenger and the share of deterred traffic per scenario.

Table 6.2 Costs per passenger in NOK per one-way trip, and share of deterred traffic (in %).

Differences in passengers' cost from today's services, per passenger, one way. **Costs for all affected passengers (*ex ante*) in bold,** *remaining travelling passengers (ex post) in Italics* (% deterred passengers from the affected flights)	**KKN**	**ALF**	**HVG**	**VDS**
P1	**276/***281* (7%)	**276/***286* (7%)	**157/***190* (5%)	**177/***193* (5%)
P2	**647/***703* (16%)	**655/***715* (17%)	**392/***450* (12%)	**443/***463* (12%)
P3	**1,350/***1,741* (39%)	**837/***972* (23%)	**816/***822* (23%)	**363/***371* (9%)
P4	**1,352/***1,741* (39%)	**833/***972* (23%)	**816/***821* (23%)	**363/***371* (9%)
U1	**2,554/***2,798* *(12%)*	**2,019/***2,126* (8%)	**1,926/***2,178* (8%)	**1,556/***1,561* (5%)

Scenario U1 has much lower traffic deterrence than the comparable scenario P4 (a hypothetical but not very realistic situation where the delays could be announced well in advance). The reason is that we have used a much lower demand elasticity of -0.2 for U1 as compared to -0.8 for the others (Figure 2.3 above). In scenario U1 many trips will have already started (e g. the affected return trips) and hence the passengers are less sensitive because they on average are likely to be significantly more reluctant to cancelling their trip. The common denominator for the "P" scenarios is that the passengers are informed in advance about delays, cancellations and/or diversions and hence they will on average have much more flexibility.

Table 6.2 shows that the passenger inconveniences are potentially high. Passengers at Kirkenes in particular, with a long shuttle distance to the alternative airport in Lakselv (Figure 1.1), gets more than NOK 5,000 in extra costs for a return trip if diversions on short notice occur. Even those with only around 70 kilometers to the nearest alternative airport get additional costs of around NOK 3,000 for a return trip under such conditions. For a planned diversion (P3) the costs are between approximately NOK 750 and NOK 2,700, respectively.

If we generalize scenario U1 to comprise all affected landings (around 500 landings in the regional and around 3,800 landings in the local airport network during an average winter season), we get an estimate of NOK 400-450 million per year for the passenger costs only. This estimate may be on the higher side due to the fact that we have not been able to isolate the landings where the flight is on time, but with a reduced number of passengers.

7 DETAILED RESULTS FOR THE FOUR AIRPORTS

This section will briefly present main characteristics of the four cases and list the number and percentages of affected and restricted landings (Klein-Paste 2018)[3]. Subsequently, we assess the impacts for the passengers and airlines, based on costs of diversion to other airports, and cancellations. We base the number of aircraft movements and passengers on the winter season 2016/17. The percentage of affected landings is given in Klein-Paste (2018). No anomalies were detected during this winter. Hence, the winter 2016/17 should represent an approximate baseline for the coming years. Adjustment for expected growth must be taken into account if future years are going to be addressed. We take arrived and departed passengers into account as well, since diverted or cancelled landings are likely to affect the corresponding departures.

7.1 KIRKENES (KKN)

Kirkenes Airport, Høybuktmoen IATA: KKN, ICAO: ENKR is an international airport located at Høybuktmoen, 15 kilometers west of the town of Kirkenes, in the municipality of Sør-Varanger, Finnmark county, Norway. Operated by the state-owned Avinor, the airport has a single 2,115 x 45-meter (6,939 x 148 ft) asphalt runway numbered 06–24. Scandinavian Airlines and Norwegian Air Shuttle operate Boeing 737-services to Oslo Airport, Gardermoen, in part generated by Høybuktmoen's function as a hub for Widerøe's regional services to other airports in eastern Finnmark. There are also summer charter flights to Central Europe to bring tourists to the Hurtigruten cruises. The airport had 258,323 passengers arrived + departed in 2017.

Table 7.1 shows the share of local municipalities that uses the airport KKN. The table also presents the time and distance between the given municipalities and the airports KKN and LKL.

Table 7.1 Travel flows from local municipalities, travel times and distances to KKN and LKL

Travel flows, local municipalities	Percent, %	Time and distance to KKN	Time and distance to LKL
Tana	6,8 %	1h 45min / 130km	3h 20min / 256km)
Vardø	3,5 %	3h 15min / 235km	5h 5min / 353km
Sør-Varanger	81,7 %	15min / 13km	4h 45min / 341km
Vadsø	4,3 %	2h 10min / 162km	4h 30min / 287km
Other (average)	3,7 %	3h 5min / 193km	2h 50min /172km
Sum	100 %		

[3] Calculated by Norwegian University of Science and Technology (Klein-Paste 2018), based on reported landings 2011-2016 and data on contamination and wind.

Table 7.2 shows the impacts on regularity for Kirkenes Airport (KKN).

Table 7.2 Impacts on landings and number of passengers, KKN. Winter 2016-17.

Factor	**Number of landings** (% in brackets)	**Passengers arrived, from Oslo**
Affected landings	108 (34)	11,200
Other landings with Braking Actions Report ("restricted landings")	197 (62)	20,500
All landings	319 1) (100)	33,000

1) There is a certain deviation from the number given by Avinor (332)

Affected landings are those where cancellations, diversions or reduced payload as compared with the flights' actual payload. For other landings with Braking Action Report, no further actions need to be undertaken. Around 1/3 of the landings during winter are likely to become affected by ICAO's new regulations.

There is a small discrepancy in the total number of landings as compared with Avinor's numbers. We will use Avinor's total numbers throughout but with NTNU's percentages on reported affected/restricted landings. This choice has no impact on the conclusions.

Table 7.3-7.7 show the economic effects for various stakeholders at KKN, calculated for the five different scenarios described above. All numbers are in millions NOK.

Table 7.3 Scenario P1: Continued use of KKN with 90 seat aircraft, 20 % fare increase.

P1: Smaller aircraft. +20% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	-17.4	-7.1	-10.3
Costs waiting for next departure	-	-	-
Costs deterred passengers	-0.6	-0.2	-0.4
Costs transferred passengers	-	-	-
Costs, passengers	*-18.0*	*-7.3*	*-10.7*
Costs per passenger	*-276*		
Increased airfare revenues	17.4	7.1	10.3
Lost airfare revenues, deterred passengers	-6.0	-2.1	-3.9
Revenue increase, airlines	*11.4*	*5.0*	*6.4*
Effects on passenger costs and airline revenues	**-6.6**	**-2.3**	**-4.3**
Increased airline costs	*-16.0*		
SUM economic effects	**-22.6**		

There are negative net economic effects mainly because of increased passenger and airline costs. All flights KKN-OSL vv. include the same number of seats as today, serviced by a 90 seat aircraft and increased frequency.

Table 7.4 Scenario P2: Continued use of KKN with 90 seat aircraft, 50 % fare increase.

P2: Smaller aircraft. +50% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	-39.0	-16.2	-22.8
Costs waiting for next departure	-	-	-
Costs deterred passengers	-3.7	-1.3	-2.4
Costs transferred passengers	-	-	-
Costs, passengers	*-42.7*	*-17.5*	*-25.2*
Costs per passenger	*-647*		
Increased airfare revenues	39.0	16.2	22.8
Lost airfare revenues, deterred passengers	-14.8	-5.1	-9.7
Revenue increase, airlines	*24.2*	*11.1*	*13.1*
Effects on passenger costs and airline revenues	**-18.5**	**-6.4**	**-12.1**
Increased airline costs	*-16.0*		
SUM economic effects	**-34.5**		

The net economic effects compared with P1 are seven more negative because of increased traffic deterrence from a 50% increase in airfares that outweighs the net increased fare revenues. As for P1, all flights KKN-OSL vv. include the same number of seats as today, serviced by a 90 seat aircraft and increased frequency.

Table 7.5 Scenario P3: Winter closure of KKN for B-737, transfer to LKL.

P3: Planned transfer to LKL (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	**-**	-	-
Costs waiting for next departure	**-**	-	-
Costs deterred passengers	-25.8	-13.9	-11.9
Costs transferred passengers	-63.3	-29.8	-33.5
Costs, passengers	*-89.1*	*-43.7*	*-45.4*
Costs per passenger	*-1350*		
Lost airfare revenues, deterred passengers	-37.0	-16.0	-21.0
Revenue loss, airlines	*-37.0*	*-16.0*	*-21.0*
Effects on passenger costs and airline revenues	**-126.1**	**-59.7**	**-66.4**
Reduced airline costs	*4.7*		
SUM economic effects	**-121.4**		

There are negative net economic effects because of a significant increase in travel costs and a significant reduction in airfare revenues, due to traffic deterrence because of a time consuming transfer to LKL for all passengers to/from OSL. The flight distance to LKL is somewhat shorter than to KKN.

Table 7.6 Scenario P4: Affected landings on KKN get a planned transfer to LKL.

P4: Planned transfer to LKL (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-	-	-
Costs deterred passengers	-8.8	-4.7	-4.1
Costs transferred passengers	-21.5	-10.1	-11.4
Costs, passengers	*-30.3*	*-14.8*	*-15.5*
Costs per passenger		*-1352*	
Lost airfare revenues, deterred passengers	-12.6	-5.5	-7.1
Revenue loss, airlines	*-12.6*	*-5.5*	*-7.1*
Effects on passengers and airline revenues	**-42.9**	**-20.3**	**-22.6**
Reduced airline costs	*1.5*		
SUM economic effects	**-41.4**		

There are negative net economic effects even from a limited number of affected landings because of a significant increase in travel costs and a significant reduction in airfare revenues, due to traffic deterrence because of a time consuming transfer to LKL.

Table 7.7 Scenario U1: Affected landings on KKN get a spontaneous transfer to LKL.

U1: Unforeseen transfer to LKL (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-16.0	-8.4	-7.6
Costs deterred passengers	-5.6	-3.3	-2.3
Costs transferred passengers	-35.6	-18.1	-17.5
Costs, passengers	*-57.2*	*-29.8*	*-27.4*
Costs per passenger		*-2554*	
Lost airfare revenues, deterred passengers	-3.6	-1.7	-1.9
Revenue loss, airlines	*-3.6*	*-1.7*	*-1.9*
Effects on passenger costs and airline revenues	**-60.8**	**-31.5**	**-39.3**
Increased airline costs	*-5.0*		
SUM economic effects	**-65.8**		

There are high negative net economic effects even from a limited number of affected landings because of a significant increase in travel costs and a significant reduction in airfare revenues. There are relatively high negative net economic effects even from a limited number of affected landings because of a significant increase in travel costs. This is mostly due to the inconvenience of transfer. The traffic deterrence and revenue loss is low because the elasticity of demand is lower in this unforeseen situation. Penalties connected to the unforeseen nature of the transfer, like extra waiting time and a roughly estimated 1 hour extra flight time including holding, are included.

7.2 ALTA (ALF)

Alta Airport, IATA: ALF, ICAO: ENAT is an international airport serving Alta, a town and municipality in Finnmark county, Norway. The airport is located at Elvebakken, 4 kilometers northeast of Bossekop in Alta. It has a single, 2,253-meter (7,392 ft) runway numbered 11/29, which lies on the southern shore of the Altafjord. Alta Airport is owned and operated by the state-owned Avinor. It served 345,223 passengers in 2017, making it the busiest airport in Finnmark.

Table 7.8 shows the share of local municipalities that uses ALF. The table also presents the travel times and distances between the municipalities and ALF and LKL.

Table 7.8 Travel flows from local municipalities, travel times and distances to ALF and LKL

Travel flows, local municipalities	Percent, %	Time and distance to ALF	Time and distance to LKL
Hammerfest	5,9 %	2h 5min / 137km	2h 10min / 143km
Kautokeino	3,2 %	1h 55min / 134km	2h 45min / 203km
Alta	82,7 %	5min / 3km	1h 30min / 172km
Nordkapp	2,6 %	2h 55min / 205km	2h 25min / 166km
Other	5,6 %	3h 5min / 193km	2h 50min /172km
Sum	100 %		

Table 7.9 shows the impacts on regularity for Alta Airport (ALF).

Table 7.9 Impacts on landings and number of passengers, ALF. Winter 2016-17.

Factor	Number of landings (% in brackets)	Passengers arrived, from Oslo
Affected landings	19 (6)	2,700
Other landings with Braking Actions Report ("restricted landings")	129 (41)	18,600
All landings	312[1)] (100)	45,400

1) There is a certain deviation from the number given by Avinor (375)

The table shows that around 6 per cent of the landings are likely to become affected, whereas around 41 per cent is likely to give a Braking Action Report. Table 7.10-7.14 show the economic effects for various stakeholders at ALF, calculated for the five different scenarios described above.

Table 7.10 Scenario P1: Continued use of ALF with 90 seat aircraft, 20 % fare increase.

P1: Smaller aircraft. +20% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers Costs waiting for next departure Costs deterred passengers Costs transferred passengers	-24.2 - -0.9 -	-11.1 - -0.4 -	-13.1 - -0.5 -
Costs, passengers	*-25.1*	*-11.5*	*-13.6*
Costs per passenger	*-276*		
Increased airfare revenues	24.2	11.1	13.1
Lost airfare revenues, deterred passengers	-8.7	-3.5	-5.2
Revenue increase, airlines	*15.5*	*7.6*	*7.9*
Effects on passengers and airline revenues	**-9.6**	**-3.9**	**-5.7**
Increased airline costs	*-15.8*		
SUM economic effects	**-25.4**		

There are negative net economic effects mainly because of increased passenger and airline costs. All today's flights with B737-700/800 are replaced with the same number of seats, serviced by a 90 seat aircraft and increased frequency.

Table 7.11 Scenario P2: Continued use of ALF with 90 seat aircraft, 50 % fare increase.

P2: Smaller aircraft. +50% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers Costs waiting for next departure Costs deterred passengers Costs transferred passengers	-54.0 - -5.5 -	-25.3 - -2.2 -	-28.7 - -3.3 -
Costs, passengers	*-59.5*	*-27.5*	*-32.0*
Costs per passenger	*-655*		
Increased airfare revenues	54.0	25.3	28.7
Lost airfare revenues, deterred passengers	-21.7	-8.6	-13.1
Revenue increase, airlines	*32.3*	*16.7*	*15.6*
Effects on passenger costs and airline revenues	**-27.2**	**-10.8**	**-16.4**
Increased airline costs	*-15.8*		
SUM economic effects	**-43.0**		

The net economic effects compared with P1 are seven more negative because of increased traffic deterrence from a 50% increase in airfares that outweighs the net increased fare revenues. As for P1, all today's flights with B737-700/800 are replaced with the same number of seats, serviced by a 90 seat aircraft and increased frequency.

Table 7.12 Scenario P3: Winter closure of ALF for B-737 aircraft.

P3: Planned transfer to LKL (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	**-**	-	-
Costs waiting for next departure	-	-	-
Costs deterred passengers	-12.2	-7.3	-4.9
Costs transferred passengers	-63.8	-34.5	-29.3
Costs, passengers	*-76.0*	*-41.8*	*-34.2*
Costs per passenger	*-837*		
Lost airfare revenues, deterred passengers	-30.1	-15.0	-15.1
Revenue loss, airlines	*-30.1*	*-15.0*	*-15.1*
Effects on passenger costs and airline revenues	**-106.1**	**-56.8**	**-49.3**
Increased airline costs	*-2.3*		
SUM economic effects	**-108.4**		

There are negative net economic effects because of a significant increase in travel costs and a significant reduction in airfare revenues, due to traffic deterrence because of transfer to LKL for all passengers to/from OSL. The flight distance to LKL is somewhat longer than to ALF.

Table 7.13 Scenario P4: Affected landings on ALF get a planned transfer to LKL.

P4: Planned transfer to LKL (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	**-**	-	-
Costs waiting for next departure	**-**	-	-
Costs deterred passengers	-0.7	-0.4	-0.3
Costs transferred passengers	-3.8	-2.1	-1.7
Costs, passengers	*-4.5*	*-2.5*	*-2.0*
Costs per passenger	*-833*		
Lost airfare revenues, deterred passengers	-1.8	-0.9	-0.9
Revenue loss, airlines	*-1.8*	*-0.9*	*-0.9*
Effects on passenger costs and airline revenues	**-6.3**	**-3.4**	**-2.9**
Increased airline costs	*-0.1*		
SUM economic effects	**-6.4**		

There are negative net economic effects even from a limited number of affected landings because of an increase in travel costs and a reduction in airfare revenues, due to traffic deterrence because of transfer to LKL.

Table 7.14 Scenario U1: Affected landings on ALF get a spontaneous transfer to LKL.

U1: Unforeseen transfer to LKL (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-4.0	-2.3	-1.7
Costs deterred passengers	-0.6	-0.4	-0.2
Costs transferred passengers	-6.3	-3.6	-2.7
Costs, passengers	*-10.9*	*-6.3*	*-4.6*
Costs per passenger	*-2019*		
Lost airfare revenues, deterred passengers	-0.1	-0.0	-0.1
Revenue loss, airlines	*-0.1*	*-0.0*	*-0.1*
Effects on passenger costs and airline revenues	**-11.0**	**-6.3**	**-4.7**
Increased airline costs	*-0.7*		
SUM economic effects	**-11.7**		

There are relatively high negative net economic effects even from a limited number of affected landings because of a significant increase in travel costs. This is mostly due to the inconvenience of transfer. The traffic deterrence and revenue loss is low because the elasticity of demand is lower in this unforeseen situation. Penalties connected to the unforeseen nature of the transfer, like extra waiting time and a roughly estimated 0.5 hour extra flight time including holding, are included.

7.3 HONNINGSVÅG (HVG)

Honningsvåg Airport, IATA: HVG, ICAO: ENHV is a regional airport serving Honningsvåg in Nordkapp, Norway. The airport is located at Valan, on the south side of Skipsfjorden, 4.5 kilometers north of the village. The airport has a 880 x 30-meter (2,887 x 98 ft) asphalt runway is operated by the state-owned Avinor. Flights are operated to other communities in Finnmark by Widerøe, who serves the airport with Dash 8-100 aircraft. The airport handled 13,133 passengers in 2017.

Table 7.15 shows the share of local municipalities that uses HVG. The table also presents the travel times and distances between the municipalities and HVG and Lakselv (LKL).

Table 7.15 Travel flows from local municipalities, travel times and distances to HVG and LKL

Travel flows, local municipalities	**Percent, %**	**Time and distance to HVG**	**Time and distance to LKL**
Nordkapp	99,8 %	8min / 5km	2h 25min / 166km
Alta	0,2 %	2h 50min / 205km	2h 30min / 172km
Sum	100 %		

In the table below the share of destinations for flights from HVG is presented.

Table 7.16 Share of destinations on travels from HVG

Destination	OSL	TOS	Local	Sum
	32,6 %	67,0 %	0,4 %	100 %

Table 7.17 shows the impacts on regularity for Honningsvåg Airport (HVG).

Table 7.17 Impacts on landings and number of passengers, HVG. Winter 2016-17.

Factor	Number of landings (% in brackets)	Passengers arrived/departed, all
Affected landings	75 (19)	950
Other landings with Braking Actions Report ("restricted landings")	149 (39)	1,950
All landings	387 (100)	5,000

The table shows that around 19 per cent of the landings are likely to become affected, whereas around 39 per cent is likely to give a Braking Action Report.

Table 7.18-7.22 show the economic effects for various stakeholders at HVG, calculated for the five different scenarios described above.

Table 7.18 Scenario P1: Continued use of HVG with 19 seat aircraft, 20 % fare increase.

P1: Smaller aircraft. +20% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	-0.92	0.41	0.51
Costs waiting for next departure	-	-	-
Costs deterred passengers	-0.03	0.01	0.02
Costs transferred passengers	-	-	-
Costs, passengers	*-0.95*	*0.42*	*0.53*
Costs per passenger		*190*	
Increased airfare revenues	0.92	-0.41	-0.51
Lost airfare revenues, deterred passengers	-0.34	0.11	0.23
Revenue loss, airlines	*0.58*	*-0.30*	*-0.28*
Effects on passenger costs and airline revenues	**-0.37**	**0.12**	**0.25**
Increased airline costs	*-2.40*		
SUM economic effects	**-2.77**		

There are almost no net economic effects because of traffic deterrence from a 20% increase in airfares. There are negative net economic effects mainly because of increased passenger and airline costs. All affected flights include the same number of seats as today, serviced by a 19 seat aircraft and increased frequency.

Table 7.19 Scenario P2: Continued use of HVG with 19 seat aircraft, 50 % fare increase.

P2: Smaller aircraft. +50% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers Costs waiting for next departure Costs deterred passengers Costs transferred passengers	-2.09 - -0.18 -	-0.94 - -0.07 -	-1.13 - -0.11 -
Costs, passengers	*-2.27*	*-1.11*	*-1.14*
Costs per passenger	*-450*		
Increased airfare revenues	2.07	0.94	1.13
Lost airfare revenues, deterred passengers	-0.85	-0.27	-0.58
Revenue increase, airlines	*1.22*	*0.67*	*0.55*
Effects on passenger costs and airline revenues	**-1.05**	**-0.44**	**-0.59**
Increased airline costs	*-2.40*		
SUM economic effects	**-3.45**		

The net economic effects compared with P1 are slightly negative because of increased traffic deterrence from a 50% increase in airfares. As for P1, all affected flights include the same number of seats as today, serviced by a 19 seat aircraft and increased frequency.

Table 7.20 Scenario P3: Winter closure of HVG for 39 seat aircraft, transfer to LKL.

P3: Planned transfer to LKL (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers Costs waiting for next departure Costs deterred passengers Costs transferred passengers	- - -0.71 -3.40	- - -0.43 -1.86	- - -0.26 -1.56
Costs, passengers	*-4.11*	*-2.29*	*-1.82*
Costs per passenger		*-822*	
Lost airfare revenues, deterred passengers	-1.56	-0.68	-0.88
Revenue loss, airlines	*-1.56*	*-0.68*	*-0.88*
Effects on passenger costs and airline revenues	**-5.67**	**-2.97**	**-2.70**
Reduced airline costs	*-0.50*		
SUM economic effects	**-6.17**		

There are negative net economic effects because of an increase in travel costs and a significant reduction in airfare revenues, due to traffic deterrence because of a time consuming transfer to LKL for all passengers to/from HFT and TOS. The flight distance to LKL is somewhat shorter than to HVG, but the resulting effect depends on the routing pattern.

Table 7.21 Scenario P4: Affected landings on HVG get a planned transfer to LKL.

P4: Planned transfer to LKL (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-	-	-
Costs deterred passengers	-0.13	-0.08	-0.05
Costs transferred passengers	-0.65	-0.35	-0.30
Costs, passengers	*-0.78*	*-0.43*	*-0.35*
Costs per passenger	*-821*		
Lost airfare revenues, deterred passengers	-0.30	-0.13	-0.17
Revenue loss, airlines	*-0.30*	*-0.13*	*-0.17*
Effects on passenger costs and airline revenues	**-1.08**	**-0.56**	**-0.52**
Reduced airline costs	*0.5*		
SUM economic effects	**-0.58**		

There are negative net economic effects even from a limited number of affected landings because of an increase in travel costs and a reduction in airfare revenues, due to traffic deterrence because of transfer to LKL. Even if the aggregated numbers are small, there are noticeable effects for the passengers.

Table 7.22 Scenario U1: Affected landings on HVG get a spontaneous transfer to LKL.

U1: Unforeseen transfer to LKL (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-0.91	-0.43	-0.48
Costs deterred passengers	-0.14	-0.10	-0.04
Costs transferred passengers	-1.02	-0.58	-0.44
Costs, passengers	-2.07	**-1.11**	**-0.96**
Costs per passenger	*-2178*		
Lost airfare revenues, deterred passengers	-0.10	-0.04	-0.06
Revenue loss, airlines	*-0.10*	*-0.04*	*-0.06*
Effects on passenger costs and airline revenues	**-2.17**	**-1.15**	**-1.02**
Increased airline costs	*-1.5*		
SUM economic effects	**-3.67**		

There are relatively high negative net economic effects for each passenger, because of a significant increase in travel costs. There is a limited number of affected landings. The traffic deterrence loss occurs because of a time consuming transfer to LKL and penalties connected to the unforeseen nature of the transfer, like extra waiting time. A roughly estimated 0.5 hour extra flight time including holding is counted for in the airline costs.

7.4 VADSØ (VDS)

Vadsø Airport; IATA: VDS, ICAO: ENVD is a regional airport in Vadsø Municipality in Finnmark county, Norway. The airport is located in the village of Kiby, 4 kilometers east of the town of Vadsø along the Varangerfjorden. The airport is operated by the state-owned Avinor and handled 62,485 passengers in 2017. The asphalt runway is 997 meters (3,271 ft) long. Services are provided by Widerøe using Dash 8-100 aircraft to other communities in Finnmark. The routes are subsidized by the Ministry of Transport and Communications through public service obligations. Vadsø is the center of Finnmark couny, and the city will have important administrative function for the merged Troms and Finnmark counties from 2020 on.

Table 7.23 shows the share of local municipalities that uses VDS. The table also presents the travel times and distances between the municipalities and VDS and Vardø (VAW).

Table 7.23 Travel flows from local municipalities, travel times and distances to VDS and VAW

Travel flows, local municipalities	Percent, %	Time and distance to VDS	Time and distance to VAW
Vadsø	83,9 %	7min / 4km	1h min / 71km
Vardø	3,1 %	1h / 71km	7min / 4km
Tana	8,4 %	1h 5min / 72km	1h 55min / 137km
Nesseby	2,5 %	50min / 55km	1h 30min / 107km
Sør-Varanger	2,1 %	1h 30min / 177km	3h 10min /244km
Sum	100 %		

In the table below the share of destinations for flights from VDS is presented.

Table 7.24 Share of destinations on travels from VDS

Destination	OSL	TOS	Local	Sum
	52,5 %	44,2 %	3,3 %	100 %

Table 7.25 shows the impacts on regularity for Vadsø Airport (VDS).

Table 7.25 Impacts on landings and number of passengers, VDS. Winter 2016-17.

Factor	Number of landings (% in brackets)	Passengers arrived/departed, all
Affected landings	197 (16)	4,100
Other landings with Braking Actions report (“restricted landings”)	518 (41)	10,500
All landings	1,254 (100)	25,600

The table shows that around 16 per cent of the landings are likely to become affected, whereas around 41 per cent is likely to give a Braking Action Report. Table 7.26-7.30 show the economic effects for various stakeholders at VDS, calculated for the five different scenarios described above.

Table 7.26 Scenario P1: Continued use of VDS with 19 seat aircraft, 20 % fare increase.

P1: Smaller aircraft. +20% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	-4.79	-2.38	-2.42
Costs waiting for next departure	-	-	-
Costs deterred passengers	-0.14	-0.06	-0.08
Costs transferred passengers	-	-	-
Costs, passengers	*-4.93*	*-2.44*	*-2.49*
Costs per passenger	*-193*		
Increased airfare revenues	4.79	2.38	2.41
Lost airfare revenues, deterred passengers	-1.50	-0.53	-0.97
Revenue increase, airlines	*3.29*	*1.85*	*1.44*
Effects on passengers and airline revenues	**-1.64**	**-0.59**	**-1.05**
Increased airline costs	*-8.50*		
SUM economic effects	**-10.10**		

There is a negative net economic effect because of passenger costs from a 20% increase in airfares. All affected flights include the same number of seats as today, serviced by a 19 seat aircraft and increased frequency.

Table 7.27 Scenario P2: Continued use of VDS with 19 seat aircraft, 50 % fare increase.

P2: Smaller aircraft. +50% on today's airfare (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	-10.99	-5.56	-5.43
Costs waiting for next departure	-	-	-
Costs deterred passengers	-0.83	-0.17	-0.50
Costs transferred passengers	-	-	-
Costs, passengers	*-11.82*	*-5.89*	*-5.93*
Costs per passenger	*-462*		
Increased airfare revenues	10.99	5.56	5.43
Lost airfare revenues, deterred passengers	-3.78	-1.35	-2.43
Revenue increase, airlines	*7.21*	*4.21*	*3.00*
Effects on passenger costs and airline revenues	**-4.61**	**-1.68**	**-2.93**
Increased airline costs	*-8.50*		
SUM economic effects	**-13.11**		

The net economic effects compared with P1 are slightly more negative because of increased traffic deterrence from a 50% increase in airfares. As for P1, all affected flights include the same number of seats as today, serviced by a 19 seat aircraft and increased frequency.

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Table 7.28 Scenario P3: Winter closure of VDS for 39 seat aircraft, transfer to VAW.

P3: Planned transfer to VAW (all landings, numbers in mill. NOK)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-	-	-
Costs deterred passengers	-0.57	0.39	-0.18
Costs transferred passengers	-8.93	-5.45	-3.48
Costs, passengers	*-9.50*	*-5.84*	*-3.66*
Costs per passenger	*-371*		
Lost airfare revenues, deterred passengers	-2.88	-1.38	-1.50
Revenue loss, airlines	*-2.88*	*-1.38*	*-1.50*
Effects on passenger costs and airline revenues	**-12.38**	**-7.22**	**-4.98**
Increased airline costs	*-7.10*		
SUM economic effects	**-19.48**		

There are negative net economic effects because of an increase in travel costs and a significant reduction in airfare revenues, due to traffic deterrence because of transfer to VAW for all passengers to/from ALF and KKN. The flight distances are somewhat longer than from VDS, but the resulting effect depends on the routing pattern. In practice, some of the routes may be diverted to KKN, which means increased passenger costs but reduced airline costs.

Table 7.29 Scenario P4: Affected landings on VDS get a planned transfer to VAW.

P4: Planned transfer to VAW (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-	-	-
Costs deterred passengers	-0.09	-0.06	-0.03
Costs transferred passengers	-1.43	-0.87	-0.56
Costs, passengers	*-1.52*	*-0.93*	*-0.59*
Costs per passenger	*-371*		
Lost airfare revenues, deterred passengers	-0.46	-0.22	-0.24
Revenue loss, airlines	*-0.46*	*-0.22*	*-0.24*
Effects on passenger costs and airline revenues	**-1.98**	**-1.15**	**-0.83**
Increased airline costs	*-1.10*		
SUM economic effects	**-3.08**		

There are negative net economic effects even from a limited number of affected landings because of an increase in travel costs and a reduction in airfare revenues, due to traffic deterrence because of transfer to VAW. In practice, some of the routes may be diverted to KKN, which means increased passenger costs but reduced airline costs.

Table 7.30 Scenario U1: Affected landings on VDS get a spontaneous transfer to VAW.

U1: Unforeseen transfer to VAW (affected landings)	**Total**	**Business**	**Other**
Costs remaining passengers	-	-	-
Costs waiting for next departure	-3.20	-2.08	-1.12
Costs deterred passengers	-0.18	-0.13	-0.05
Costs transferred passengers	-3.02	-1.92	-1.10
Costs, passengers	*-6.40*	*-4.13*	*-2.27*
Costs per passenger	*-1561*		
Lost airfare revenues, deterred passengers	-0.23	-0.12	-0.11
Revenue loss, airlines	*-0.23*	*-0.12*	*-0.11*
Effects on passenger costs and airline revenues	**-6.63**	**-4.25**	**-2.38**
Increased airline costs	*-3.90*		
SUM economic effects	**-10.53**		

There are relatively high negative net economic effects for each passenger, because of a significant increase in travel costs. There is a limited number of affected landings. The traffic deterrence loss occurs because of transfer to VAW and penalties connected to the unforeseen nature of the transfer, like extra waiting time. A roughly estimated 0.5 hour extra flight time including holding is counted for in the airline costs. Some of the routes may be diverted to KKN in this case as well, which means increased passenger costs but reduced airline costs.

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APPENDIX

Driving time (in minutes) between municipalities and airports in Finnmark

	SOJ	HAA	HFT	HVG	MEH	BVG	BJF	VDS	VAW	ALF	LKL	KKN	TOS
Vardø								61	6			195	
Vadsø								7	60			132	
Hammerfest			7	155						121	129		
Kautokeino			233	275						113	166		
Alta			130	172						5	147		
Loppa		119	239	281						116	256		
Hasvik		19	370	412						248	388		
Kvalsund			38	126						92	100		
Måsøy			165	164						174	145		
Nordkapp			164	8	350					173	145		
Porsanger			132	137	212					141	6	281	
Karasjok			193	198	268					173	62	223	
Lebesby			352	357	35					361	222	277	
Gamvik			344	349	4			222		340	214	268	
Berlevåg			460	465	536	6	89	195		340	201	184	
Tana			331	336	406			67	116	311	201	106	
Nesseby			346	360	422			51	90	327	216	88	
Båtsfjord			433	437	292	95	11	167	220	413	302	206	
Sør-Varanger			416	421	492			148	201	396	285	16	

Distance (in km) between municipalities and airports in Finnmark

	SOJ	HAA	HFT	HVG	MEH	BVG	BJF	VDS	VAW	ALF	LKL	KKN	TOS
Vardø								71	4			235	
Vadsø								4	71			162	
Hammerfest			3	176						137	143		
Kautokeino			272	334						134	203		
Alta			142	205						3	172		
Loppa		32	259	322						120	289		
Hasvik		16	304	367						165	334		
Kvalsund			35	146						106	113		
Måsøy			170	178						193	154		
Nordkapp			182	5	387					205	166		
Porsanger			144	161	224					167	3	331	
Karasjok			219	236	297					201	76	257	
Lebesby			379	396	32					402	235	330	
Gamvik			369	386	2			260		392	226	320	
Berlevåg			532	549	610	4	88	205		395	228	221	
Tana			399	416	477			72	137	381	256	130	
Nesseby			417	445	495			55	107	399	274	111	
Båtsfjord			505	522	295	94	7	177	243	486	361	235	
Sør-Varanger			484	501	562			177	244	466	341	13	

Additional time spent and distance traveled for the five scenarios

	Additional time spent				Additional km (mi) traveled			
	KKN (LKL)	ALF (LKL)	HVG (LKL)	VDS (VAW)	KKN (LKL)	ALF (LKL)	HVG (LKL)	VDS (VAW)
P1	0	0	0	0	0	0	0	0
P2	0	0	0	0	0	0	0	0
P3	3h55min	2h	2h20min	50min	285km	140km	160km	62km
P4	3h55min	2h	2h20min	50min	285km	140km	160km	62km
U1	3h15min	2h50min*	2h20min*	1h20min*	330km*	170 km*	165km*	67km*

* For U1 it is assumed that the trip has already started so that the additional time is from the airport of origin or destination, where the unplanned disruption is assumed to be announced to the passengers. For the other scenarios, the trip is assumed to start at home or at the point of destination (e.g. the city center of Oslo) as planned at the outset.

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