



## Forecasting air traffic demand for major infrastructure changes

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### ARTICLE INFO

#### JEL classification:

D61  
E17  
H54  
L93

#### Keywords:

Airports  
Aviation  
Forecasting methods  
Traffic forecasts

### ABSTRACT

The paper provides a review of traffic forecasting methods and compares the predictions generated by using different quantitative methods based on a case example from a planned Norwegian airport. The paper focuses particularly on two forecasting methods. The case airport exemplifies how analogies as a forecasting method might be better suited than elasticity methods for studies of major changes in infrastructure. The difference in traffic forecasts will depend on the methodological approach chosen and some generic considerations are given on this topic. In the studied case, we find that the airport project has a negative net present value when the lowest traffic forecasts are used and a positive net present value when the highest traffic forecasts are used. Hence, the inability to draw unambiguous conclusions would be confusing for decision-makers when deciding on whether to build the airport.

### 1. Introduction

The process of planning new transport infrastructure requires the assessment of a wide range of social and economic impacts. The most common method for economic appraisal of projects is cost-benefit analysis (CBA), which aims to quantify and value relevant variables in order to assess a project's viability for society in economic terms. The accuracy of CBA depends on precise forecasts for a range of impact categories, of which the most important for transport infrastructure projects are construction costs and travel demand (Nicolaisen & Driscoll, 2014). The former is usually the biggest expense, while the latter is used to estimate travel time savings for existing and generated trips, which is by far the most dominant benefit in the majority of cases (Banister, 2008). Therefore, the quality and accuracy of ex-ante estimates of both investment costs and traffic volume are crucial for the outcome of a CBA. As CBA is often used to rank projects according to their economic merit, distorted values due to inaccurate forecasts could disturb the priority process and mislead decision-makers into making decisions based on wrong assumptions.

Traffic forecasts are predictions of traffic volumes at a given point in time in the future conditioned on the information we have today (point forecasts). If traffic forecasts are too low, effects that increase with traffic volume will be underestimated. This could, for example, result in under-dimensioning of facilities, such as a terminal at an airport or a lack of noise-mitigating measures (e.g. noise screens and barriers along a new

road) compared with what would have been the case with more accurate forecasts. If traffic forecasts are too high, the opposite would be the case – over-dimensioning of facilities. In both situations, inaccurate forecasts may lead to inappropriate policies and hence undesirable economic effects.

Some forecasting methods are best suited for making short-term forecasts, whereas other methods are most suitable for making long-term forecasts. Some methods are well suited for forecasting traffic on existing routes or markets, whereas other methods are more appropriate when traffic forecasts on new routes shall be prepared. Some methods are most suitable for analysing the expected effects of minor changes in the transport infrastructure, whereas other methods are more suitable when major changes are taking place (Makridakis, Wheelwright, & Hyndman, 1998). Furthermore, forecasting methods differ with respect to the need for data, the costs of obtaining the data, the time taken to prepare a forecast, and the costs of making a forecast (Hanke & Wichern, 2005).

Evaluations have shown that transport demand forecasts are often inaccurate (Flyvbjerg, Skamris Holm, & Buhl, 2005; Nicolaisen & Driscoll, 2014; Odeck, 2013; van Wee, 2007), and the reasons may include errors in the data material, choice of forecasting method, and/or the forecaster's competence, as well as dramatic events during the forecasting period (e.g. the September 11 attacks). However, according to van Wee (2007), poor forecasts could also be explained by the strategic behaviour of some actors. Therefore, improvements should not only be

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looked for in the area of transport modelling, but also focus on the institutional structures in which forecasts are developed, the people who do the forecasting, and the way forecasts are used and interpreted.

The aim of this paper is to compare the predictions of different methods used in making traffic forecasts. After a literature review focusing on the accuracy in traffic forecasts in transport projects, we present a case example of a planned Norwegian airport for which passenger traffic forecasts have varied considerably.

The paper is structured as follows. Section 2 gives a review of different quantitative methods used in traffic forecasting. Section 3 discusses the uncertainty in traffic forecasts for large transport infrastructure projects. Section 4 presents the airport project, for which different forecasts have been prepared for expected traffic at a new airport that will be built in the Helgeland district of Nordland County in Northern Norway. We discuss the applicability of two main types of forecasting approaches for making traffic forecasts for major transport infrastructure changes. Finally, Section 5 concludes and presents possible implications.

## 2. Quantitative forecasting methods

Forecasting techniques fall into two major categories: qualitative methods and quantitative methods. The first category is useful when little or no quantitative information is available, but sufficient qualitative knowledge exists (Makridakis et al., 1998). Qualitative methods include, for example, executive judgement, market research and Delphi techniques (Doganis, 2010). The second category is applicable when sufficient quantitative information is available. There is no absolute truth in forecasting and no optimal method that can guarantee accuracy exists (Doganis, 2010; Hanke & Wichern, 2005).

The forecasting methods are characterised by different methodological problems. For example, in the aviation industry airlines may prepare forecasts of traffic growth based on the assumption of continuation of current regulations and competitive conditions. The forecast can be for both passenger and freight traffic, segmented on a specific route, groups of routes or geographical regions. From these forecasts, airlines have to predict their own market share of the traffic, often under the assumption that business conditions will remain unchanged. However, this is rarely the case, at least not in the long run. Changes in economic activity, exchange rates, tourism preferences, and so forth can create uncertainty in forecasts. Additionally, demand is sensitive to changes in service quality, in the form of fares and aircraft type, frequencies, and schedules, among others. Expected changes in these factors must also be taken into consideration when traffic forecasts are prepared. Traffic forecasting for new routes, for which no historical traffic data exist, are usually the biggest challenge. Such forecasts may require different forecasting techniques from those normally used (Doganis, 2010).

According to Makridakis et al. (1998), quantitative forecasting can be applied when information about the past is available. The information can be quantified in the form of numerical data, based on the assumption that some aspect of the past pattern will continue into the future. Doganis (2010) distinguishes between time series projections (annual average growth, moving average growth, exponential smoothing, simple trend, and moving average trend) and causal models (regression analysis and gravity models). In addition, analogy methods can be used (i.e. in comparative studies).

*Time series forecasting* treats the system as a 'black box' and does not attempt to discover the factors affecting demand (Makridakis et al., 1998). The only independent variable affecting traffic is time; as time progresses, so too will traffic. The objective of time series forecasting is to discover the pattern in the historical data series and extrapolate that pattern into the future. When using average growth rate to forecast demand, historical traffic data for a given period (e.g. the last 10 years) can be used to estimate the average annual growth rate ( $b$ ) in that period. Assuming that traffic will continue to grow at the same rate, a

traffic forecast ( $y$ )  $t$  years ahead could be estimated by using the formula  $y(t) = a(1 + b)^t$ , where  $a$  is actual traffic last year. To dampen the effect of large traffic variations from one year to another, a moving average could be used to determine a trend. If we consider the recent past is a better determiner of the future than is the more distant past, exponential smoothing can be applied. Additionally, traffic demand can be estimated by using linear trend projections. Ordinary least squares (OLS) regression is used to estimate the growth rate ( $b$ ) either by using the actual historical traffic data (simple trend) or by using moving average data and estimating the moving average trend. A traffic forecast can then be made by using the formula  $y = a + bt$ , where  $a$  is estimated traffic last year.

*Causal models* or explanatory models assume that the demand ( $y$ ) exhibits an explanatory relationship with one or more independent variables ( $X$ ):  $y = f(X_1, X_2, \dots, X_n, \epsilon)$ , where  $n$  is the number of independent variables and  $\epsilon$  is the randomly distributed error term (see e.g. Wooldridge, 2006, p. 65). In aviation, two explanatory variables are most frequently used in traffic forecasting: airfare and some measure of per capita income (e.g. Tsekeris, 2009). If the functional relationship between the dependent variable and the independent variable is thought to be linear, the regression coefficients can be determined by performing regression analysis of historical data. Most airline forecasting models express the relationship between the dependent variables and the independent variables in logarithmic form (Clewlow, Sussman, & Balakrishnan, 2014), which make it easy to determine the elasticities with regard to the independent variables, such as price and income elasticities. When assuming the change in the independent variables from year  $t$  to  $t + k$ , price and income elasticities can be used to make a demand forecast for year  $t + k$ . However, the common approach of point-elasticities assume marginal changes which could make it unsuitable for assessing the effects related to major infrastructure investments (see discussion in section 4.3). Jørgensen and Solvoll (2012) estimated traffic forecasts (number of passengers) to/from Norwegian airports in 2020 and 2030 based on assumptions about the development in GNP, air fares and the price of using competing modes of transport.

Time series analysis and regression models often have relatively limited applicability when traffic forecasts for new routes are to be prepared. In this case, one possible approach is to use a gravity model, which is a subcategory of causal models (Doganis, 2010). Gravity models applied to the aviation industry assume that the air traffic between two points is proportional to the product of their populations and inversely proportional to the distance between them, so that  $T_{ij} = K((P_i P_j) / D_{ij})$ , where  $T_{ij}$  is the traffic between two airports  $i$  and  $j$ ,  $K$  is a constant,  $P_i$  and  $P_j$  are the populations of the catchment area for the airports, and  $D_{ij}$  is the distance between them. The great advantage of gravity models is their ability to forecast traffic between airports that have not been served by air links previously. As an example, Grosche, Rothlauf, and Heinzl (2007) present two gravity models for the estimation of air passenger volume between city pairs. Their generated data from flights between Germany and 28 European countries showed that the models were a good fit for the observed data.

*Analogy models* are a group of models used mainly in sales forecasting and are not common when forecasting air traffic demand. Historical analogy uses the demand for a similar item that was introduced in the past to judge the demand for a new item (Makridakis et al., 1998). For example, a publisher forecasts sales for a new book based on the assumption that it will follow the same pattern as that of a similar book published recently (Waters, 2003). The main problem is finding a recently introduced product that is similar enough, and has the characteristic life cycle curve to actual demand. In this regard, different approaches can be used. Green and Armstrong (2007) discuss a structured procedure that experts can use to work out forecasts by using analogies. Lee, Goodwin, Fildes, Nikolopoulos, and Lawrence (2007) conducted an experiment to investigate whether a forecasting support system could lead to more accurate forecasting by analogy. Dortmans

and Eiffe (2004) used historical analogies to improve and test the quality of a specific planning method scenario. In aviation, a variant of an analogy method was used to forecast demand for a new airport in the northern part of Norway (Müller, Bråthen, & Svendsen, 2015). A limitation of the analogy approach is that the interpretation and transferability of the results obtained in other periods and at other places would depend on the context.

We have only briefly accounted for qualitative and quantitative approaches to forecasting. Doganis (2010) provide further details on characteristics of the models. The aviation case addressed specifically in our study includes information suitable only for quantitative methods. Hence, we focus on some of these forecasting techniques in the following sections. While all methods can generate forecasts of traffic growth under normal conditions, only a few are suitable for forecasting demand on a new route or for a completely new airport. If the purpose is to make a traffic forecast on a new route, a qualitative technique or either a gravity or analogy method is most applicable.

### 3. The accuracy of traffic forecasts – some results from the literature

Traffic forecasts are by nature uncertain. In this section we will review findings from previous studies having compared traffic forecasts with real traffic. The extent to which a new road, metro, railway, or airport will be used will depend on macro-economic conditions such as income levels, demography and employment. It will also depend on the cost of using the new facility expressed by either generalised costs or ticket price. The price and quality of alternative modes of transport will also influence demand. Hence, uncertainty about future demand is inevitable, and has been demonstrated in a number of studies conducted within the transport sector.

The first large-sample study to investigate the accuracy of traffic forecasts was conducted by Flyvbjerg et al. (2005), who studied 210 road and rail projects from 14 countries. They found that the inaccuracy of forecasts was high: in 9 out of 10 rail projects, traffic was overestimated; the average overestimation was 106%; for half of all road projects, the difference between actual and forecasted traffic was more than  $\pm 20\%$ , and on average road traffic was 9.5% higher than forecasted in the first year of operations. Flyvbjerg et al. (2005) did not find any improvements in forecast accuracy during the 30-year period from which the sample was collected.

Nicolaisen and Driscoll (2014) reviewed 12 studies of road and rail forecast accuracy and found that inaccuracy was problematic for all categories of projects. Compared with the forecasts, the mean inaccuracy in the opening year varied from 65% below the forecasts to 23% above them. Further, Nicolaisen and Driscoll (2014) found that traffic was generally underestimated in road projects and overestimated in rail projects. In addition to the observed bias in forecasts, they pointed out the large variation in accuracy. The majority of studies reported standard deviations above 30%, while half the studies of rail projects reported standard deviations above 50%. Nicolaisen and Driscoll (2014) concluded that demand forecasts are not useless as decision support, but that the uncertainty upon which forecasts are made should be communicated to decision-makers.

Facilities based on user payment seem to be more vulnerable to overestimation than when usage is free. Odeck and Welde (2017) reviewed studies of toll road forecasts from around the world and found that traffic was generally overestimated. In their own sample of Norwegian toll projects, they found that traffic levels fitted well with forecasts, since traffic was on average just 4% above the forecasted amounts. However, the variation was high, with a sample standard deviation of 23% in the first year of operations (Odeck & Welde, 2017). The accuracy of aviation forecasts seems to be much less documented than the accuracy of forecasts of other modes of transport. The only study of multiple airports that we are aware of is that conducted by Maldonado (1990), cited in Mierzejewski (1995), who examined the

accuracy of 5-, 10- and 15-year forecasts for 22 airports in the New England region of the USA. The accuracy of five-year forecasts varied from  $-36\%$  to  $+96\%$ ; for 10 years it varied from  $-42\%$  to  $+140\%$ , and for 15 years it varied from  $-34\%$  to  $+210\%$ . The dispersion of results, measured by standard deviation, ranges from 30% to 69%.

In Norway, Oslo Airport (OSL), at Gardermoen, provides an interesting reference case. The airport opened in 1998 after decades of discussions. It replaced an airport situated much closer to the city centre of Oslo. The passenger forecasts for OSL were prepared by the Institute of Transport Economics and presented in a parliamentary bill in 1992, in which the Norwegian parliament made the formal decision to build the airport. The forecasts, which were based on a transport model for domestic air traffic and air transport to and from Norway, predicted 17.7 million terminal passengers at OSL in 2010 (NOU, 1999, p. 28). After the forecasts had been prepared, the Norwegian economy moved into a recession, followed by an economic recovery fuelled by high oil prices in 2000. Real traffic in 2010 turned out to be 19.1 million passengers, 14% above forecasts. The forecast for 2020 was 25.8 million terminal passengers, a level that was reached in 2016 (Avinor, 2017).

From the above-mentioned studies, it is evident that forecasting is by no means an exact science. As argued by de Neufville, Odoni, Belobaba, and Reynolds (2013, p. 671), 'any forecast of phenomena involving people is inherently unreliable and likely to be wrong'. This means that total accuracy is impossible and that some degree of uncertainty must be expected. However, it should be noted that most studies of forecast accuracy in the transport industry are based on improvements to existing infrastructure. Even then, the uncertainty measured by the standard deviation is normally high — up to 50%. This uncertainty may be at odds with the certainty of forecasts presented to decision-makers that normally are presented with point estimates of traffic levels. It is, however, out of scope for this study to measure the uncertainty of the studied forecasts.

### 4. The Helgeland aviation case

Norway has one of the highest air transport dependencies among all countries in Europe (Williams, Fewings, & Fuglum, 2007). While Norway had a domestic air trip rate per capita of 1.87 in 2003, most European countries had less than one-third of this value. The trip rate varies significantly between different regions of Norway. In the Helgeland district of the county of Nordland, there was a trip rate of 3.98 in 2003, which was the second highest after the northernmost county of Finnmark, which had a trip rate of 5.81 (Denstadli, Rideng, & Strand, 2004).

The state-owned company Avinor owns and operates 44 airports and one helipad in Norway, and the total annual traffic was 55 million terminal passengers in 2019. Many of these airports are regional airports with short runways (<1.199 m). To secure an appropriate public transport service in the rural areas of Norway, the government purchases flight connections – public service obligation (PSO) routes – between regional airports and to/from the nearest airport with flight connections to/from Oslo Airport (OSL) at Gardermoen. Norway holds nearly 20% of all restricted PSO routes in Europe (European Commission, 2019).

#### 4.1. The regional airports in Norway

The Norwegian network of regional airports was established at the end of the 1960s and during the 1970s. It has remained virtually unchanged since then. Since the 1970s, travel time by car between cities with regional airports has been considerably reduced due to investment in roads, bridges, tunnels, and ferry connections (Mathisen & Solvoll, 2012). The case airport is planned for the Helgeland district (Nordland County) in northern Norway (Fig. 1). Travel time by road between the three regional airports at Mo i Rana, Mosjøen and Sandnessjøen was reduced by more than 30% from 1967 to 2009, and there are further



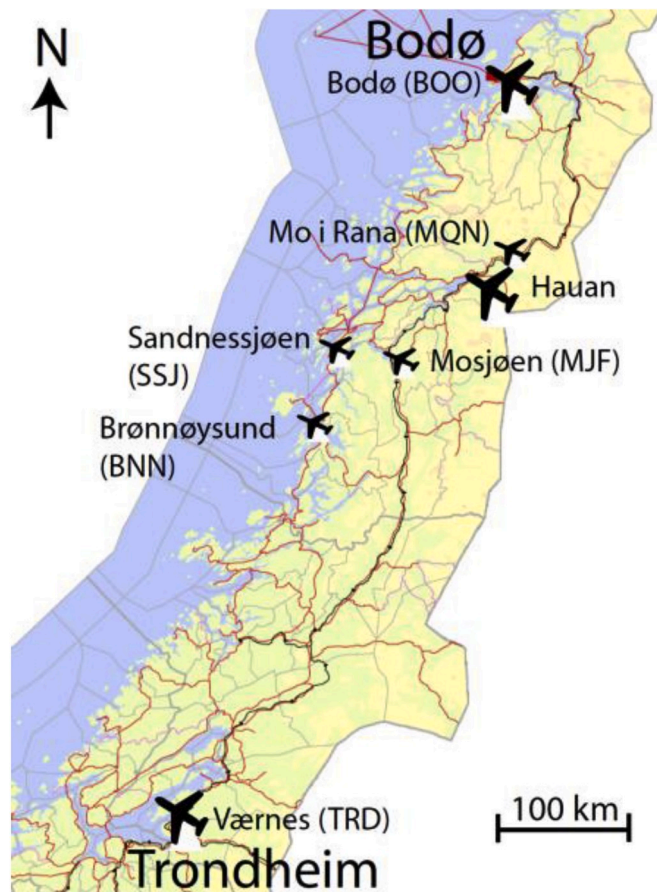


Fig. 1. Airport structure between Trondheim and Bodø, and the planned Hauan Airport (HAP).

planned improvements in the road infrastructure (Mathisen & Solvoll, 2012). This has revitalised the discussion about the structure of the regional airport network in Norway in general, and in the Helgeland district in particular (Lian & Rønnevik, 2011).

The Helgeland district is located some 900 km north of the capital city of Oslo and has about 85,000 inhabitants. The region is 18,800 km<sup>2</sup> and is dominated by the four towns of Brønnøysund, Sandnessjøen, Mosjøen, and Mo i Rana. Helgeland is one of the most important districts for salmon farming in Europe and is rich in natural resources. There is a well-developed manufacturing industry that makes use of extensive mineral resources. Since the early 1990s, oil and gas exploration has also become an increasingly important part of the economy in the Helgeland district.

There are four airports in the Helgeland district: Mo i Rana (MQN), Mosjøen (MJF), Sandnessjøen (SSJ), and Brønnøysund (BNN). All four airports provide direct flights using Bombardier Dash 8 aircraft on routes south to Trondheim and north to Bodø, the administrative centre of the County of Nordland. Flights to the capital, Oslo, involve transferring at either Bodø Airport or Trondheim Airport, and ticket prices are high.<sup>1</sup> Since the airports in Helgeland are relatively close in distance (ca. 110 km between Mosjøen Airport and Mo i Rana Airport) and since none of them can accommodate large jet aircraft, there has been a 20-year regional discussion on where to locate a new regional airport. After an assessment of 20 different locations, a political decision has been made to establish an airport with a long runway (>2,000 m) outside the

<sup>1</sup> In addition, there are some commercial (non-PSO routes) non-stop flights to Oslo from SSJ, BNN and MQN.

largest town in the region, Mo i Rana. The new airport, Hauan (HAP)<sup>2</sup> will replace the existing airport, at Mo i Rana (MQN), and will affect the catchment area of the airports in Mosjøen and Sandnessjøen. The users of Brønnøysund Airport is located too far away to be part of the primary catchment area to HAP (see Fig. 1).

The investment costs for HAP is estimated to be approximately NOK 2.36 billion (Meld.St. 33 (2016–2017)), where the Norwegian government will contribute with NOK 1.23 billion and local industry and the municipality of Mo i Rana with the remaining funds. A new airport is expected to be a major contributor to regional development in the airport's catchment area.

#### 4.2. Forecasts

A number of traffic forecasts have been made for a new regional airport in Helgeland, financed by both private and public clients, and carried out by a variety of research institutions and consultants. The forecasts are based on different methods and assumptions. In all studies, the existing airport MQN is assumed to be discontinued. In Table 1, we build on the work of Solvoll and Mathisen (2016), who compared all available forecasts and transformed them to a common opening year that was set to 2025. The passenger traffic forecasts are divided into forecasts for both the total number of passengers and the number of passengers on an expected new direct connection to/from the capital Oslo, called the Oslo route. The forecasts with a reference year earlier than 2015 were adjusted with actual growth in air traffic at the three Helgeland airports from the forecasts' reference year to 2015.<sup>3</sup> Furthermore, the annual traffic growth rate was set to 0.9% between 2015 and 2025 for these forecasts, and between the actual reference year and 2025 for the other forecasts. This was the growth rate used by the most conservative study. It is somewhat lower than the 1.7% used in Avinor's perspective analysis with a horizon toward 2040 (Avinor, 2015).

The forecasting methods and the assumptions made in the different studies on which Table 1 is based are not commented on further in this paper. The main purpose of Table 1 is to highlight the differences in the traffic forecasts and group the studies into the method categories 'elasticity', 'analogy' and 'transport model'. For further information about the preparation of the different forecasts, see the references cited in the notes to Table 1.

The forecasts can be grouped into three categories of models according to method: 'elasticity', 'analogy' and 'transport model'. The elasticity methods are causal models (see Section 2), in which price elasticities are used to estimate an expected rise in traffic demand due to expected changes in generalised travel costs (the sum of passengers, money cost, and time cost of the journey) for the inhabitants in the new airport's catchment area. Studies that applied analogy methods to forecast expected traffic at a new major airport in Helgeland compared the traffic at other airports with long runways and adjusted for differences in population density in the airports' catchment areas, differences in industry structure and the access to transport alternatives (e.g. Müller et al., 2015). Studies using this method have also pointed out the weakness of comparing cases with different contexts (e.g. Hanssen et al., 2008).

The transport model forecasts used the Norwegian national transport model (NTM6) for passengers taking long distance trips. With respect to

<sup>2</sup> The abbreviation HAP is used as an example to indicate Hauan Airport. Since the old airport will be closed down, it is possible that the new airport will have the IATA code MQN.

<sup>3</sup> In Table 1, for the methods 'elasticity' and 'transport model', the reference year is the year for which the traffic forecast is intended to be valid. For the methods 'analogy', the reference year reflects the year in which the data used to make the forecast are valid. The year for which the forecast is assumed valid is not specified.

**Table 1**

Passenger traffic forecasts for Hauan Airport (HAP) by performing institution, method, reference year, funding, and assumptions about the airport structure in the Helgeland district (developed from Solvoll & Mathisen, 2016).

Study <sup>a</sup>	Method	Reference year	Funding	Change in airport structure	Number of passengers extrapolated to 2025		Oslo route's share of total
					Oslo route	Total	
HHN 1	Elasticity	2007	Private	MQN closed down	185,000	265,000	70%
HHN 2	Analogy	2007	Private	MQN closed down	230,000	330,000	70%
TØI <sup>b</sup>	Elasticity	2018	Private	MQN, MJF and SSJ closed down	153,000	394,000	39%
Gravity 1	Elasticity	2018	Public	MQN closed down	162,000	262,000	62%
Gravity 2	Elasticity	2018	Public	MQN and MJF closed down	175,000	305,000	57%
GMT	Elasticity	2011	Private	MQN and MJF closed down	160,000	221,000	72%
Urbanet 1	Elasticity	2025	Public	MQN closed down	85,000	164,000	52%
Urbanet 2	Elasticity	2025	Public	MQN and MJF closed down	100,000	196,000	51%
MFM 1	Analogy	2014	Private	MQN closed down	307,000	–	–
MFM 2	Analogy	2014	Private	MQN closed down	362,000	–	–
MFM 3	Transport model	2025	Private	MQN and MJF closed down	400,000	–	–
				Average	210,818	267,125	
				Standard deviation	98,458	70,122	
				Minimum	85,000	164,000	
				Maximum	400,000	394,000	

<sup>a</sup> HHN = Nord University Business School ([www.nord.no](http://www.nord.no)), Hanssen, Mathisen, and Solvoll (2008); TØI = Institute of Transport Economics ([www.toi.no](http://www.toi.no)), Thune-Larsen and Lian (2009); Gravity = Gravity Consult ([www.gravityconsult.com](http://www.gravityconsult.com)), Draagen and Wilsberg (2011); GMT = Gravity Consult, Møreforsking Molde and Institute of Transport Economics, Bråthen et al. (2012); Urbanet = Urbanet Analyse ([www.urbanet.no](http://www.urbanet.no)), Øvrum and Berg (2015); MFM = Møreforsking Molde ([www.moreforsk.no](http://www.moreforsk.no)), Müller et al. (2015; 2016).

<sup>b</sup> The forecast from TØI was not made for Hauan, but for a possible airport located more centrally in the catchment area than Hauan.

the methods described in Section 2, the model is constructed based on a gravity approach. The models included in the NTM6 system can estimate the number of trips, choice of transport mode and destination (differentiated on travel purpose) between zones located more than 75 km from each other. For a thorough description of the model, see Rekdal et al. (2014).

It is evident from Table 1 that traffic forecasts for the Oslo route vary from 85,000 to 400,000 annual passengers, and the route's share of total traffic varies from 39% to 72%. The analysis with the lowest share estimate (Thune-Larsen & Lian, 2009) is the only analysis in which it is assumed that both MQN, MJF and SSJ are closed down.

The substantial differences in expected numbers of passengers on the Oslo route are due both to the use of different forecasting methods and the underlying assumptions. For the group of forecasts using 'elasticity methods' this includes assumptions such as the new airport's catchment area, ticket prices, price elasticities of demand and the actual traffic in the reference year. Interestingly, the seven forecasts made using an 'elasticity method' all have estimates of the number of passengers that are in part significantly lower than in the three forecasts made using an analogy method and in the forecast made with the use of the transport model (NTM6) (see Fig. 2).

With expected investments costs, Øvrum and Berg (2015), reporting the lowest traffic forecast, calculated that the airport would make a negative net present value, whereas Müller, Rekdal, Svendsen, Zhang, and Bråthen (2016), reporting the highest traffic forecast, concludes that the airport will generate a positive net present value. The main reason for Muller et al.'s conclusion is that the large difference in the number of passengers will lead to a significantly larger consumer surplus. Since benefits normally increase with traffic volume, there is a direct relationship between the benefit–cost ratio and forecast when the cost estimate is constant. Both of the above-mentioned analyses took into account the economic consequences of reduced numbers of transfer passengers at the airports in Bodø and Trondheim.

Table 1 illustrates that the forecasts differ in some of their assumptions regarding future airport structure in the Helgeland district. In addition, the assumptions regarding the size of the catchment area, and the expected competition among the airlines differ, but this information is not given in Table 1. There is consensus among the forecasters that a non-stop route flown by passenger jet aircraft to Oslo would be an important demand driver for the passenger traffic at HAP. The range in traffic forecasts for the Oslo route is illustrated in Fig. 2.

Fig. 2 clearly shows that forecasts made by use of causal methods

(elasticity methods) give significantly lower forecasts than forecasts made using analogies or using the National Transport Model (NTM6). It is also interesting to observe that the five highest forecasts all had private funding (see Table 1), which included funding from the company responsible for planning and constructing the new airport. The lowest traffic forecast was commissioned by the Ministry of Transport and Communications. Thus, there is a need to consider both who has developed the forecasts and who has financed them when interpreting the results of forecasts. Furthermore, it suggests that there may be a need to remove the bias from forecasts by using external quality assurance and due diligence when taking investment decisions based on forecasts of future traffic demand (Flyvbjerg, 2013).

#### 4.3. Comparison of the forecasts according to different methods

The main weakness with the elasticity method is its validity only for marginal changes (Pindyck & Rubinfeld, 2013). Expected changes in the price and quality of the air services between HAP and OSL are not marginal. The major challenge with the analogy method is to find airports located in regions that are comparable to Helgeland (Müller et al., 2016). However, it is important to keep in mind that forecasts made using the analogy method, as used by Müller et al. (2016), are not directly comparable with forecasts made using the elasticity method. The elasticity method gives the expected traffic change immediately after the airport is opened. When using the analogy method, it is assumed that the forecast reflects traffic after the market has 'settled' in the long run. This means that we have a market in which demand and supply have 'converged' over time.

In the following, we look at the two main forecast approaches: 'analogy' and 'elasticity'. In Fig. 3, the horizontal axis denotes time ( $t$ ) and the number of passengers ( $X$ ) is measured along the vertical axis. It should be noted that the curves in Fig. 3 are merely an illustration of the concepts and the traffic growth, and do not represent any specific mathematical relationships.

We start at time  $t_0$ , which represents the forecast origin – the time when the forecast is prepared. There is an underlying growth in the number of passengers until the airport opens at time  $t_1$ , which for the case airport is 2025. In total, this growth has been 2.4% per year from 2007 to 2015 at the three airports in the Helgeland district. When the new airport opens, and better air services are available, we get an immediate growth in traffic of  $(X_1 - X_0)$  passengers at time  $t_1$ . This increase is estimated, for example by Hanssen et al. (2008), to be about 50%

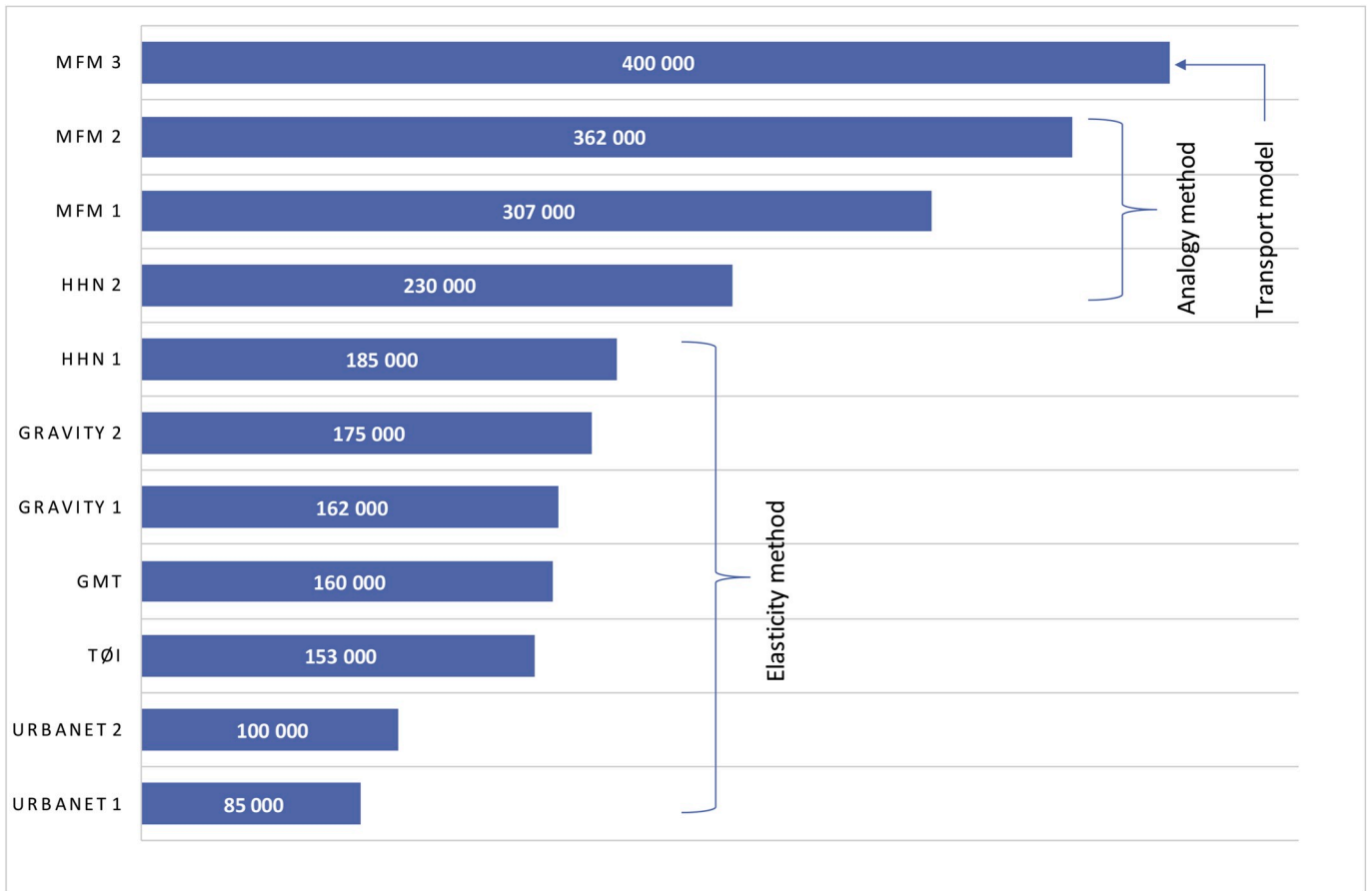


Fig. 2. Traffic forecasts (annual number of passengers) for the route between Hauan Airport (HAP) and Oslo (OSL) by performing institution. Reference year 2025 (developed from Solvoll & Mathisen, 2016).

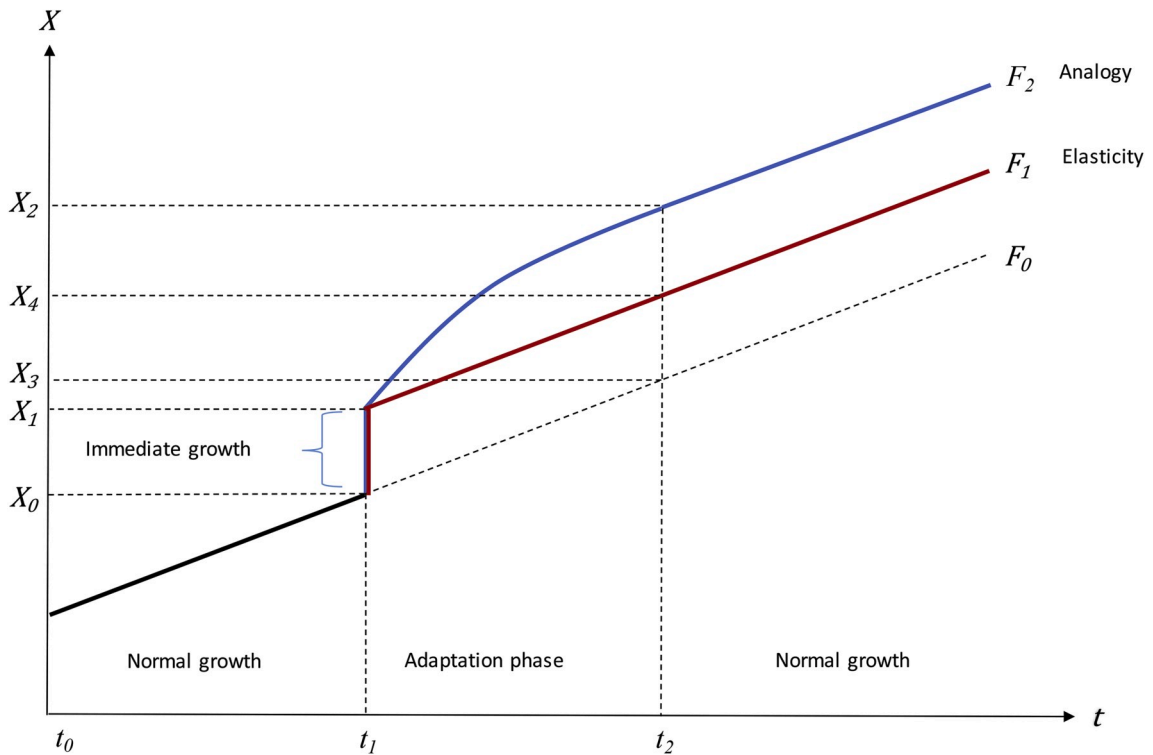


Fig. 3. Principal graph of forecasted traffic growth following the establishment of a new major airport.

based on change in generalised travel cost, a price elasticity of demand of  $-0.7$  for business trips and  $-1.0$  for leisure trips, and the precondition that the ticket price for both business and leisure trips makes up some 60% of generalised travel costs.

Furthermore, the new air services will provide an expected higher annual traffic growth than the underlying growth before the airport opened. This 'extraordinary' growth takes place in what we have denoted the adaptation phase, and is expected to last until time  $t_2$ . Thereafter, traffic growth follows normal growth, as for comparable airports. The magnitude of the 'extraordinary' growth will depend on both the supply side and the demand side, where the supply side will be influenced by the competition and the demand side by demographic conditions and business activity.

The growth curves in Fig. 3, with the exception of the adaptation phase, are illustrated by straight lines for simplicity. Fig. 3 aims to present a generic framework and is therefore not directly related to the growth rates forming the basis for the forecasts in Table 1. However, with equal percentage annual growth we get a convexly increasing curve. Nevertheless, the interpretation of Fig. 3 is not determined by the slope of the lines. In a very long time horizon it is reasonable to assume that air traffic will reach a saturation level. For example, Jørgensen, Mathisen, and Solvoll (2011) provide a forecast for traffic to/from Norwegian airports made with GDP in Norway and with price indexes for flights and for other transport alternatives as explanatory variables. Since it is very difficult to specify the saturation level for air traffic, an S-curve is estimated, in which the saturation level is calculated from the estimation results. However, with regard to Fig. 3, the saturation level would occur far to the right of  $t_2$ .

In Norway, increased frequencies and lower prices on the main air routes followed when the low-cost carrier Norwegian started operations in competition with Scandinavian Airlines (SAS) in 2002. This led to a growth in the number of passengers. Most of the increase in the number of passengers came quite early after the change in the competitive situation. This situation indicates that the growth in air traffic after a significant service improvement is largest initially and gradually flattens out and returns to the underlying national growth.

In Fig. 3,  $X_1$  is the traffic forecast for the reference year  $t_1$  when using the elasticity method. When we use the analogy method, the passenger forecast obtained can be interpreted as  $X_2$ . This number of passengers will be reached at time  $t_2$ , which is the point in time at which we assume that the extraordinary traffic growth in the adaptation phase has converged towards the underlying national growth. Consequently, traffic forecasts made using the two different methods are not directly comparable in time because it is difficult to relate the traffic forecast made using an analogy method to a specific point in time. In Fig. 3, we show a situation in which we assume that the adaptation phase ends at time  $t_2$ . When we extrapolate the forecasts made for time  $t_1$  using the elasticity method and the expected underlying national traffic growth rate (line  $F_0$ ), we get the traffic forecast  $X_4$ . Without the new airport, we assume that traffic growth would have followed the growth rate  $F_0$ , with a corresponding traffic forecast at time  $t_2$  of  $X_3$ .

Using the above-described two methods, the difference in traffic forecast at time  $t_2$  depends partly on the size of the extraordinary traffic growth in the adaptation phase ( $X_2 - X_4$ ) and partly on the assumptions about the underlying national traffic growth rate, the slope of the line  $F_0$ . The difference is therefore dependent on the size of the short-run and long-run generalised travel cost elasticity. In a case with marginal service improvements after the opening of a new airport, the short-run and

long-run elasticities will be about equal, implying that  $(X_2 - X_4) \approx 0$ . However, with large improvements in services, such as presumed in Fig. 3,  $(X_2 - X_4) > 0$ . If the long-run generalised travel cost elasticity were known at time  $t_0$ , differences in traffic forecasts made using the elasticity method and the analogy method would be reduced.<sup>4</sup>

The duration of time period ( $t_2 - t_1$ ) will vary between projects and is difficult to estimate precisely. However, it is reasonable to assume that most of the 'extraordinary' traffic growth occurs quite early after the opening year because the airline operators have been able to prepare for the opportunities offered by the new airport long before it opens, and thus can adjust their routes to/from the airport early.

## 5. Summary and concluding remarks

In this paper, we have compared predictions based on different methods to forecast the traffic level on new airports using the case of a planned Norwegian airport for which traffic forecasts have varied considerably.

The need for long-term traffic forecasts creates particular challenges because of the high levels of uncertainty relating to many of the key factors that influence future air traffic. For the case airport, Hauan, ten traffic forecasts for the main route vary from 85,000 to 400,000 annual passengers (370% difference). With investment costs of approximately NOK 2.4 billion in 2017, the airport has been found to have a negative net present value (NPV) according to the lowest traffic forecast, and a positive NPV according to the highest forecasts. This would be confusing for decision-makers when deciding whether to build the airport.

We argue that forecast methods with strengths when estimating the effects of marginal quality changes, are less suitable for making traffic forecasts for projects that are expected to cause significant changes in passengers' generalised travel costs. Consequently, in these cases, analogy methods are expected to be better suited than more traditional methodologies based on an elasticity approach. Since the decision to build the airport in the Helgeland district has been made, evidence regarding traffic figures will emerge in a few years. Furthermore, our data indicate that reports financed by private organisations acting as airport promoters have the highest traffic forecasts. Whether or not that is the case for other controversial transport projects is uncertain, but funding organisations should be aware that it is a potential issue. However, in the case of Hauan Airport, it is the choice of method and assumptions that must be debated, not the potential motives of those who have funded the study.

Historically, regional policy objectives have been important in Norway, which has made positive regional impacts more important for project priorities than net economic benefits calculated by a CBA (Knowles, 1981). In our case, this is reflected in the political debate regarding the new airport.

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<sup>4</sup> Normally, long-run elasticities are greater than short-elasticities in absolute terms. All things equal, this implies that the analogy method, taking the long-run perspective, gives higher traffic forecasts than the elasticity method. However, with the increased environmental focus and the introduction of the term 'flight shame' in 2019, it is possible to imagine that this could change in the future.



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