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Determining optimal frequency at ferry crossings

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ABSTRACT

The paper derives a model that shows how welfare optimal frequency at a ferry crossing depends on its level of traffic, ferry users' time costs, the cost structure of ferry operations, and the length of the crossing. The model takes into account the fact that travellers may not arrive randomly at the ferry terminals due to long headways, and it demonstrates in a clear way the influences of crossing and ferry fleet characteristics on optimal frequency. Using Norwegian data for ferry users' time costs and for the costs of operating ferry services, the model's results indicate that the authorities recommend too low a frequency, especially on high-traffic ferry crossings. The results also emphasise that the length of the crossing has a great impact on optimal frequency; optimal frequency at long crossings is less than half that of short crossings for all levels of traffic. Lastly, the model shows that it is more serious from a welfare perspective to undersupply frequency with X units than to oversupply it with X units.

1. Introduction

From an economic point of view, the service level in scheduled passenger transport is important for two reasons. First, important service elements, such as the quality of the means of transport and the number of departures per day, strongly influence the direct and external costs of operating the services. Second, the service level influences the passengers' generalised travel costs and, thereby, their welfare; see, for example, Jørgensen and Pedersen (2004), Mathisen and Solvoll (2010), and Laird (2012). Taken together, these two impacts affect the social surplus of the service in question. Consequently, setting the right service level for public transport is an important task for the transport operators and authorities (Mathisen and Solvoll, 2010; Preston, 2015).

Ferry services play an important role in the national transport system in European countries with long coastlines and many inhabited islands. This is definitely the case in Norway. In 2014, there were 121 ferry crossings in Norway, served by approximately 160 ferries. When we disregard some small ferry crossings, the crossings were operated by four shipping companies. A national administration reform implied, among other things, that the administrative responsibility for quite a few of the ferry crossings was transferred from the central authorities to the Norwegian county councils on 1 January 2010. As the counties do not necessarily have to follow the current national ferry standard, the transfer of responsibility paved the way for differentiation between crossings with respect to service level and fare setting.

Even though many ferry services in Norway have been replaced with bridges and underwater tunnels during the last two decades, the ferries still serve a very important function in the transport infrastructure in coastal areas. Without these ferry crossings, many settlements and enterprises along the Norwegian coastline could not be upheld. For example, analysis shows that approximately 75 percent of the Norwegian ferry crossings were profitable from a social welfare point of view, but only *one* was run without subsidies (Jørgensen et al., 2011). In 2014, the ferries carried more than 21 million vehicles, 34.5 million passenger car equivalents (PCE),[1] and approximately 42.5 million passengers (including drivers). The cost of operating the ferry services this year was approximately 5000 million NOK (approximately 590 million €), and the revenue from vehicles and passengers was approximately 2600 million NOK. This resulted in a subsidy requirement of approximately 2400 million NOK.[2] For further descriptions of the Norwegian ferry industry, see, for example, Jørgensen et al. (2012).

The aim of this article is to estimate how optimal frequency, defined by the level of frequency that minimises total social costs of the ferry operations, is influenced by

- The predetermined level of traffic.

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[1] PCE is a compound production measure introduced to handle the multiproduct problems related to transporting different types of vehicles. For example, a passenger car (<6 m) counts as 1.025 PCE, whereas a heavy goods vehicle (>19 m) counts as 10.682 PCE. In Norway, the vehicles are grouped into nine different categories. For a thorough description of the PCE concept, we refer to Mathisen (2008).

[2] The numbers for costs, revenues, and subsidies are relatively rough estimates given by the Norwegian Public Roads Administration.

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- The ferry users' time costs.
- The costs of ferry operations.
- The length of the crossing.

These issues are very important to the authorities when defining requirements regarding the frequency of crossings in tenders.

The article is organised as follows: Chapter 2 gives a brief literature review of work related to setting the optimal frequency for public transport. Chapter 3 presents briefly the Norwegian nationwide ferry standard guidelines. In Chapter 4, we discuss how different crossing-specific factors influence optimal frequency from a welfare perspective and give numerical estimates of optimal frequency using Norwegian data. These estimates are compared with the guidelines for daily frequency of ferries. Lastly, in Chapter 5, some conclusions and possible implications for policy makers are drawn.

2. Literature review

Optimal service level and optimal pricing for public entities have received attention from several researchers. In this chapter we will focus, in chronological order, on some relevant works published during the last forty years on these issues. Many contributions have focused on the socially optimal simultaneous choice of price and service level for monopolies; see, for example, Spence (1975) for a general discussion on whether profit maximisation monopolies undersupply quality. There is an extensive body of literature dealing with frequency and price decisions, and quite a few works dealing with transport issues have focused on optimal quality setting for public transport.

Panzar (1979), in dealing with air transport, determined optimal price and frequency, specifying demand as a function of these two variables and the load factor. Jansson (1993) analyses the simultaneous optimisation of price and frequency. He emphasises two important effects of frequency on passenger behaviour. The first effect is the dual behaviour, indicating that, for low-frequency services with a reliable timetable, travellers plan their trips according to the table, whereas for high-frequency services, they prefer to arrive at the stops spontaneously, rather than consult a timetable. The second effect relates to the fact that the disutility of waiting at stops is higher than is that of waiting at home or at work, and that the passengers' waiting time costs may vary with the duration of the wait.

An analysis of an airline's choice of service level under two network types, shows that both social optimal flight frequency, traffic level and aircraft size are higher than the monopoly solution gives, (Brueckner, 2004). Zhang et al. (2006) developed a regression-based methodology for determining the optimal combination of policy instruments, using the predictions from a conventional transport model. The methodology has been applied to six UK cities. In a scenario in which public transport fare changes are not allowed, the model suggests an increase in frequencies that require significant funds to finance the increases in frequencies. It is also relevant to mention the article by Fosgerau (2009), which developed a model that aims to derive the marginal social cost of headway for a scheduled service. The model takes into account the travellers' scheduling considerations, such as the share of users who plan for a specific departure as a function of headway, the value of waiting time, and the planning costs.

Chien et al. (2010) investigated the relationship between stop spacing and headway, considering a realistic wait time and operable transit capacity. Their model's objective function is users' travel time, which is minimised by the optimised stop spacing and headway, subject to the constraints of operable fleet size and route capacity. dell'Olio et al. (2011) used an optimisation model for sizing the buses and setting frequencies on each route in the system with constraints on bus capacity and levels of demand. The model considers the optimisation of the system's social and operating costs; these are understood to be the sum of the user's and operator's costs. Hadas and Shnaiderman (2012) used a model where the objective function is to minimise the total costs of a public transit system with decision variables of either frequency or vehicle capacity (vehicle size).

Based on a preliminary work by Jørgensen and Pedersen (2004), Jørgensen et al. (2013) discussed service level issues when transport operators placed different weight on profit versus consumer surplus and under specific assumptions regarding the demand and cost structures they are facing. The findings transferred to our problem imply that when ferry operators wish to maximise profit and can control both fare and service level, their fare will be higher than the welfare optimal fare, whilst it is uncertain whether they will undersupply quality. The latter depends on both the demand and the cost conditions that the operators face at the different crossings. Consequently, the degree to which operators' chosen service level differs from the welfare optimal level may vary between different ferry services, even though the operators pursue the same goals. Ferry users' generalised travel costs will, however, always increase the higher the weight that the operators place on profits. This means that the effect of increasing fare will always outweigh the eventual benefits from better transport quality.[3]

When the fare level is uncontrollable for the ferry operators (as in Norway), profit maximising ferry operators will always set a service level (e.g., frequency) that is lower than the welfare optimal one and, hence, users' generalised travel costs are higher than they should be from a welfare perspective (Jørgensen et al., 2013; Gómez-Lobo, 2014). Whether the magnitude of the difference between welfare optimal quality and quality set by profit-maximising companies' increases with the level of the predetermined fare is uncertain, see Jørgensen et al. (2013) for a thorough discussion of this issue.

In the end we will mention two recently published works by Dandapat and Maitra (2015) and Börjesson et al. (2017). The first one demonstrates an approach for identifying an optimal bus service, giving due consideration to both user costs and operational viability. The effects of demand level and route length on optimal service attributes were also analysed. The last one develops a model to derive optimal bus pricing, bus frequency, bus size and bus lanes for a congested corridor in Stockholm. It concludes that optimizing bus frequencies for the current prices increases welfare significantly. Optimal pricing adds a relatively small welfare gain when compared to the welfare gain obtained by optimizing frequencies.

Summing up, the total welfare and distributional effects of different price and quality levels within public transport are thoroughly analysed theoretically, and empirically for some modes of transport. Ferry transport is, however, scarcely dealt with empirically, probably due to lack of available data. It is also worth noting that the substantial literature on frequency decisions mostly focuses on high frequency services where users randomly arrive at the place of departure. However, for less frequent services, like Norwegian ferry services, most users will plan their trips according to the timetables. This fact is accounted for in our frequency modelling. Our work is, therefore, the first attempt to deduce optimal frequency for ferries using available data for demand and costs.

3. Guidelines regarding service quality

National Transport Plan 2014–2023 (Meld.St.26 to the Storting, 2012–2013) defines the government's transport policy regarding all public transport infrastructure, whether it is by road, rail, air, or sea. Although the counties are responsible for quite a few ferry crossings, the Norwegian ferry operations are still highly regulated by the state with respect to fare and quality setting. Two of the most important service elements, frequency and opening hours, are according to the National Transport Plan determined by the amount of traffic and the classification of the crossing. An extract from the national ferry standard is shown in Table 1.

[3] A transport user's generalised costs (G) are given by the sum of the fare (P) and the time costs of the journey (TC); that is $G = P + TC$. When operators place a higher weight on profits versus consumer surplus, G will increase. Thus, $\Delta P > -\Delta TC$.