Journal of Maritime Research, Vol. IV. No. 3, pp. 55-66, 2007
Copyright © 2007. SEECMAR

Printed in Santander (Spain).
ISSN: 1697-4840

VESSEL CAPACITY UTILISATION IN FERRY SERVICES AND THE BRIDGE SUBSTITUTE DILEMMA

L. Styhre[1] and K. Lumsden[2]

Received 2 April 2007; received in revised form 11 ApRil 2007; accepted 28 August 2007

ABSTRACT

The purposes of this paper are to investigate vessel capacity utilisation in Scandinavian ferry services and to describe the concept of bridge substitute. The paper relies upon goods and passenger statistics for 19 ferry services that operate within and to/from Sweden, Denmark and Norway. The empirical outcome shows that the average annual utilisation of the vessels is 42.3% and proves that there are considerable imbalances and variations in goods and passenger flows. Furthermore, there is a relationship between vessel capacity utilisation and frequency: the utilisation is significant lower for routes with high frequency.

The paper focuses in particular on ferry services with high frequency that often fulfil the same function as a bridge, and on the understanding of the variables defining this "bridge substitute". The bridge substitute function requires good accessibility to transport networks, high frequency and excess capacity in order to reduce the total transport time for goods and vehicles by minimising the waiting time in port. The five bridge substitutes included in the study showed all a frequency above 100 departures per week and an average vessel capacity utilisation of 33.6%.

Keywords: Ferry service, capacity utilisation, vessel capacity, frequency, bridge substitute.

---

[1] Project manager, SSPA Sweden (linda.styhre@sspa.se), Chalmers tvargata 10, 40022, Göteborg, Sweden.

[2] Professor, Chalmers University of technology, (kenth.lumsden@chalmers.se), Vera Sandbergs allé, 41396, Göteborg, Sweden.

INTRODUCTION

Within the geographic area of the Scandinavian countries there exists a multitude of sea links supporting the societal and commercial needs of transportation and logistics. Ferry and RoRo traffic are important components in this international transport network. Even though the market development for ferry services in recent years has faced some challenges, for example the construction of fixed links (e.g. the Öresund Bridge between Malmö and Copenhagen), new regulations and increased price of fuel (Dunlop, 2002), the goods transportation in Scandinavia has increased over the last few years. The intra-European trade and travel is rapidly expanding and cost-efficient, convenient and easily accessible transport connections are critical especially to the peripheral regions and nations (Baird, 1997).

The purpose of this paper is to investigate vessel capacity utilisation in Scandinavian ferry services. The paper focuses also on the understanding of the variables defining the "bridge substitute", i.e. short sea shipping links with good accessibility, high frequency and excess capacity.

METHODOLOGY

This paper relies upon goods and passenger data for 19 ferry services, within and to/from Sweden, Denmark and Norway (see appendix). Ten of the main shipping companies in the region are operating the routes. The transport time, distance and frequency for each route were compiled, and the maximum available lane metres (the method of measuring space capacity of ferry and RoRo ships) were collected for each vessel operating one of the routes. The different vehicles (private cars, caravans, buses, trailers with/without tow cars and lorries with/without trailers), reported on a monthly basis for export and import during the year 2004, were converted into used lane metres per month. The vessel capacity utilisation was considered to be the ratio of the actual vessel utilisation to the maximum vessel capacity. ANOVA and the Tukey's post hoc test were used for calculation of significant differences between the groups of routes.

This study has highlighted the benefits of focusing on the physical capacity utilisation of the vessels and not on price or profitability of services. Thus, a more general approach was created that enabled a comparison between sea links and between shipping concepts.

FRAMES OF REFERENCES

Physical capacity utilisation in transportation

Capacity utilisation is an important performance measure in transportation. Factors that have an effect on the transport company's ability to make use of available resources can be divided into five groups (adapted from Lumsden,1995):

— *Structural imbalances (LCU_S)* in the goods flow caused by an uneven transport demand in a bi-directional transport relation.

— *Operational imbalances (LCU_O)* occur when the goods and the resources are not optimally adapted to each other.

— *Technical imbalances (LCU_T)* occur when a carrier (e.g. vessel) is not adapted technically to varying types of goods.

— *Chain imbalances (LCU_C)* are caused by delays and unadjusted time schedules in the links and in the nodes, which affect the goods' total time through the chain.

— *Demand imbalances (LCU_D)* are caused by variations in demand (e.g. seasonal variations, state of the market).

A transport system can be the subject of different imbalances that cause losses in capacity utilisation (LCU) according to:

$$\text{Capacity utilisation} = 1 - (LCU_S + LCU_O + LCU_T + LCU_C + LCU_D).$$

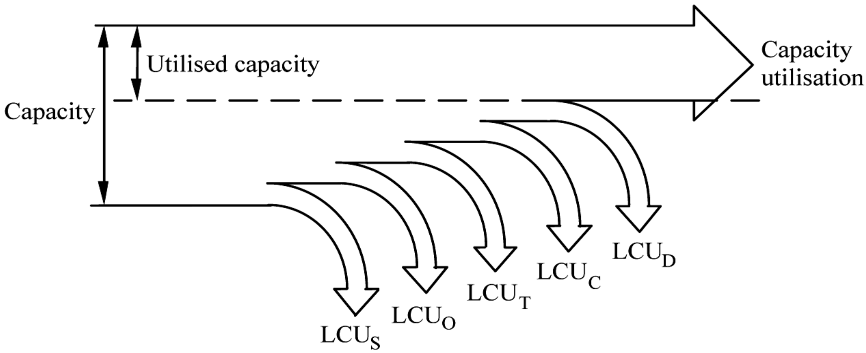

Figure 1. Different losses in capacity utilisation (adapted from Lumsden, 1995).

The imbalances are an artefact of technical factors and structural conditions of supply and demand. Imbalances due to trade pattern often involve substantially excess capacity as the shipping companies have to deploy larger vessels then necessary for the low season or for the low volume sea leg (Haralambides, 2004). This might result in significant costs. Liner shipping is particularly vulnerable to issues of matching supply and demand because of large variable demands, fixed supply in the short term and a considerable time between ordering and addition of new productive capacity (Fusillo, 2004).

Excess capacity may also be the result of strategic behaviour (Wenders, 1971; Hilke, 1984; Lieberman, 1987; Driver, 2000; Fusillo, 2003), as it can perform the function of a buffer, for precautionary reasons (Driver, 2000). Profit-maximising companies hold precautionary extra capacity in markets where demand is cyclical or stochastic or where resources are inherently lumpy or subject to economics of scale (Lieberman, 1987). Excess capacity may also be employed as a strategic defence against rivals when a threat of entry or expansion is revealed (Spence, 1977; Hilke, 1984; Lieberman, 1987; Driver, 2000; Fusillo, 2003). The company can immediately decrease prices or increase output when entry is threatened without incurring large incremental costs. Thereby, the probability of entry is decreased by reducing the revenue prospects of potential entrants. Furthermore, larger vessels increase the shipping companies' choices (Fusillo, 2003), and also capture economies of scale which provide lower units costs. If the cost of supply shortage is higher than the cost of carrying excess capacity, the companies are more likely to err on the side of excess capacity rather than be caught short during periods of high demand (Fusillo, 2003).

The trends concerning distribution are more frequent deliveries (Lumsden, 1995), which can lead to inventory savings (Lagoudis et al., 2002). As the need for goods transportation is a derived demand from the trade and manufacturing industry (Hultén, 1997), this has resulted in increased frequency in the transport system. The importance of high frequency for shipping services is for example emphasised in studies of ferry choice in RoRo freight transportation (Mangan, 2002) and freight mode choice (Lagoudis et al., 2002; Shinghal and Fowkes, 2002). The increased frequency brings about a trade-off with economies of scale for the transport companies. The average waiting time in the nodes, and thereby the total transport time, decreases for the customers at the expense of excess capacity in the transport system.

The concept of the bridge substitute

Due to the geographical characteristics of Scandinavia, which is almost surrounded by water, short sea shipping is an important complement to the land-based infrastructure. Some ferry services are intimately connected to the road and railway networks to such an extent that they serve as replacements for bridges, and therefore can be regarded as "bridge substitutes". The function of the bridge substitute requires similar adaptability as a bridge in order to meet the demands from the user of the ferry link and to minimise the waiting time for the goods and vehicles in port. Important requirements that need to be fulfilled are:

— Good accessibility to other transport networks
— High frequency
— Excess capacity

Equivalent terms and concepts exist within shipping and transportation, e.g. bridge concept, land bridge, trailer bridge and airlift. However, these concepts show quite different characteristics and are not defined in this context.

EMPIRICAL OUTCOME

Level of vessel capacity utilisation

The empirical data of the 19 studied ferry services within and to/from Scandinavia shows that the average annual utilisation of the vessels reaches 42.3% of the total capacity, with an annual mean value per route from 23.5-62.9%. Although most shipping companies reduce the number of departures during the low season, the vessel capacity utilisation in November is as low as 35.4%, whereas the utilisation during the busiest month July, comes to 53.8% on average (table 1).

Table 1. Average vessel capacity utilisation per month for the 19 ferry routes.

	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Mean	35.9	37.9	40.7	43.2	44.6	44.4	53.8	50.7	41.5	41.2	35.4	36.5
Maximum	63.1	67.7	93.7	73.5	78.3	72.8	81.0	100.8	74.6	68.6	62.2	64.2
Minimum	18.5	21.5	24.3	20.2	20.2	12.7	19.9	25.6	4.4	18.2	18.0	17.8
Standard deviation	13.9	12.9	17.1	17.3	16.6	15.6	15.5	19.1	17.6	15.0	11.4	11.9

Structural imbalances in goods and passenger flows

All the studied ferry services show structural imbalances of export and import of goods (trucks and lorries). When the passenger vehicles (personal cars, buses and caravans) are also included, the total imbalances of inbound / outbound vehicles are reduced, since the deviations in the incoming and the outgoing passenger flows are much lower than for the goods transportation. Consequently, ferry services with a higher proportion of passengers onboard do not suffer as much as goods ferry services when it comes to structural imbalances. In table 2, the level of structural imbalances and the fraction of goods onboard (related to total transported lane meters) are shown. The t-test confirms that the differences between the two groups are significant ($P<0.05$).

Table 2. Structural imbalances in the total flows of goods and passenger vehicles.

Imbalances inbound / outbound	Number of routes*	Mean imbalances	Standard deviation	Average % goods
<10%	12	2.9	2.2	32.4
>10%	5	31.7	11.5	58.3

* In two cases, the export and import figures were summarised and structural imbalances can not be calculated.

Imbalances due to seasonal variations

Fluctuation of goods volumes and number of passengers due to seasonal variations is apparent for most ferry routes (in four cases no conclusions can be drawn since there are too few departures part of the year). The significant increase in passengers in July and August implies that the majority of the vessels' resources are engaged with personal cars, caravans and buses. At the same time, holidays implies a reduction of lorries and trucks onboard the vessels. Total utilised lane meters (lm) for the 19 ferry services are shown in figure 2.

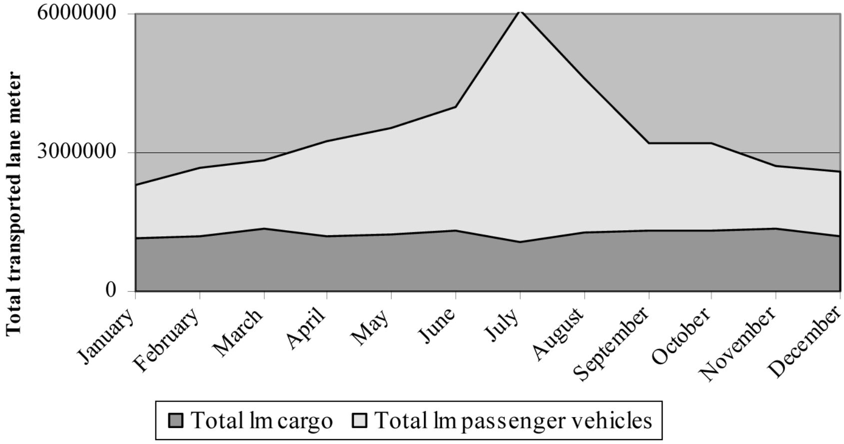

Figure 2. Total transported lane meters per month for the included ferry services show seasonal variations of goods and passenger vehicles.

Vessel capacity utilisation and frequency

The empirical outcome shows a relation between vessel capacity utilisation and departure frequency. The utilisation is significantly lower for routes with high frequency (figure 3). The ferry services with a frequency above 100 departures/week (total numbers of departures in both directions, which implies at least 7 departures/day in each direction) show an average vessel capacity utilisation of 33.6% (table 3). The result of one way ANOVA indicates a significant difference between the three groups ($F = 28.24$, $P < 0.0001$).The Tukey's method of post hoc comparison indicates that there are significant differences between the three groups at the 0.05 level.

Table 3. Total vessel capacity utilisation (as %) for the 19 routes grouped into frequency ranges.

Departures/week	<10	10-100	>100
Average annual vessel capacity utilisation	46.8	44.3	33.6
Standard deviation	15.3	11.6	8.6
Average departures/week	6	27	448
Average distance	196	105	19
Numbers of routes	6	8	5

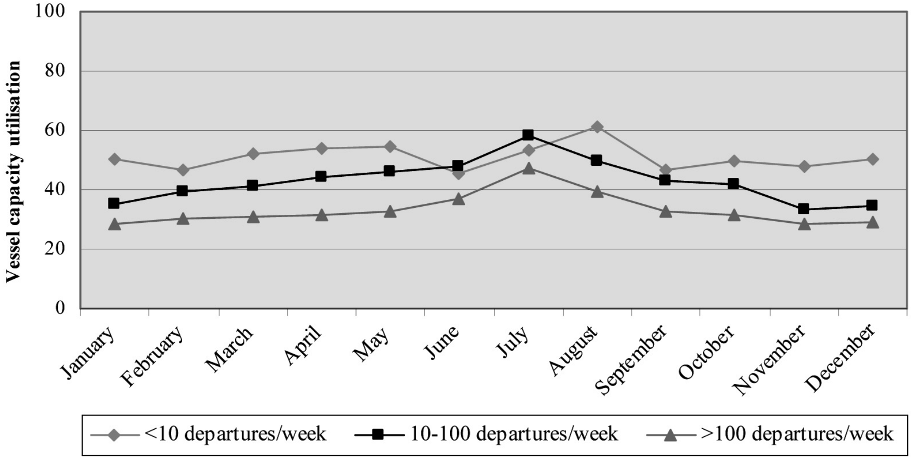

Figure 3. Relations between vessel capacity utilisation and frequency reported on a monthly basis.

The bridge substitute in practice

The bridge substitute needs to meet the requirements for 1) good accessibility to transport networks, 2) high frequency, and 3) excess capacity. The five ferry services in the group "more than 100 departures/week" fulfil these requirements and are therefore classified as bridge substitutes (table 4).

Table 4. Characteristics for the five bridge substitutes.

	Frequency (dep./week)	Distance (nm)	Transport time (h)	Average waiting time in port**
Gedser - Rostock	107	30	1 h 45 min	3 h 8 min
Göteborg - Fredrikshamn	109	50	3 h	3 h 4 min
Helsingborg - Helsingör*	505	2	20 min	40 min
Rodby - Puttgarden	684	10	45 min	29 min
Helsingborg - Helsingör*	833	2	20 min	24 min

* Two shipping companies operate the route Helsingborg - Helsingor.
** "Average waiting time in port" is the expected average time for the vehicle or passenger with random arrival in port.

First, the accessibility to the ports is good, as the five ferry services classified as bridge substitutes are integrated and complementary parts of the land-based infrastructure and they bridge natural gaps over sounds and channels. Second, frequent departures assure short waiting time for goods and passengers in port. All the routes have a frequency that exceeds 100 departures per week, which means at least 7 departures/day in both directions. This corresponds to an average waiting time in port of 24 minutes for the route with the highest frequency: Helsingborg – Helsingor. Third, the study shows that the bridge substitutes have a high level of excess capacity with an annual average vessel capacity utilisation of 33.6% per departure. However, even if the monthly utilisation is low, some of the departures during the peak season are certainly full booked, even though the monthly reported transport figures do not allow an analysis of each single departure. It should also be noted that the vessels operating high-frequency round-the-clock services often spend less time in port compared to other vessels in short sea shipping. This implies that even though the vessel has large unutilised capacity per departure, the total utilisation of the vessel per year can still be high.

The transport distances for the five ferry services are fairly short. This is not a necessity for a bridge substitute, but a longer distance requires a larger fleet in order to maintain the high frequency. This is possible if the volume of goods or the number of passengers is high, which is not the case for Scandinavia. In other regions, for example in some densely populated parts of the world, the maximum distance for bridge substitutes is probably longer than in Scandinavia. This relationship between high frequency and short distance and vice versa can be seen in table 3.

DISCUSSION AND CONCLUSION

In shipping, increases or reductions in capacity are made in large and discreet units, at relatively high cost and often with a substantial time between ordering and installing. Due to losses in capacity and institutional peculiarities, the average annual vessel capacity utilisation in the studied Scandinavian ferry services only reached 42.3%.

Losses in capacity were identified in the 19 ferry services. First, *structural imbalances* in export and import figures were noted. These imbalances are difficult to handle or reduce in size because they are due to international transport patterns and caused by density of the population, separations of centres of production and consumption, type of transported goods, alternative infrastructure, etc. Second, *demand imbalances* probably cause the main losses in capacity utilisation, since the size of the vessel needs to be matched to the highest peak in the summer. As a consequence the vessels have a high level of excess capacity during the rest of the year. Shipping companies handle these variations by influencing the travel pattern by price differentiation, or by adding and removing departures. However, withdrawing capacity is costly and it may be more economical to sail even if the level of utilisation is extremely low. Even though the passenger traffic counterbalances some of the larger structural imbalances and variation in demand, these discrepancies are still of major concern for the ferry operators.

Losses can also be caused by: *Operational imbalances*, i.e. discrepancies between goods and carriers. One important issue related to providing enough vessel capacity at the right time and place is the sailing schedule. The shipping company's timetable needs to be adjusted to suit transport demands, customers' working hours, travel pattern, port slots and travel time among others. Operational imbalances are not further discussed in this paper. Neither are *technical imbalances* that are linked to the load units and vehicles a ferry accommodates. Finally, *Chain imbalances* are not included in the study since there is a focus in this paper on the sea links with a firm perspective on the shipping company rather than a goods flow perspective (Styhre, 2005) that includes the whole chain from sender to receiver.

Low vessel utilisation due to a chronic level of excess capacity can also be explained by strategic motives. One important issue is "the concept of oversized ships". An oversized ship is in the short run too large for its transported goods volumes, which results in a high level of excess capacity. Nevertheless, this extra capacity implies that the shipping companies avoid turning down transport assignments and that they are in a better position with respect to competitors. Even though this involves higher costs, this does not mean that it will be unprofitable. However, the excess capacity should be increased only up to that point where the incremental benefits are matched by the incremental costs. Further, with linear demand growth overtime and new capacity added in large and discreet sizes, oversized ships makes future growth in volume possible, without the need for new investments in vessels. Consequently, a certain amount of unutilised capacity is tolerable in the shipping industry.

Finally, this paper shows that unutilised vessel capacity is a prerequisite of the creation of efficient shipping bridges. A "bridge substitute" can be defined by its function: to bridge gaps between land borne transport networks, offering high-frequent departures and enough capacity in order to limit the waiting time for goods and passengers in port. The bridge substitute dilemma is the trade-off between the demands for accessibility to transport networks, high frequency and excess capacity as set by the shipping companies' customers, and internal goals for high vessel capacity utilisation.

REFERENCES

Baird, A. (1997) A Scottish east coast European ferry service: review of the issues. *Journal of Transport Geography,* 5 (4), 291-302.

Driver, C. (2000) Capacity Utilisation and Excess Capacity: Theory, Evidence, and Policy. *Review of Industrial Organization*, 16, 69-87.

Dunlop, G. (2002) The European ferry industry – challenges and changes. *International Journal of Transport Management,* 1 (2), 115-116.

Fusillo, M. (2003) Excess Capacity and Entry Deterrence: The Case of Ocean Liner Shipping Markets. *Maritime Economics and Logistics,* 5 (2), 100-115.

Fusillo, M. (2004) Is liner shipping supply fixed? *Maritime Economics & Logistics*, 6, 220-235.

Haralambides, H. E. (2004) Determinants of price and price stability in liner shipping, *Workshop on the Industrial Organization of Shipping and Ports.* National University of Singapore, Singapore.

Hilke, J.C. (1984) Excess Capacity and Entry: Some Empirical Evidence. *The Journal of Industrial Economics,* 33 (2), 233-240.

Hultén, L. A.R. (1997) *Container logistics and its management.* Göteborg: Chalmers University of Technology.

Lagoudis, I. N., Lalwani, C. S., Naim, M. M., King J. (2002) Defining a conceptual model for high-speed vessels. *International Journal of Transport Management,* 1 (2), 69-78.

Lieberman, M. (1987) Excess Capacity as a Barrier to Entry: An Empirical Appraisal. *The Journal of Industrial Economics*, 35 (4), 607-627.

Lumsden, K. (1995) *Transportekonomi – Logistiska modeller för resursflöden*. Lund: Studentlitteratur.

Mangan, J., Lalwani, C., Gardner, B. (2002) Modelling port/ferry choice in RoRo freight transportation. *International Journal of Transport Management,* 1 (2), 15-28.

Shinghal, N., Fowkes, T. (2002) Freight mode choice and adaptive stated preferences. *Transportation Research Part E.* 38 (5), 367-378.

Spence, M. (1977) Entry, capacity, investments and oligopolistic pricing. *Bell Journal of Economics,* 8 (2), 534-544.

Styhre, L. (2005) *Towards improved port performance in intermodal transportation*. Göteborg: Chalmers University of Technology.

Wenders, J. (1971) Excess capacity as a barrier to entry. *The Journal of Industrial Economics*, 20 (1), 14-19.

APPENDIX

Table 5. Shipping services and routes included in the study.

Route	Shipping company	App. transport time (h)*	App. distance (nm)**	Frequency (dep./year)***
Frederikshavn - Larvik	Color Line	6.5	105	941
Frederikshavn - Oslo	Stena Line	8.5	156	647
Gedser - Rostock	Scandlines	1.75	30	5577
Göteborg - Fredrikshamn	Stena Line	3	50	5687
Hanstholm - Egersund-Haugesund - Berge	Fjordline	18	280	352
Hanstholm - Torshavn	Smyril Line	35.5	550	118
Havneby - List	Romo-Sylt Linie	0.6	3	2464
Helsingborg - Helsingör	Scandlines	0.33	2	43331
Helsingborg - Helsingör	HH - ferries	0.33	2	26285
Hirtshals - Kristiansand	Color Line	4.5	69	2105
Hirtshals - Larvik	Color Line	5.5	87	407
Hirtshals - Oslo	Color Line	9	139	614
Kobenhavn - Oslo	DFDS Seaways	16.5	272	728
Kobenhavn - Swinoujscie	Polferries	9	130	496
Rodby - Puttgarden	Scandlines	0.75	10	35544
Ronne - Sassnitz	Scandlines	3.5	52	334
Ronne - Swinoujscie	Polferries	5.25	76	24
Varberg - Grenå	Stena Line	4.25	61	781
Ystad - Ronne	BornholmsTrafikken	2	36	2918

* Source: Shipping companies' sailing lists.
** Source: www.world-register.org/dist.htm, www.distances.com and users.pandora.be/tree/wreck/north-sea/distances.html.
*** Source: Danmarks Statistiks opgørelse af transport i internationalt færgefart til og fra Danmark 2004.