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Small Island Public Transport Service Levels: Operational Model for Estonia

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ABSTRACT: The maritime connections are vital to success of islands. Estonia has 19 permanently habited islands with at least five inhabitants. 16 of those are considered as small islands with an area below 100 km2. Their sea connections are secured (i.e. organized, financed) by the government or municipality. These small islands are very diverse - in terms of population, economic activity, infrastructure capacity and needs, etc. In this study, we have analyzed ten connections to seven Estonian small islands based on seven criteria. The criteria are as follows: passenger and vehicle volumes, frequency, reliability, speed and time, vessel suitability, harbours and transport access to the harbours from the landside. Thereafter, we have classified the connections to islands to four levels: (i) daily, (ii) scheduled, (iii) invitation-only and (iv) tourism. Finally, we raised several actions to improve the connections based on the defined service levels. This article addresses the problem of small island communities, the criteria that influence service, proposes service levels and scenarios and the tools for decision-makers to better organise the connections to island communities and to serve local residents and business as well as tourism. Keywords: small islands, connectivity, sustainability, connection service levels, adequate resources.

1 INTRODUCTION

According to the EU Treaty of Functioning islands are considered as one of the least favoured regions in terms of economic, social and territorial cohesion. [1] In order to increase cohesion and reduce disparity accessibility is key for islands sustainability and therefore in Estonia it is responsibility of the state or municipality by the law. Accessibility must be sufficient to ensure that the island's inhabitants can carry out their daily activities and have access to services and supplies.

Islands are not similar in terms of distance from either mainland or major city or populated area, accessibility by transport (boat, plane, car). It is therefore necessary to look at the transport connection for each island separately. When selecting the suitable transport connection, one must also take the limited and optimal use of public resources into account. Decision makers must find a compromise between conflicting interests. On the one hand, good and adequate connectivity, and on the other hand, public resource constraints make it difficult to make decisions that satisfy all parties.

The research question of this study is to analyse the maritime connections to seven Estonian small islands – Ruhnu, Kihnu, Manilaid, Abruka, Vormsi, Prangli anf Piirissaar. The managerial result of the study suggestion of the service levels of the small island connections. For this work, interviews were conducted with different actors involved in the community, statistical material from 2017 to 2020 was

analysed, and how the same problem has been addressed in other research articles was examined.

2 LITERATURE REVIEW

Transport and logistics studies focus mainly on liner shipping and freight logistics. Studies of ferry transport connections and accessibility are scarce but still exist. In most of those approaches, many measurement methods have been developed for land transport and urban areas, which may not be directly applicable to measuring transport options in the archipelago when the ferry-based transport system is, in many respects, a specific case. [2]. Previous studies have looked, for example, at traffic management between the Canary Islands [3] ferry services in Scotland with Baird [4] and Laird [5], and Greek ferry connections in Spilan [6]. The Norwegian ferry connections have been thoroughly studied by Odeck and Høyem, dealing with both logistical [7], [8]and operators' procurement arrangements [9]. Also, Norwegian samples of service quality aspects were researched by Mathisen et al.[10]. The organization of transport connections between the islands of Finland has been analyzed by Makkonen [2], As well as the Finnish ministry of agriculture and forestry[11]. Tanko et al. the comparative analysis focused on the innovative transport policy of urban areas in Sweden and Australia, namely ferry-oriented development (FOD)[12].

The first concept of Levels-of-Services (LOS) in ferry systems was already developed more than 30 years ago in the USA by Khisty [13]. Jorgensen et al. proposed a model for designing capacity and service levels based on data from research on Norwegian ferry users' habits. [14].

Their model illustrates how varied factors like route lengths and size of ferries affect the optimal value of one of the most important service elements, namely frequency. It also shows the importance of having reliable forecasts for these variables over the contract period. The larger uncertainty in these variables, the more reasonable it would be for transportation administrations to design flexible tenders that can be changed during the contract period.

According to Spilanis et al., the islands, especially the smaller ones, are characterized by a disruption of space and are considered one of the least accessible areas. This shift in emphasis will consider additional aspects of accessibility, which include the availability of access services necessary to meet the needs of islanders and the needs of the various destinations where they may be available, and the time that may have to be spent on accessing these services to reach those destinations. Islanders face-off, especially for smaller islands, where access to selected services can require up to four destinations, with virtual distances 4 to 6 times longer than "actual distances." What is the "actual" distance between the two points in time? Geographical distance measures when two places are located "far" or "close,"; but this is not enough to assess the complexity of access. Geographical distance only partially determines the accessibility of small islands. The choice of transport is limited to public transportation at fixed frequencies, where the transport time is much higher (and the cost). In addition, different services are in other destinations. Combined with the inability to return overnight from many of these destinations, it can take several days to return from the trip. Therefore, the geography of the inhabitants of these small islands seems to be very different from the "usual" map, according to these factors, space contracts, or subtractions. [6]

Accessibility is the main output of a transport system. It determines the locational advantage of an area relative to others. [15] Accessibility for islanders has both a "real" and "psychological" or perceived dimension: the first is related to infrastructure or services (available transportation modes and the quality of each craft/vessel), the frequency of connections, the destination (the mainland, or another island) about the reason for travel, and of course cost. The latter dimension is related to how people perceive and evaluate accessibility. [16] Makkonen et al. discovered a close connection between island population distribution patterns and transport opportunities; as a rule, the islands with the largest populations have the best ferry transport services.

3 CURRENT SITUATION

Eurostat defines island for NUTS 3 level island regions as territories having: minimum surface of 1 km^2; a minimum distance between the island and the mainland of 1 km; a resident population of more than 50 inhabitants; no fixed link (for example, a bridge, a tunnel, or a dyke) between the island(s) and the mainland. [17] In Estonia, the island is classified habited when they have only 5 people living there. According to the Estonian "Permanently Inhabited Small Islands Act" there are big islands and small islands. Big islands are Saaremaa, Hiiumaa and Muhu [18]. Small islands are considered to be islands with an area below 100 km2 and with a population of at least five inhabitants. [18] The list of small islands is established by a regulation of the Government of the Republic of Estonia. Currently there are 17 small islands on the list [19]: Abruka island, Aegna island, Heinlaid, Kesselaid, Kihnu island, Kräsuli island, Kõinastu islet, Manilaid orManija island, Mohni island, Naissaar, Piirissaar, Prangli island, Ruhnu island, Viirelaid, Vilsandi island, Vormsi island and Väike-Pakri island. In this research connections to Ruhnu, Kihnu, Manilaid, Abruka, Vormsi, Prangli anf Piirissaar were analysed. The locations of islands are shown on the Figure 1 and specific details are shown in Appendix 1.

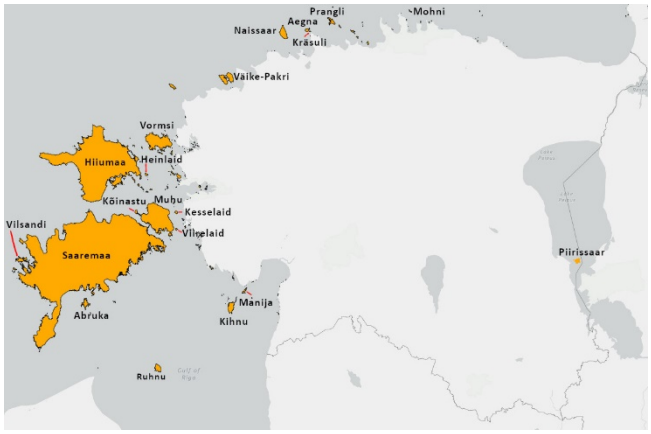

Figure 1. Islands of Estonia.[20]

In January 2022 1874 people lived in small islands [21]. Of those Kihnu, Vormsi, Prangli, Ruhnu and Piirissaar were most populated, with Kihnu as the biggest, roughly 700 inhabitants.

On several islands, the population is significantly smaller in winter than in summer. For example, in Vormsi there are officially 444 inhabitants but only 200 of them are living on island all year round [22]. In Ruhnu two-thirds of inhabitants live on island only during summer. In addition to that, summer is the main tourist season. Increased number of islanders and visitors means that there is bigger demand for products and services on island. All this results in a growing demand for connectivity in summer, which increases severalfold.

There isn't unified pattern of activities which describes economies of small islands in Estonia. Tourism is the only activity which plays significant role for all islands. The importance of other activities varies from island to island.

Historically the main source of income was fishing. Today fishing is more of a secondary activity. For the small islands important source of income comes from tourism and its related activities – accommodation, crafting and selling handicrafts and souvenirs, catering, organising trips/visits, renting means of transportation etc. In recent years recreational boating has gained popularity and the importance of providing service for small crafts and their visiting guests has increased.

There isn't any significant industrial activity on islands, except in Vormsi. For Vormsi forestry has a major impact to the island's economy.

From agricultural activities, livestock farming is the most important. Land cultivation is carried out mostly for own consumption or for supporting of one's own other activity.

Islands that are municipal entities, like Vormsi, Kihnu and Ruhnu, additional jobs are created by fulfilling responsibilities of the local government.

4 CURRENT TRANSPORTATION ARRANGEMENT

Main connections to the small inhabited islands are arranged by seagoing vessels. For Ruhnu there is also connection by air from Pärnu which is the closest city on mainland.

Maritime connections between small inhabited islands and mainland or big islands are considered as public transport and therefore is financed, planned and managed either by the state or municipality or their institutions (e. g Ministry of Economic Affairs and Communications, Transport Board, Public Transport Centres). Other parties involved in creating connections are shipping companies/operators, ports, islanders, island-related businesses, associations like Association of Small Islands. Operators will be found through public procurement. Depending on the connection operating party either must own the vessels or vessels are provided by the state/local municipality. Three transport connections, Abruka, Piirissaar and Ruhnu, are sailing only summertime and pre- and after summertime with the main vessel (Table 1).

Table 1.Overview of connections and characteristics of main serving vessel

Island	Connection	Connection type	Freq.	Main vessel characteristics
Abruka	Abruka-Roomassaare	Maritime	Year-round (tug-ice-breaker when ice)	L=14,8; B=4,56; D=1,445; GT=32; Pass 24; Cars 1; v=13kn
Kihnu	Kihnu-Munalaid	Maritime	Year-round	L=45; B=12; D=2,7; GT=924 Pass 200; Cars 32; v=12,2 kn
Manilaid	Manilaid-Munalaid	Maritime	Year-round	
Piirissaar	Piirissaare-Laaksaare	Maritime	Year-round (hovercraft – when ice)	L=32; B=6; D=1; GT 236; Pass 50; Cars 5; v=10
Prangli	Kelnase-Leppneeme	Maritime	Year-round	L=24,7; B=6; D=1,9; GT 139; Pass 74; Cars 1; v= 12 kn
Ruhnu	Ringsu-Roomassaare Ringsu-Munalaid Ringsu-Pärnu	Maritime	01.05-31.10	L=23,9; B=8; D=1,48; GT=169; Pass 60; Cars 2; v=25 kn
	Pärnu-Ruhnu-Kuressaare	Air	01.10-30.04	
Vormsi	Sviby-Rohuküla	Maritime	Year-round	L=45; B=12; D=2,7; GT=924 Pass 200; Cars 32; v=12,2 kn

Remarks: L – Length, m; B – Breadth, m; D – Draft, m; Pass – Passengers; v – speed, knots

Users of the transport services can be divided to four groups [22]:

1. permanent residents, for whom a fixed connection is also vitally important for their daily activities. They either arrange their transport themselves or use the service provided by the government.
2. island residents who live on the island only during the summer period.
3. tourists. In the case of small islands, we can speak of 1) day tourists who do not necessarily make use

of the services offered on the island, but they may leave something behind, e.g. with rubbish; or,2) tourists staying overnight or longer period. Day tourists may be on the island in the context of a cultural, sporting or other such event, and in this way in which case they also use the services provided on the island. Tourists staying overnight on the island make use of the services offered on the island, e.g. restaurants, shops, etc.

4. businesses, industry, service providers for whom a transport link is vital for their part of their supply chain, either in terms of supply or distribution.

5 CRITERIA FOR MAINLAND CONNECTIONS

Accessibility is a key factor in ensuring the sustainability of small islands as remote places. This is ensured by fixed connections, either by sea or by plane or even by car. The main connection to Estonia's inhabited small islands is by sea. Regular air connections are only available on the most remote island, Ruhnu. Various parties are involved in ensuring a high-quality fixed link at national and local government level, operators, associations of island residents, and, most importantly, island businesses.

When interviewing stakeholders, the following criteria were found as important for connectivity: speed, time, reliability, frequency, passenger and vehicle volumes, vessel suitability, harbours, landside access to harbours. [22]

The time it takes to service connection depends on the distance of a connection ports and speed of the vessel. All but one connection between small island and mainland or big island have distance 10 or less nautical miles (Table 2) and trip time doesn't exceed one hour. The only exception is Ruhnu. Ruhnu has three different connections, two to mainland and one to island Saaremaa (Table 2). As for connections with other islands travel time is not big issue. For Ruhnu it is one of the key aspects in planning connection. Currently trip from Ruhnu to Saaremaa takes 2 h 10 min, to mainland 2 h 50 min and to Pärnu 3 h 10 min. Travel time depends heavily on weather conditions, which means that during rough weather travel time will be longer.

Table 2. Connections of analysed islands

Island (port)	Connection	Distance from port to port, nm	Distance of the port to closest city/populated area, km
Abruka	Abruka-Roomassaare	5	5,5 (Kuressaare)
Kihnu	Kihnu-Munalaid	10	40 (Pärnu)
Manilaid	Manilaid-Munalaid	0,5	40 (Pärnu)
Piirissaar	Piirissaare-Laaksaare	4,5	30 (Räpina) / 48 (Põlva) / 69 (Tartu)
Prangli	Kelnase-Leppneeme	10	6 (Viimsi) / 16 (Tallinn)
Ruhnu	Ringsu-Roomassaare	37	5,5 (Kuressaare)
	Ringsu-Munalaid	43	40 (Pärnu)
	Ringsu-Pärnu	55	0 (Pärnu)
Vormsi	Sviby-Rohuküla	5,4	9 (Haapsalu)

5.1 *Passenger and vehicle flows*

The island connections are characterised by a high seasonality in passenger and vehicle/cargo flows. During the winter season, permanent residents predominantly use the connection. In the summer season, the volumes on the routes/connections increase severalfold Figure 2, with no exceptions. There are several reasons for this: the islanders themselves travel more, the number of permanent residents on the island increases in the summer period, which increases the volumes and, lastly, the tourists who visit the island for one day or stay 2-3 nights.

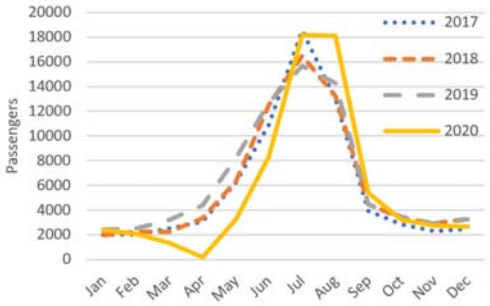

Figure 2. Number of passengers in Kihnu line, 2017-2020. [22]

The same pattern applies to the servicing of vehicle flows Figure 3, but the fluctuations are slightly smaller. The main reason for this is that vehicle movements are mainly related to local residents and smaller groups of tourists do not visit the islands with their own cars.

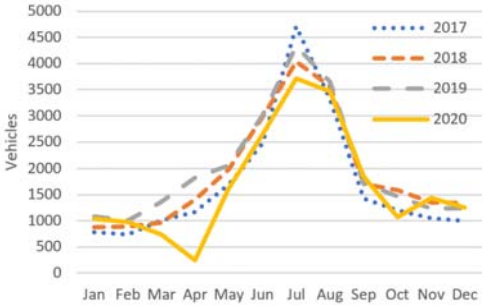

Figure 3. Number of vehicles in Kihnu line, 2017-2020. [22]

From the point of view of connection planning, unevenly distributed demand also means different numbers of connections per season. For some islands, this may mean reducing the number of daily trips to a few trips per day or per week. Due to natural conditions and the type of vessels used, there may not be regular maritime connections during the winter period.

5.2 *Vessels*

There are two aspects when considering a vessel's suitability for the traffic. First, fit and proper vessel ensures reliability. The vessel can be trusted to be running according to the schedule. An unsuitable vessel will lead to congestion in the system, poor quality of service and additional costs. The choice of vessel must take into account the natural conditions of the area, the weather, the conditions in the ports and

desirable service speed. The characteristics of the vessel include the type of hull, hull material, engine power, speed, ice class in the region and the loading/unloading capacity for passengers and cargo. The second aspect of suitability of the vessel itself, vessel's suitability to the passenger and cargo traffic needs and also passenger comfort during the voyage.

With limited financial resources, the owner of the vessel must make trade-offs between these and a number of additional characteristics. A good example is the longest of the routes considered, the Ruhnu connection, where the design of the current vessel gave priority to higher speed and shorter voyage duration. As a result, for example, the freight capacity of the route is lower and the catamaran used as a vessel is more sensitive to weather conditions, reducing the reliability of the connection. At the same time, over time, the demand for both passengers and freight has increased. The same problem is faced by some other connections such as Prangli and Abruka. Over time, the vessel initially suitable in terms of capacity has become undersized, causing disruptions even in basic services.

Estonian waters are very shallow. Depths close to the islands are all less than 5 m which means that drafts of usable vessels are limited. Limited depths set constraints to vehicle capacity of vessels used. Majority vehicles are either islanders' personal cars or commercial vehicles. For visitors there is no need to travel to the island by car or bus. For tourists, the transport is usually organized by the hosts. Cycling is a good way to get around the small islands and there is growing demand for vessels to transport bicycles. There is also some parcel carrying capacity needed as islanders are on board by foot and they bring some bigger parcels with them. Some of such passengers have transport means on both end of the connection or they use some other transport solutions on land.

5.3 *Harbours and landside access*

Harbours play an important role in the service system of small islands. The adaptability of ports to provide connections ensures the reliability of the connection. Port characteristics, such as depths and widths of access roads, depths in the harbour, dimensions of ramps, influence ship design. When developing connections in the long term, port development can take into account the optimal vessel serving the connection and adapt the port accordingly.

The location of the ports and waterways to be used, determine the length of the routes and the duration of the voyage. When changing the location of ports, it must be borne in mind that the locations have a long history and that the infrastructure needed to handle passenger and freight flows has been developed around them. As a rule, the introduction of a new port at a new location also means the development of completely new supporting infrastructure. There are practically no alternative port locations for the connections under consideration.

In the case of the island of Prangli, a southern port would shorten the journey significantly, by about 40%, compared to the current port on the northern shore. The insufficient depths at the alternative location, land ownership, lack of infrastructure, are all factors that make the use of a new port location not viable. As a further argument, the current harbour location is better for tourists with yachts and other small craft, for whom the current location of the port is more suitable as a part of a longer journey.

An alternative harbour location on the island of Vormsi creates an interesting new situation. In particular, it would significantly change the nature of the community. Firstly, the alternative link would be significantly shorter than the existing one (1.5 nm vs 5.4 nm). Due to the specificities of the new connection, the vessel used would not have to fully comply with the SOLAS rules but can follow directive 2009/45/EC. The cost of the maritime link would be significantly reduced. The shorter sea route would, however, extend the land connection to the nearest town, Haapsalu (37.5 km vs 9.3 km). For passengers travelling to Tallinn, with which many islanders are more closely connected, the journey is significantly shorter. For public transport passengers, who may be more connected to Haapsalu, the new route would be longer, more time-consuming.

An important specificity of the connections under consideration is that the connecting ports on the mainland and the main islands are located far from settlements. This means that, in addition to the functioning of the sea link, the functioning of the land link, the public transport, is essential. Cooperation is needed between the carrier and the land-based public transport operator to harmonise the timetables of the various modes of public transport.

5.4 *Reliability and Frequency*

Reliable transport connection ensures sustainability in small islands in terms of time, transport, other additional resources. Therefore, reliability can be considered as main value for such kind of services.

In small islands transport connection context we can define reliability of a transport service as the ability to meet the agreed timetable and passenger and freight volumes on time or with minimal deviations. Reliability is determined not only by the technical conditions but also by the wider conditions under which the system operates. Technical conditions include, for example, the ability of the vessel to operate according to its technical specifications, its reliability under normal and abnormal conditions, the suitability of the vessel for the route (resistance to natural conditions, their unexpected changes), the suitability of the physical characteristics of the port and the vessel, the suitability of replacement vessels. The performance of the system can be characterised by the feasibility of the agreed conditions, the flexibility of the functioning system, i.e., the ability to react to changes.

Reliability means looking at the trips themselves, the reasons why they were cancelled. In current case study the connections didn't have unified pattern in terms of reasons of cancelled trips. Main reasons for cancelled trips were strong winds, technical failure, unsuitable water level (too high or too low) and in 2020 emergency situation due to COVID pandemic.

Timeliness is also aspect of reliability. Due to lack of statistical data on this aspect, we can't say how big impact did weather, technical issues or other aspects affected timeliness. For current case, there were two vessels that served more than one connection. This meant that in case of cancelled or not timely trip following connection was or could have been affected by that. In order to improve reliability, the root causes of missed trips need to be investigated, causes which were described in previous paragraph.

Frequency is also an important factor for the connections studied for the user of the service, the highest possible frequency would of course be the best, but limited public resources must be taken into account here. Therefore, an optimal frequency has to be found to match the demand for a given time period. As shown in Figure 2 and Figure 3, there is a significant increase in demand for connections during the summer period and therefore the frequency is higher during these periods. For Kihnu connection there are three distinct periods considering frequency – summertime (from June to August on average 74 round trips per month), pre- and after summertime (April, May and September 94 roundtrips per month) and wintertime (from October to March 74 roundtrips per month). For Vormsi and Ruhnu there are two distinct periods. As Kihnu, both connections have summertime period from June to August. Second period for Vormsi is from September to May, but as Ruhnu line doesn't operate during winter then Ruhnu's connection second period is period is May, September and October. Frequency increases from a few trips per week or per day to several trips per day.

6 SERVICE LEVELS

To be able to define desired small ferry traffic for islands, it is necessary first to define criteria for the traffic. The service level requirements for all service level categories are, based on criteria of [23]:

1. The necessary mobility and transport required for basic safety needs, e.g. transport of fire and rescue services and police services as well as medical transport, is organised by a variety of modes of transport.
2. Connecting vessel traffic, for its part, ensures, in cooperation with other modes of transport, with basic safety mobility and transport needs on-demand basis.
3. Postal transports required by law are arranged on connecting vessels in accordance with the at least once a week.
4. In severe weather or ice conditions, the service level decreases and passenger transport organised by alternative modes of transport, such as hydrocopters, helicopters or hovercraft.

Traffic peaks are levelled with extra shifts for based on call traffic. This kind of flexibility, to adjust the connection frequency, is necessary to define in tender contract. It must be adjustable on both ways, during peak time higher frequency and during low demand lower frequency.

Based on criteria the requirements for four levels of service are:

The requirements for Level I are:
- Service level enables school transport, commuting, postal transport and the nearest service point of the daily service trip to the scheduled traffic.
- The level of service allows the contact ships to use them to business and trade transport not transported separately heavy cargo vessels.
- The basic frequency and the size of the vessels depend on the importance of the route and the need for transport. The frequency shall be adjusted according to the traffic volume and the capacity of the vessel in such a way that, under normal circumstances, all transport users fit in the shift they've been waiting for.

The requirements for level II are:
- Service level enables regular scheduled traffic several business trips per week to the nearest service point.
- The service level enables regular scheduled services on connecting vessels the necessary transport of agriculture, horticultultinations, business and trade, which are not transported by separate heavy goods transport.

The requirements for Level III are:
- The service level enables at least two weekly trips from the island to the nearest service point on an invitation-only basis.
- Transport needs of housing and business are safeguarded in at least once a week.

The requirement for Level IV is: serves tourism.

6.1 *Service levels for the current connections*

Based on the aforementioned criteria and established service levels, we can define service levels of the specific connections (Table 3).

Table 3. Defined service levels of the connections of some small islands in Estonia. [22]

Connection	Island to be served	Service level today	Future service level
Sviby–Rohuküla–Sviby	Vormsi	1	1
Kihnu–Munalaid–Kihnu	Kihnu	1	1
Manilaid–Munalaid–Manilaid	Manilaid	2	2
Ringsu–Munalaid–Ringsu	Ruhnu	2	Differences for passengers and freight respectively 1, 3
Ringsu–Pärnu–Ringsu	Ruhnu	2	
Ringsu–Roomassaare–Ringsu	Ruhnu	2	
Laaksaare–Piirissaare–Laaksaare	Piirissaare	2	2
Kelnase–Leppneeme–Kelnase	Prangli	1	1
Roomassaare–Abruka–Roomassaare	Abruka	2	2

We found that service levels depending on the route plan, are in line with demand, but that service stability should be improved so that trips cancelled due to weather or technical failure can be replaced without affecting passenger and freight mobility.

The distribution of service levels must take account of the fact that the routes serving small islands are partly seasonal. The route is operated by aircraft and hovercraft or support vessels during

periods when the operation of a scheduled vessel is not possible.

At certain conditions there is need to separate passenger and cargo flows as they met different criteria. This will allow a better quality of service to be achieved for both categories of flows. This is the case for the island connections examined in the context of this study, i.e. the connections to the island of Ruhnu. However, different service levels mean different vessels. For passengers, speed is the main criterion, while for freight the main criterion is the necessary capacity. This means an additional vessel, a freighter, to serve the connections. In order to make better utilization of the additional cargo vessel, it should also be used to serve other islands in the same area.

7 CONCLUSION

The research question of this study was to analyse the maritime connections to seven Estonian small islands – Ruhnu, Kihnu, Manilaid, Abruka, Vormsi, Prangli anf Piirissaar. The following factors were considered when analysing the small island traffic: speed, time, reliability, frequency, passenger and vehicle volumes, vessel suitability, harbours, landside access to harbours.

Although each island's transport connection needs to take into account the specific characteristics of the island and the community, in the broader context it is useful to have a coherent approach to planning fixed links. In this article, this is done by determining the service levels of the islands' connections under consideration. Under certain conditions, it is necessary to look at passenger and freight transport separately and to assign different service levels to them. This approach is suggested for the island of Ruhnu. Passenger service would be at level 1 and freight at level 3, which implies the use of different vessels. In order to make better use of national resources, a vessel dedicated to freight could be used to transport freight to other islands in the same area.

Major obstacle for the in-depth analysis of the connections of small inhabited islands in Estonia was lack of more detailed and comparable data.

It should be noted that the results presented in this article are valid for the system under study, with its own parameters and constraints. At the same time, the presented solution for the definition of service levels, as well as the criteria influencing the connections, can be extended to other similar systems.

This research brings new knowledge in the academic literature by applying the use of four service levels to a real world case. We found that the service levels give good start for the analysis, however, factors affecting connections have to be defined case by case.

Future studies in the same topic should find out whether such a definition of service levels can be applied for other island connections as well and what the determining criteria are for establishing connections.

APPENDIX

Appendix 1. Big and small inhabited islands in Estonia

	Island	Area, km²	Population	Distance from port to port, nm
Big island	Saaremaa	2673	31436	
	Hiiumaa	989	9557	
	Muhu	198	1998	
Small inhabited island	Abruka	8,8	46	5 (Roomassaare)
	Aegna	3,01	21	7 (Tallinn)
	Heinlaid	1,49	6	2,7 (Heltermaa)
	Kesselaid	1,75	9	4 (Virtsu)
	Kihnu	17,33	700	10 (Munalaid)
	Kräsuli	1,69	5	2,4 (Rohuneeme)
	Kõinastu	2,62	8	2
	Manija	2,06	49	0,5 (Munalaid)
	Naissaar	18,93	22	9,3 (Tallinn)
	Piirissaar	7,76	102	4,5 (Laaksaare)
	Prangli	6,4	216	10 (Leppneeme)
	Ruhnu	11,9	179	37 (Roomassaare) 43 (Munalaid) 55 (Pärnu)
	Vilsandi	9,4	30	4,2 (Papissaare)
	Vormsi	95	444	5,4 (Rohuküla)
	Väike-Pakri	13,5	9	2,2 (Kurkse)
	Mohni	0,61	5	2,5 (Viinistu)
	Viirelaid	0,87	7	2,6 (Kuivastu)

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