




Article

Collection of Waste from Passenger Ships and Its Impact on the Functioning of Tourist Port City Świnoujście

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Abstract: The aim of this study was to examine the issue of waste collection from passenger ships in tourist port cities using the example of Świnoujście, Poland. This is an important issue from the perspective of sustainable development, including that of tourism, because an improperly organized waste collection process may endanger the natural environment and disrupt the life of the local community. After the analysis of the types of waste generated on vessels, the means of transport used for their collection were identified with particular regard to those used at the seaport in Świnoujście, a tourist city. The selected waste quantities collected from ships in 2017–2019 were quantitatively analyzed. In addition, the number of waste collections was analyzed in the context of the number of vehicles involved in this process. The latter element is important in terms of impact on the port city's transport system, which has a spa and tourist function.

Keywords: port city; waste collection; seaport; sustainable tourism; sustainable development; strategic city management



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1. Introduction

Maritime transport is developing dynamically, which favors the global economy. International marine trade, transportation, and tourism are sea-based activities that are crucial for the economic development of modern society [1–3]. Unfortunately, they produce both air and water emissions and influence the environment in many other ways [4,5]. Waste generation is inseparably connected with the transport process, resulting from the operation of the means of transport, and is associated with the crew and, in the case of ships adapted for this, passengers. For this reason, some of the largest waste generators are cruise ships [6] and ferries, which carry a large number of passengers. Thus, ports receive and handle large quantities of different kinds of waste every year [7,8], and waste collection is one of the basic services they provide [9]. Its proper implementation is a condition for ensuring the safety of the environment and the people inside it [10]. Therefore, ships' waste management is a subject of interest as part of the broader issue of marine pollution [11].

The collection and handling of waste is strictly regulated by international and domestic laws. In addition, most European ports have, in recent decades, developed environmental policies and set objectives for environmental improvements, which include the handling of ship waste [12,13]. Strict regulations and high awareness of the seriousness of the problem mean that waste collection in ports is usually efficiently and safely conducted. However, ports are not independent entities in this respect [14]. After collection, the waste is exported from ports to the places of their storage, use, or processing, often located in port cities or their surroundings. Means of transport cause additional traffic flow, which occupies the cities' traffic resources and causes normal traffic quantities of road sections or road networks to drop or congest [15,16]. They also burden the transport systems of cities, which are struggling with the growing problems of organization distribution of goods and services in urban areas [17]. As the transport policy of ports and operator companies

aims to minimize the berthing time of ships in ports, waste collection must be completed in the shortest possible time. When servicing larger vessels, this necessitates the use of many specialized vehicles for waste collection, which, practically at the same time (or at short intervals), leave the port area and join urban traffic, causing its intensification [18]. This phenomenon may be even more burdensome in the case of passenger transport, the intensity of which is often characterized by seasonality [19,20]. Some actions taken to, for example, reduce travel time, traffic congestion, or the city's gas pollution positively affect the comfort of citizens' lives and the realization of the goals of local authorities [21].

The aim of this study was to examine the issue of waste collection from passenger ships in the port city of Świnoujście, Poland, which additionally plays an important tourist and spa function. Although all cities are multifunctional by nature, as a rule, a leading function can be identified. In Świnoujście, tourism and port functions are equally important, so the need for proper city management, considering these specificities, is particularly important. Tourism developed in the urban space and all activities with a port function, including transport, interact with each other [22]. For the city's economy, a conflict-free coexistence of the port located in the central part of the city and residential and tourist districts is crucial. Disrupting the lives of residents may negatively impact their attitude toward developing tourism, and may thus affect the quality of the tourist trip of people staying in the city [23]. Thus, any conflicts in this respect may result in serious financial losses.

To the best of our knowledge, waste collection from tourist units has been relatively rarely analyzed. Our study additionally considered a city that combines port with tourist functions of a spa nature, which makes the study even more original.

The remainder of this article is organized as follows: In Section 2, the study methodology is presented. In Section 3, basic information on the types and specificities of ship-generated waste is described. Section 4 outlines the relationship between the proper organization of the waste collection process and the sustainable development of cities. Section 5 presents basic information on vehicles used to collect waste from passenger ships operated at the port of Świnoujście. Ships, which mainly service this area and generate the most waste, are listed, and basic measures of their statistics are listed. In addition, the number of waste collections was analyzed in the context of the number of vehicles involved in this process. Section 6 contains the results and discussion, with particular emphasis on the analysis of the structure and quantity of waste collected from passenger ships in Świnoujście in 2017–2019. The final part of the manuscript, Section 7, provides the conclusions.

2. Methodology

The functioning of cities depends largely on the effectiveness of transport systems, which is determined, among others, by parameters of existing roads. It is not a flexible resource, because their expansion is very costly and time-consuming, and sometimes even impossible due to the specificity of a given city. Properly organized waste disposal carried out in the city should take into account these resources, so as not to impede the fulfillment of other transport needs, although obviously waste transport will always be an additional burden on the city's transport system [15]. The road system of cities does not always enable the optimization of waste transport routes, thus requiring the introduction of other organizational solutions [24].

However, bearing in mind that the transport system largely affects the sectors of the economy and the social sphere (often not only the cities themselves, but also regions), taking measures to improve it should be treated as extremely important [25].

However, it should be noted that the introduction of any solutions must be preceded by thorough data analysis and should take into account the specificity of a given city. In the case of Świnoujście, it is important to take into account its port character and equally important tourist and spa functions.

From the cited sources, it was found that it is worthwhile to examine the issue of waste collection in the port and the coexistence of this process with the city's transport system.

To address our aim, a research process was designed, which allowed answering the following research questions (their formulation is the result of an analysis of the research currently carried out in the field of the article):

- Is it possible to collect waste discharged from passenger ships in Świnoujście without placing additional burden on the city's transport system? (RQ1)
- Does the type of waste collected from passenger ships in Świnoujście affect the city's transport system? (RQ2)

The analysis focused on the passenger ships handled in the port of Świnoujście, as this type of vessel generates the most waste, related to the handling of a large number of people for whom services of various types are provided on board the ship.

Case studies have consistently been one of the most powerful research methods in operational management [26]. Of course, this is not their only area of application. In addition, researchers using this method emphasize its quantitative or qualitative nature, although this method is most often associated with qualitative research [27]. A combination of these two approaches is also increasingly common. According to the research conducted by Himola, approximately 23% of the articles published in the years 1995–2015 used this mixed approach to the case study used in the research [28]. The article also uses a combined approach, but with a greater share of quantitative analysis. The formulated research questions were treated as an introduction to case study analysis (step: getting started), which was combined with the second step (step: selecting case) [29]. Such a combination became possible because the autotelic case study was used in the research [27]. Świnoujście is a specific port city, an attractive tourist destination with an unusual geographic location; this is discussed later in the article. Hence, the case itself is interesting. This city is known to the authors of the article. It was also the subject of earlier research, mainly in terms of its tourist and spa attractiveness [30], as well as the interaction of this function with aspects of city logistics [31]. The authors also participated in study trips. With regard to the collection of waste from passenger ships in the port of Świnoujście, the data provided by Espadon Sp. z o.o. are exclusive in this regard. It was not possible to collect these data in any other way. There were also talks with a representative of this company. Obtaining triangulation in the research was treated as a combination of quantitative analysis supported by qualitative analysis on the basis of this information. In addition, it is planned to repeat this research.

The first stage of the research procedure was the analysis of the types of waste generated on vessels, which was mainly based on the legal acts in force. This part of the study related directly to the second research question (RQ2) and allowed distinguishing two types of waste for analysis. At the same time, means of transport used to collect waste from vessels were identified, with particular emphasis on those used in the sea port in Świnoujście. In this part of the study, the method of critical analysis of literature and legal acts was mainly used. Internet resources were also explored. Additionally, the interpretation of information obtained from the company that collects waste from passenger ships in the port of Świnoujście—Espadon Sp. z o.o.

Based on the data obtained during the research (Maritime Office in Szczecin, Poland [32], Central Statistical Office, Poland [33], and Espadon Sp. z o.o. [34]), we quantitatively analyzed the amount of selected waste collected from ships in 2017–2019. Ships that were mainly serviced in this area, i.e., generated the most waste, were listed, and the basic descriptive statistics (central tendency, dispersion, and asymmetry) were obtained. The analyses are illustrated using graphical data presentation techniques, including histograms and boxplots. The number of waste collections performed was analyzed in the context of the number of vehicles involved in this process. The last element is important in the assessment of the impact on the city's transport system and directly relates to the first research question (RQ1). The problems that may be generated by the waste collection process for various groups of stakeholders, mainly inhabitants of Świnoujście and tourists, were examined.

3. Types of Waste Generated on Vessels

Waste is defined as substances or objects that are disposed of, to be disposed of, or that are required to be disposed of in accordance with the provisions of national legislation. Ship waste is all waste, both non-hazardous and hazardous, that has been produced during ship navigation, as well as the waste being transported by cargo vessels [35,36]. Such substances are considered waste until they are transferred to port reception facilities [37]. A similar term, although more precise, was presented by the Polish Register of Shipping [38]. The provisions of the conventional supervision of sea-going vessels state that waste is “all kinds of food waste, household and operational waste, all plastics, cargo residues, cooking oil, fishing equipment and corpses of animals that arose during normal operation of the ship.”

The ship, being a highly advanced device in constant use, is a source of large amounts of waste. To efficiently collect waste generated on vessels, the types of waste generated during their operation should be distinguished, as this determines the handling method. There are two basic waste classifications. The first divides waste into hazardous and non-hazardous. Hazardous waste may pose a threat to human or animal health or life after entering the environment. It is characterized by at least one of the following properties: corrosive, infectious, flammable, carcinogenic, irritant, mutagenic, oxidizing, reactive, mutagenic, or toxic to reproduction [39], whereas the definition of non-hazardous waste corresponds to the previously presented definitions. The second classification applicable, among others in the waste catalog in force in Poland [40], divides waste according to its state of aggregation into solid, liquid, and gaseous waste. Among these basic groups, however, there are also groups, subgroups, and types associated with the place of origin of this waste as well as materials and substances predominant in their composition.

Waste generated on ships is characterized by a certain specificity resulting from the nature of maritime transport (high mass transport in the case of cargo ships, a large number of passengers at the same time with long intervals between ports in the case of passenger ships, diesel as the basic fuel, and large mass of the units). Therefore, port instructions describing how to handle individual types of waste, considering their specificity, constitutes yet another classification according to which there are four main groups of waste generated on ships [41]: oil, solid, sewage, and residues from flue gas treatment.

According to the Helsinki Convention, oils are “crude oil in all forms including crude oil, fuel oil, sludge, oil waste and refined products” [42]. The oil waste group includes:

- Oily bilge water: “Bilge water is the result of water and oil leaks from equipment and pipelines located in the ship’s engine room during their operation and repair works. These leaks, accumulating in bilge wells, mix to form oily mixtures.”
- Oil residues (sludge): “Oil waste generated during normal ship operation, such as: waste from centrifugation of oil fuels or lubricating oils for main and auxiliary engines, or waste separated in filtering devices, or waste accumulating in sewage tanks and used hydraulic oils and lubricating ones.”
- Other oils.

Solid waste (garbage) is the most diverse type of waste generated on vessels and can include both hazardous and non-hazardous waste. The origin of solid waste from ships can be divided into:

- Waste from the machinery department: Waste related to equipment maintenance, i.e., gaskets, scrap, dirty rags, etc.; the amount of waste depends on the capacity and load capacity of the ship;
- Kitchen waste and food waste, where the amount of waste depends on the size of the crew;
- Waste from the deck department: Waste from tools and materials used for maintenance works, i.e., stowage waste, cargo waste, paint packaging, used ropes, etc.; the amount of waste depends on the capacity and load capacity of the ship;

- Waste from cabins: Various types of waste from the life of the ship, i.e., clothing, waste paper, etc., the amount of which depends on the number of crew.

These wastes do not decompose in the environment and they are mostly light enough to float on the water surface. This not only affects the aesthetics of the sea shore, but also disturbs the biological balance and threatens the life of birds, fish, and humans.

Sources of sewage, referred to as “water used for domestic and economic purposes” [43] on ships are: washrooms, bathrooms, sinks, laundries, floors, and holds. According to the sources of these types of wastewater, there is:

- Grey wastewater: Not perfect, containing water without feces, the source of which is mainly showers, washing machines, and kitchens;
- Black sewage: Fecal, mainly from toilets, urinals, rooms with live animals, etc.

The correct collection of waste from ships in ports is crucial because any shortcomings in the process can lead to contamination of the environment. For example, oil waste is hazardous waste and can lead to permanent contamination of waters if spilled into the water. The result of such contamination may be the absorption of harmful substances by living organisms, leading to their disease and to death and extinction. Failure to remove oil pollution can lead to the destruction of flora and fauna in attractive tourist regions. Sewage waste, on the other hand, poses an epidemiological threat due to the large number of bacteria it contains. After entering the environment, it can also lead to the destruction of flora and fauna and cause numerous diseases among people.

4. Waste Collection and Sustainable Development of a Tourist Port City

A properly organized waste collection process is one of the basic conditions for sustainable development [44]. As noted by Hannan et al., it can be easily directly or indirectly linked to 10 of the 17 United Nations’ Sustainable Development Goals [45]. These goals were defined in the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015. Among those that can be directly related to the issues of waste collection are: good health and well-being, clean water and sanitation, industry, innovation and infrastructure, life on land, and, most of all, sustainable cities and communities [46]. The Sustainable Development Goals concern the whole world (developed and developing countries) and are based on three coherent elements: economic growth, social inclusion, and environmental protection. They should stimulate activities in the most important areas: people, our planet, prosperity, world peace, and partnership. They are an expression of common global tasks tailored to the capabilities of the country and regions [47]. Waste management has been also included in 1 of 20 key groups of sustainable development issues in tourism [48], which is important from the aspect of the functioning of a tourist city, such as where the Świnoujście sea port is located. As part of the work of the United Nations Environment Program (UNEP), the Global Initiative on Marine Litter, in which 12 marine regions from different continents participated, formulated the basic areas in which problems are related to sea water pollution [49]. Part of the sea pollution is generated by ships (including passengers ones), and can be relatively easily eliminated only if the ports properly meet their obligation to collect waste. This is extremely important because it can contribute to the reduction in illegal discharge of ship-generated waste and cargo residues to the sea [7]. According to the definition, sustainable tourism should meet the needs of present tourists and host regions while protecting and enhancing opportunities for the future. This requires the management of all resources so that economic, social, and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity, and life support systems [50]. Later in the article, the issue of waste collection from passenger ships operated in a port located in a port city is discussed. This reception, so as not to interfere with both the residential and tourist functions of the city, requires efficient city logistics activities carried out in accordance with the principles of sustainable development.

5. Means of Transport Used to Collect Waste from Vessels

The correct process of collecting waste from ships in ports requires close integration of port reception facilities with specialized vehicles provided by waste management companies. Port reception facilities include [51]:

- devices constituting the port infrastructure: fixed devices for direct waste collection from ships or devices for their management;
- other port reception facilities: technical equipment devices enabling direct or indirect collection of waste from ships, i.e., port floating rolling stock, transshipment equipment, or waste collection and treatment devices.

Waste collection vehicles can be diverse in terms of types, capacity, and technological advancement. Which vehicles serve a given port depends on the choice of the company with which long-term contracts are usually signed to provide this type of service. In this article, the problem of collecting selected waste from the aspect of its impact on the city's transport system is discussed using the example of the port in Świnoujście. This port has a contract with the company Espadon Sp. z o.o., which has provided comprehensive services to various enterprises throughout Poland in the field of hazardous and non-hazardous waste management for recovery and disposal since 2004 [34].

Waste from ships calling at the port of Świnoujście is collected by several types of vehicles depending on the type of waste received, including:

- articulated vehicles with a total length of 16.5 m and a total capacity of 26 m³, used to collect petroleum waste (it has an ADR (the European Agreement concerning the International Carriage of Dangerous Goods by Road) certificate allowing the transport of dangerous goods and it is equipped with a pump and hoses for collecting oil waste);
- a road tanker with a total length of 9.5 m and a total capacity of 15 m³, which is used to collect petroleum waste (it has an ADR certificate allowing the transport of dangerous goods and is equipped with a pump and hoses for collecting oil waste);
- a slurry tanker with a total length of 9 m and a total capacity of 12 m³, used to collect fecal waste (equipped with a pump and hoses to collect liquid waste);
- a car with a body adapted for lifting and transporting containers with a capacity of 7–10 m³ (used for collecting solid waste and has ADR certificates authorizing the transport of dangerous goods); and
- a delivery van with a lift (it has an ADR certificate allowing the transport of dangerous goods and is used to collect solid waste and residues from flue gas cleaning; the installed lift allows placing four containers with a 1100 L capacity in the vehicle).

These oil waste collection vehicles can also be used to collect fecal waste if they were cleaned, which would be confirmed by relevant documents.

The selection of the correct vehicle for the task is the basis for the efficient collection of waste from watercraft. When choosing a vehicle, it is necessary to consider not only its adaptation to receive a given type of waste, but also its capacity, which, in the case of ships producing a greater amount of waste, will allow collection without the need for transshipment. In addition, a device must be chosen whose dimensions will allow efficient maneuvering on the quay. The number of transport means provided and their frequency of transports depends on the number of ships calling at the port and the amount of waste they discharge.

6. Results and Discussion

Świnoujście is considered an attractive tourist city with powiat rights within the administrative boundaries of the West Pomeranian Voivodeship in Poland. The development of this area is determined by its specificity. In the latest strategic document, Tourism development strategy for the city of Świnoujście for 2019–2028, the tourist vision of Świnoujście was formulated as an international, modern, and safe resort park in a large urban center with a port window to the world [52]. This provision considered the tripartite nature of this area, i.e., a port, tourism, and a spa resort. Świnoujście is a seaside town with the status of

a health resort, with a sea port of primary importance for the national economy in Poland. All this necessitates reconciling these three spheres, causing the flow of people, goods, and information in a city characterized as a spa, an industrial-spa, and a tourist structure [53].

Świnoujście lies on 44 islands, 3 of which are most significant: Uznam, Wolin, and Karsibór, because they are the only ones inhabited. On the island of Uznam, there is an administrative and service center, a seaside district with tourist and spa facilities, as well as the main residential district that contains 80% of the population of Świnoujście. The next island is Wolin (it is also the largest Polish island with an area of 265 km²), which is separated from the mainland by the Dziwna Strait. The part of Świnoujście lying on the island of Wolin acts as an industrial district; here are the largest maritime facilities and transportation hubs: ferry terminal and bus and train stations. The third inhabited island is Karsibór, an island of mainly recreational importance [54]. The island location of the city therefore presents a huge challenge for the transport system. Individual districts of Świnoujście, lying on separate islands, are connected by ferries. Traveling from the islands of Wolin and Karsibór to the island of Uznam (where the city center is located) for city residents and non-motorized people who are not residents of Świnoujście is possible via the city ferry. Arriving there by car from other Polish cities is only possible through the ferry crossing at Karsibór. Ferries usually run every half hour, which, during the tourism season, is not enough and causes congestion on the access and exit road to Świnoujście. Sometimes, it is even necessary to wait several hours for the ferry. Access to the other islands is provided by the bridge in Wolin. The construction of a tunnel under the Świna River is currently underway to improve transportation between the islands of Uznam and Wolin. The estimated length of this tunnel is 3.2 km. Completion of construction was planned for 2022, but delays are most likely due to the pandemic [55].

The port in Świnoujście, together with the port in Szczecin, forms one of the largest port complexes in the Baltic. Świnoujście has the largest ferry terminal in Poland in terms of ferry calls and the quantities of passenger and freight traffic. This terminal is adapted for transshipment in the roll on–roll off (Ro–Ro) system of railway wagons, semitrailers, trucks, and passenger services, mainly to Sweden. There are five stations serving rail car and passenger car ferries.

In terms of handling international passenger traffic, the seaport in Świnoujście is a leader in Poland. According to data from the last few years, nearly 60% of this traffic occurs in this port [33]. The passenger traffic at the port of Świnoujście in 2010–2019 is shown in Figure 1. The number of passengers who arrived at the port and departed from the port during this period is specified. In 2019, the values increased by 26.02% and 21.76%, respectively, compared to 2010.

Figure 2 shows how the quantities of liquid and solid waste collected from passenger vessels at the seaport in Świnoujście developed in 2017–2019. As part of liquid waste, oil waste was included in accordance with the previously presented classification of waste generated on ships [41]. In the analyzed years, the quantities of liquid waste remained at a similar level; the highest was in 2018. However, in an upward trend was noted in of solid waste, with quantities in 2019 being higher by 21.66% than at the beginning of the analyzed period. However, the one-year increase in 2018 was greater than a year later.

Most of the waste collected by Espadon Sp. z o.o. in the port of Świnoujście was from eight passenger vessels, the capacity of which (gross tonnage) fluctuated within around 14,000–30,000 GT, but five have a capacity below 20,000 GT. From data on solid waste collected in 2017–2019, a statistically significant (at significance level 0.05) positive relationship between their size and unit capacity (correlation coefficient around 0.8) was observed. However, in relation to liquid waste, the correlation was moderate and statistically insignificant.

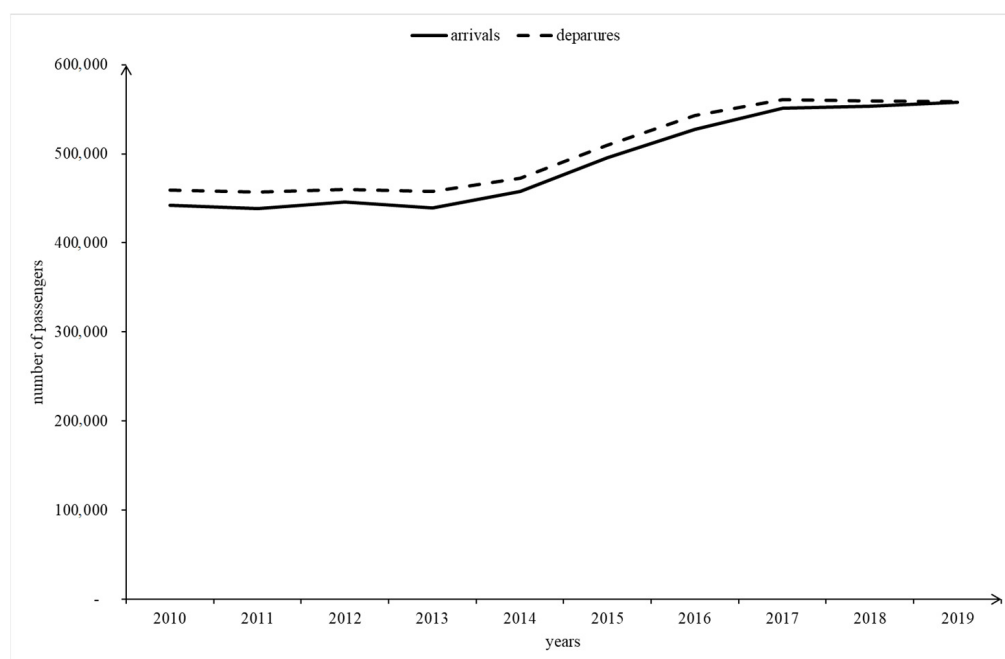


Figure 1. Passenger traffic at the seaport in Świnoujście in 2010–2019 (Source: own study based on data provided in [32]).

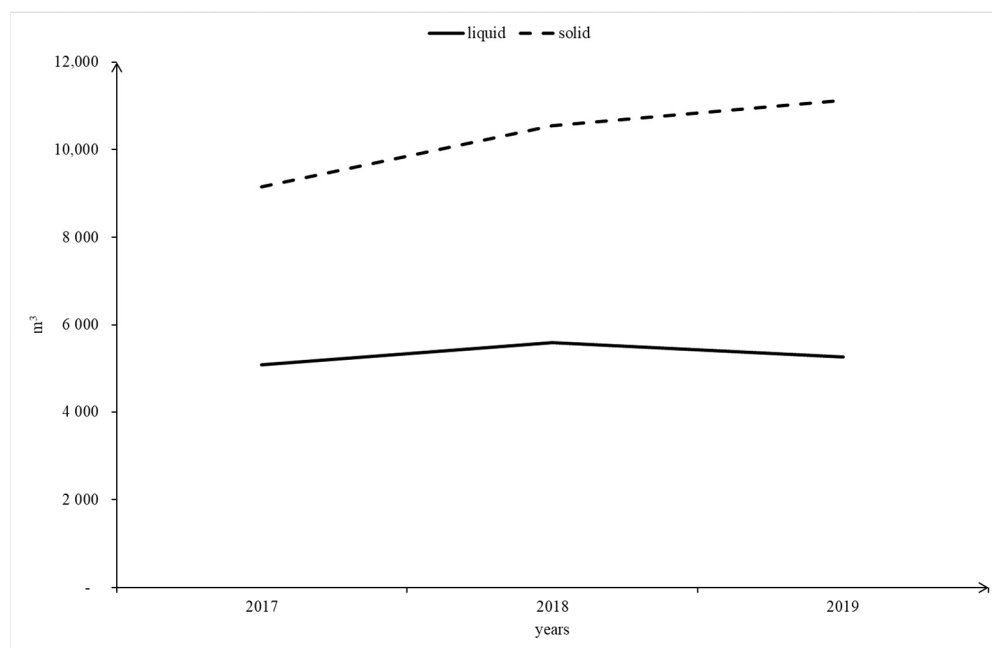


Figure 2. Total quantities of liquid and solid waste disposed of in the seaport in Świnoujście in 2017–2019 (Source: own study based on data provided by [34]).

Figures 3 and 4 present histograms and box charts of the size distribution of liquid and solid waste collected at the seaport in Świnoujście in 2017–2019.

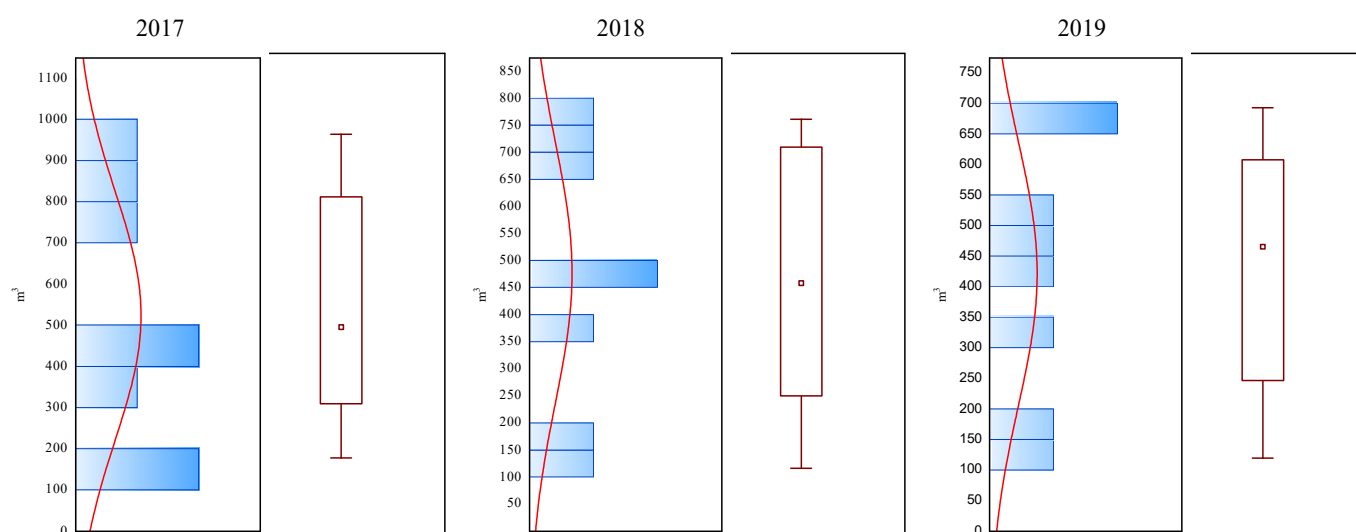


Figure 3. Histograms (left) and boxplots (right) of liquid waste collected from ships in Świnoujście in 2017–2019 (Source: own study based on data provided in [34]).

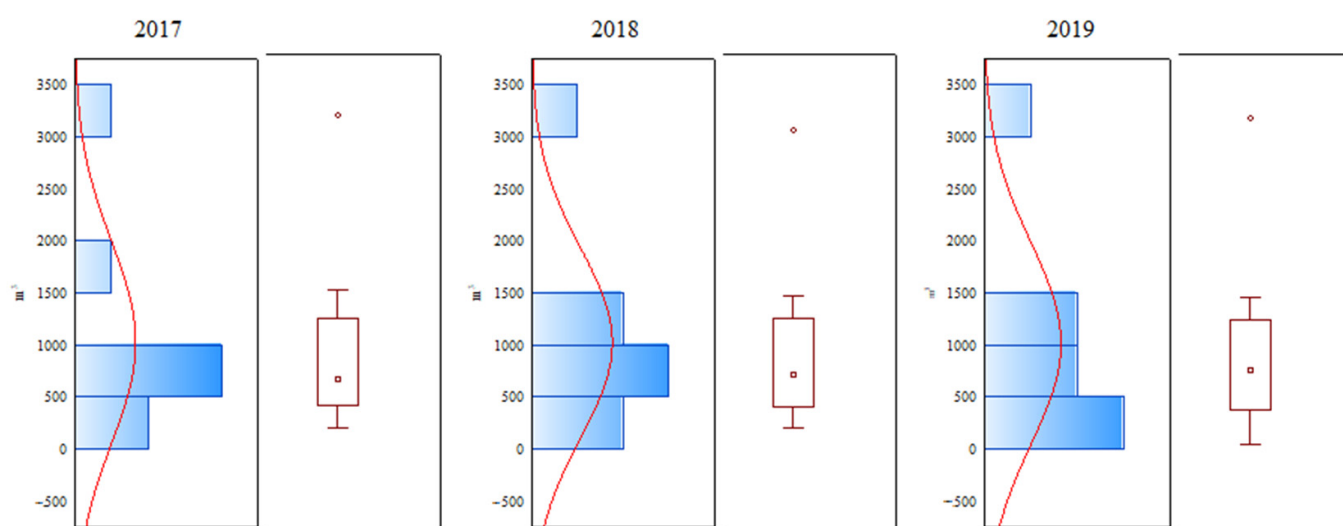


Figure 4. Histograms (left) and boxplots (right) of solid wastes collected from ships in Świnoujście in 2017–2019 (Source: own study based on data provided in [34]).

Distributions for liquid waste (Figure 3) showed little asymmetry (right-sided in 2017 and left-sided in 2018 and 2019); the mean and median values were similar. Quite characteristic is 2019, in which the highest range was noted: from two ships, the amount of liquid waste close to the maximum was collected, while the other quantities were diverse. Both of these vessels were not the largest, which confirms the lack of a statistically significant correlation between their capacity and the amount of liquid waste collected in the examined years. To further illustrate waste quantity distributions in terms of central tendency, dispersion, and asymmetry, boxplots were prepared, illustrating the median, lower, and upper quartiles, and minimum and maximum of values [56]. The middle values (medians) are similar in subsequent years, while the average quantities of liquid waste are decreasing.

The distribution for solid waste (Figure 4) was characterized by strong right-hand asymmetry in each of the analyzed years: the average values were higher than the median and dominant values. The strongest was in 2017, when as many as six units (75%) handed over waste with quantities of less than 1000 m³. In the remaining years, the waste of the

same units was in the range of up to 1500 m³. The exact values of the upper quartile (75%) were similar in the years studied: 1262 (2017), 1264 (2018), and 1250 m³ (2019). At the same time, unusual values were noted as deviations from other values. These were the amounts of solid waste collected in the years under study from the same ship whose capacity was close to 30,000 GT.

In addition to the quantities of waste collected during the year, the number of collections and their distribution in individual months were analyzed. In the case of liquid waste, the total numbers of collections in 2017–2019 were similar. In 2019, solid waste was collected more often than in 2017, an increase of 19.28% (by 242 collections). Figure 5 shows the number of collections for both types of waste, specifying the months in the period considered. The number of liquid waste collections was similar over the year. For solid waste, larger fluctuations each year were observed. At the end of each year, there was an increase compared to the beginning. In 2017, it was the most stable (with a linear upward trend with a fairly good match with empirical data at 87%).

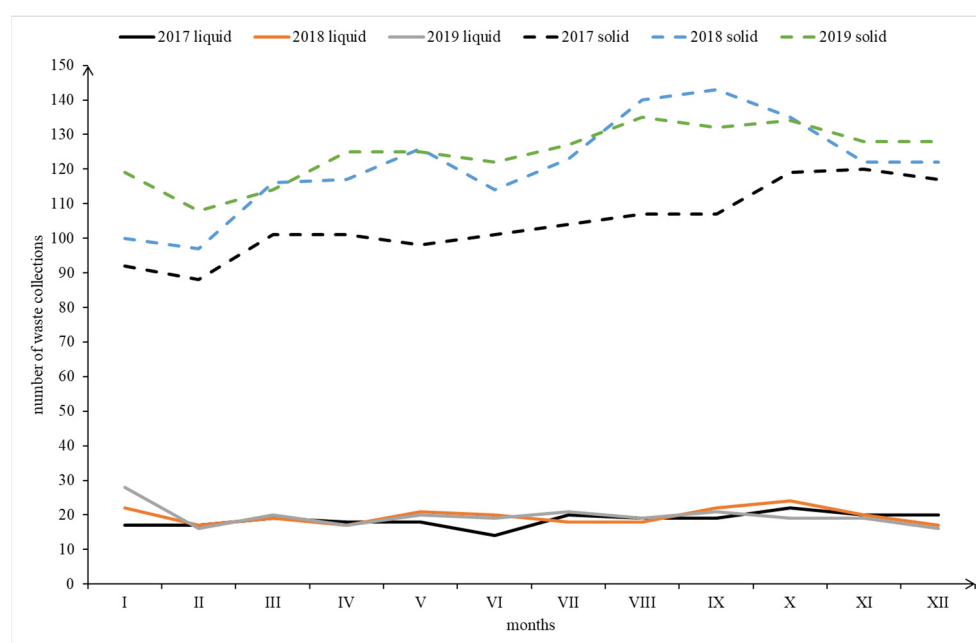


Figure 5. Number of liquid and solid waste collections in Świnoujście in 2017–2019 by month (Source: own study based on data provided in [34]).

The number of waste collections in the port is important because it involves the means of transport entering the port and then transporting the waste to the place of its storage. This generates vehicle traffic in the city. Waste is transported to different destinations. Part of the liquid waste is transported about 100 km to distant Szczecin, and part is transported to a treatment plant near the ferry terminal in Świnoujście. Solid waste is transported to a place located in Świnoujście; however, reaching it requires using the ferry crossing the Świna River (dividing the Warszów district located on the Wolin Island and the city center on Uznam Island). Figure 6 presents a map with directions of waste transport from the passenger quay.

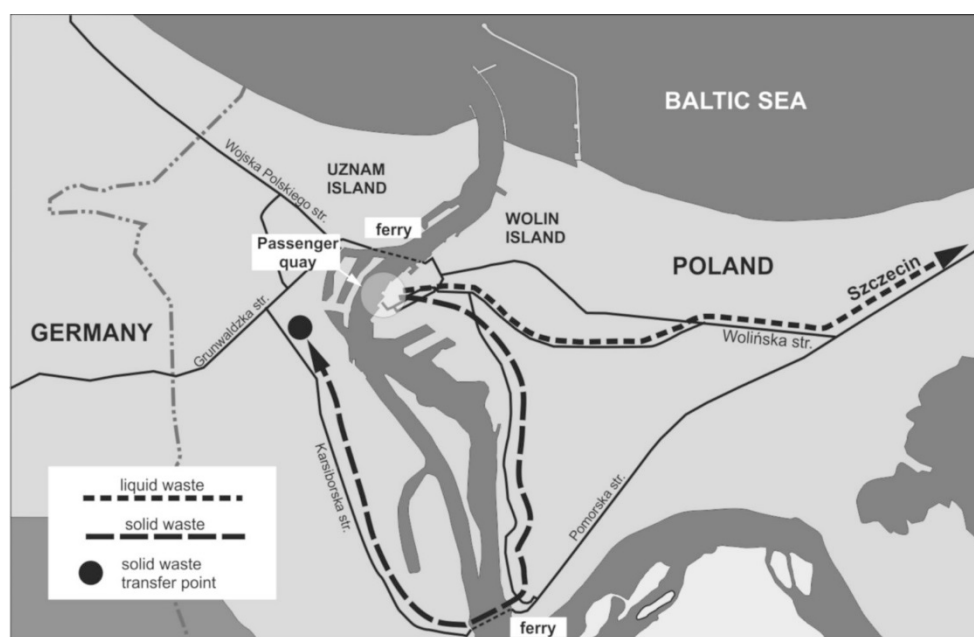


Figure 6. Location of the passenger quay at the seaport in Świnoujście with directions of waste transport (Source: own study based on data provided in [34]).

The number of collections was not the same as the number of service vehicles. Based on the data on the quantities of collected waste and information on the organization of the collection process regarding the means of transport used (presented in Section 5), received from Espadon Sp. z o.o., and the rules for combining waste and the method of transferring it from ships, the number of vehicles used was estimated. Figure 7 shows the number of vehicles that were used in the waste collection process. However, we considered those that generate traffic toward Szczecin (part of liquid waste) and those that, when removing waste, must use the aforementioned ferry crossing (solid waste). Certainly, more traffic is generated by the solid waste collection process. It is so important that it occurs within the city limits, and it can be bothersome in a place with almost year-round tourist traffic with clear seasonality in the summer months.

Then, the implementation of individual services generates diverse logistical and organizational dependencies that result from their specificity. This usually forces small orders and frequent on-time deliveries, which contributes to their low efficiency [57] and increases the number of vehicles required [58]. This requires the use of measures to eliminate organizational and infrastructural transport problems [53].

Environmental sustainability is becoming increasingly important to various stakeholder groups [59]. The waste (both solid and liquid) collection process generates problems between various groups of stakeholders: those directly involved in the implementation of the process and those who bear certain consequences in the form of perceived inconveniences in connection with its implementation (Figure 8).

This applies especially to the inhabitants of Świnoujście and tourists. Although vehicles collecting waste from passenger ships do not enter the city center, they can cause problems with the capacity of the access road to the city and the ferry crossing. This should be considered; therefore, it is necessary to implement an integrated transport management in the city using the partnership approach. They should be supported by an efficient flow of information between various groups of users of urban space. Only in this way will it be possible to ensure efficient and safe collection of waste, which is the basis of the sustainable development of the city, while ensuring that the comfort of residents and tourists is not disturbed. The condition of the road infrastructure, which should have adequate capacity, is also important. The ferry connection between Świnoujście and the rest of the country is not a favorable factor in this case.

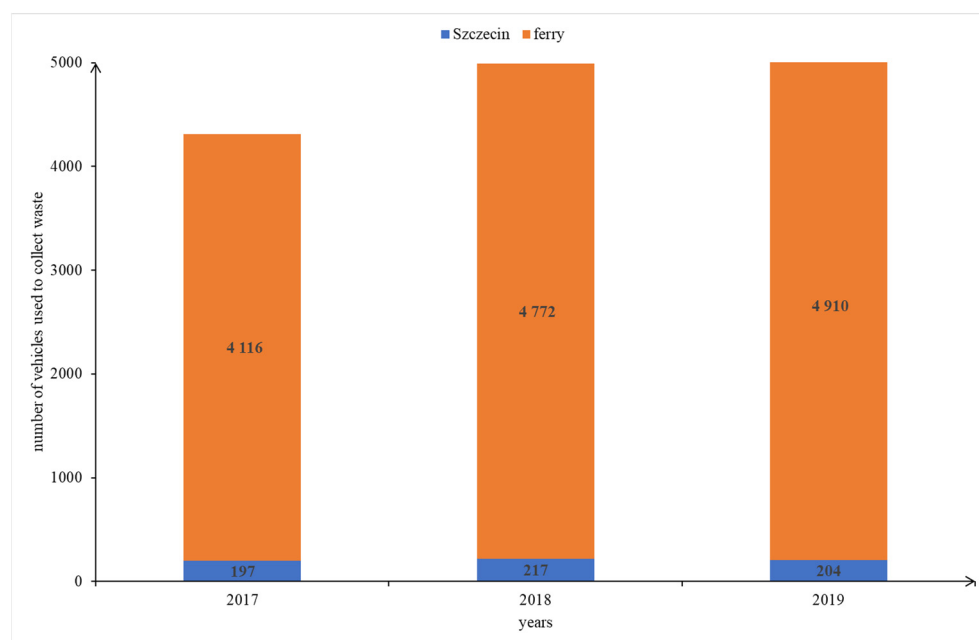


Figure 7. The number of vehicles used in the selected waste collection process in 2017–2019 (Source: own study based on data provided in [34]).

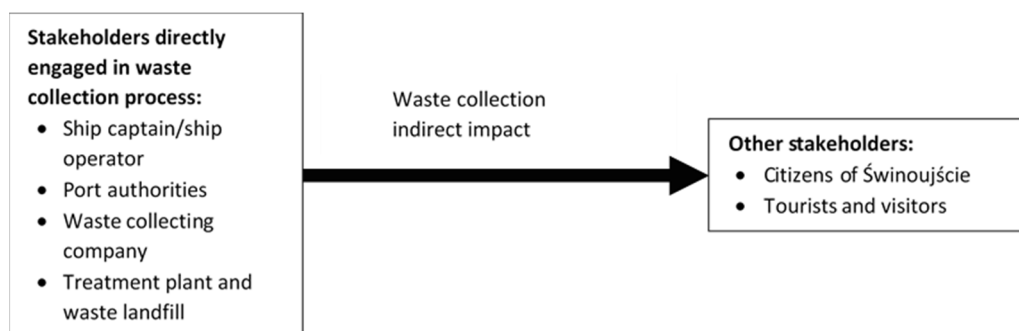


Figure 8. Stakeholder groups related to the collection of waste from passenger ships from the port in Świnoujście.

7. Conclusions

Waste collection from ships is one of the basic services that must be provided by seaports. After collection from vessels, the waste must be sent to specialized units that are responsible for their further management. All this must be conducted in compliance with the principles of sustainable development. To this end, it is necessary to efficiently manage the process, ensuring close cooperation of the port with external entities. These entities are responsible for the export of waste from the port by specialized vehicles, adapted to the type of received substances, and then for its transfer to other cells dealing with municipal waste management, recycling, processing of petroleum waste, sewage treatment plants, and refineries.

Vehicles leaving the port join urban traffic, becoming users of road infrastructure and elements of the transport system. The larger the quantities of waste collected from ships, the more vehicles are involved in their collection. Due to the nature of ship handling, it is not always possible to schedule pick-up during hours with low traffic. Therefore, the traffic of vehicles carrying out waste collection may intensify transport problems already existing in a given city. It is necessary for those responsible for urban logistics to consider this fact.

In Świnoujście, which, apart from being a port city, is also one of the most important Baltic tourist cities and Spa resorts, the problem of limiting the flow of car traffic can be

particularly challenging. During the tourist season, which is characterized by increased passenger traffic, the presence of waste collection vehicles on the road may be an additional nuisance (it is related to the first research question). Their large dimensions mean that on board the ferry, which they use to cross from the island of Wolin (on which the passenger quay is located) to the island of Uznam (where solid waste is managed), they take the place of several passenger vehicles. According to the conducted analyses, in 2017–2019, vehicles carrying solid waste constituted the majority of vehicles receiving waste from the Świnoujście port (it is related to the second research question).

One of the solutions that will relieve the load caused by the movement of vehicles transporting solid waste is the construction of the Świna tunnel. The tunnel is to be commenced at the beginning of 2021, and in September 2022, all works related to the construction of the tunnel under the Świna River should be completed [60].

Regarding vehicles transporting liquid waste, they pose no significant nuisance for the urban transport system (it is also related to the second research question). The location of the port on the island of Wolin, which has a bridge connection with the rest of the country, provides a considerable benefit. Due to this, vehicles transporting waste to Szczecin do not have to use the ferry. The small number of these vehicles cannot be considered an important factor in congestion formation. Congestion on access roads during the summer may be burdensome for the waste collection company. They extend the duration of the process and reduce the efficiency of using the means of transport.

The implementation of integrated transport management in the city may lead to reducing fuel consumption, noise, and emissions. The assessment of the profitability of selected undertakings requires additional studies, which are planned in the future. However, at this stage, the need to adapt these solutions was noted, considering the needs of individual stakeholder groups related to the collection of waste from passenger ships from the port in Świnoujście.

The situation related to the collection of waste will change after the aforementioned tunnel under Świna river is operating. We then plan to resume the conducted research. Notably, this research concerned the collection of waste from passenger ships, which are one of several types of ships using the Świnoujście port. They were selected because they carry the most passengers on board and have the largest crew, so they produce the most waste. However, in the future, the research could be extended to the analysis of data from other ships, which will contribute to obtaining more comprehensive results.

As the data from 2017–2019 were analyzed for the purposes of this study, we did not consider the specific situation in which Świnoujście found itself during the coronavirus pandemic. Due to the enormous impact of the pandemic on tourism (marine, recreational, and spa, all of which occur in the city), separate studies on this topic are required.

The results presented in the article have application significance, both in scientific and practical terms. They can be useful for Świnoujście city authorities and regional authorities, economic entities dealing with waste collection and management of the city's transport system, as well as scientists and students conducting research in the field of urban logistics and sustainable tourism.

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