International Journal of Tourism Research

Cruise passenger impacts on mobility within a port area: case of the Port of Barcelona

Journal:	*International Journal of Tourism Research*
Manuscript ID	JTR-16-0472.R2
Wiley - Manuscript type:	Research Article
Keywords:	Mobility impacts, Cruise passengers, Disembarkation, Passenger flow, Modal distribution, Cruise operation

Cruise passenger impacts on mobility within a port area: case of the Port of Barcelona

Keywords:
Mobility impacts
Cruise passengers
Disembarkation
Passenger flow
Modal distribution
Cruise operation

1. Introduction

Cruise tourism is currently the segment of the international tourism market that has grown most strongly worldwide (Brida & Zapata, 2009; Sun et al., 2014; Polat, 2015). Despite the global economic crisis in 2008, cruise tourism has experienced significant growth, reaching a total of 24.2 million passengers in 2016. According to CLIA (2017), this number is expected to reach 25.3 million passengers in 2017. This growth in cruise tourism has been reflected not only by passenger volume but also by the number of calls, the number of new destinations and the size of cruise ships (London & Lohmann, 2014). From 2009 to 2013, cruise capacity increased by 18% (CLIA, 2015). Furthermore, in the coming years (2017-2026), the leading cruise lines are planning to build up to 17 vessels with capacities of more than 5,000 passengers (Cruise Industry News, 2017). Thus, the trend towards giant cruises is expected to continue.

The increasing number of passengers entails a set of economic, environmental and socio-cultural impacts for the cities and ports that attract these cruises (Brida et al., 2010).

Many studies have investigated the economic impacts of cruises in various ports around the world: Australia (Dwyer & Forsyth, 1996), France (Torbianelli, 2012), Malta (McCArthy, 2003), Greece (Lekakou et al., 2011), the Caribbean (Brida et al., 2012), Jamaica (Kerswill, 2013), Spain (AQR-Lab, 2015) and globally (Pallis, 2015).

In terms of environmental impacts, although maritime transportation is considered the most cost-effective mode of transport compared to road, rail or air (Butt, 2007), cruise ships produce serious adverse effects on the marine environment and human health that cannot be neglected (Poplawski et al., 2011; Maragkogianni & Papaefthimiou, 2015). The main environmental impacts are the emission of harmful gases into the atmosphere and the generation of waste. A typical cruise can generate between 2.5 and 4.0 kg/pax·day of solid waste, 0.16 kg/pax·day of hazardous waste, 40 l/pax·day of black water, 340 l/pax·day of grey water and 10 l/pax·day of bilge water (European Commission, 2009; Caric, 2015). In addition, a cruise ship emits an average of 33.6 g/pax·h of NO_x, 29.8 g/pax·h of SO_x and 3.1 g/pax·h of PM_{10} (CENIT, 2016). All of these pollutants have significant effects, especially considering the growth forecasts for this industry. Therefore, further measures are needed to mitigate the environmental effects of cruises in order to make cruises a more sustainable mode of transport (Klein, 2002; Butt, 2007). These measures may include legislative restrictions and adopting specific procedures for waste management (Commoy et al., 2005; Dragovic et al., 2015).

The third category of impacts frequently associated with cruise tourism is socio-cultural. The large daily and, in particular, short-term passenger flows affect the quality of life of the local population. The main problems that have been identified are overcrowding, the homogenization of the port experience and the need to honestly represent cultural and historical sites (Klein, 2011).

Inside a port, the impacts associated with cruise activity are essentially related to mobility and are based on providing good service to a high volume of passengers who typically arrive en masse all at the same time (Klein, 2011). The port must guarantee sufficient operating space at the piers assigned to cruise activity for all of the transport modes used by passengers (Fogg, 2001). Therefore, a sufficiently wide esplanade is required to serve all available transport modes: taxis, public buses, shuttle buses, excursion buses and private vehicles (PIANC, 2016). These transportation links should not be underestimated, since transportation to and from the port is the cruise passenger's first and last impression of the port (Fogg, 2001) and since the environment is one of the most valued factors for cruise passengers (Baker, 2015). It is also essential to have roads with enough entry and exit lanes so that passengers can reach their destination cities quickly, safely and efficiently. However, in most cases, available space on the pier is a scarce resource (McCarthy, 2003) because it is land reclaimed from the sea. Therefore, optimizing the free space is very important (Fogg, 2001).

A passenger's decision to choose one transport mode over another depends on several factors, such as whether the port is a homeport or a port of call, the length of stay, whether he or she is travelling alone or with family, income level, and age. Many studies have been conducted regarding passenger behaviour, focusing on the motivations that encourage passengers to take a cruise ship (Andriotis & Agiomirgianakis, 2010; Brida et al., 2012; Sanz-Blas et al., 2015). However, none of these studies have specifically addressed the passengers' choice of transportation; therefore, this is still a not well understood phenomenon (Ferrante et al., 2016).

The Port of Barcelona, which is a cruise port that had 2.6 million passengers in 2016 (Port de Barcelona, 2017), is considered one of the largest European turnaround cruise ports and the fourth busiest port internationally (European Commission, 2015). At this port, the most common transport option is a taxi. Taxis are often used by passengers travelling to or from the airport, railway stations or hotel, since they are carrying their luggage. Another available transport mode is a public bus, which typically heads to the city centre. These buses are chartered by the Port Authority depending on the number of cruise ships that day. Despite their low cost, however, public buses are still rarely used. On certain cruises, cruise lines operating at the port offer shuttle buses to the city. However, due to their high cost compared with other transport modes, the shuttle buses are not widely used. The cruise lines and the associated travel agencies also organize excursion buses to the main museums and city landmarks. Another travel option is a private vehicle, although this option requires long-term parking at the pier. Finally, as the cruise terminal is located near the city, passengers can travel on foot (see Fig. 1).

The main mobility problems, queues and waiting times, arise during disembarkation, as passengers usually exit at the same time. Disembarkation is therefore a complex process that requires tremendous logistical effort (Gibson, 2006) and, in the worst case, can last up to 12 hours (Fogg, 2001). In contrast, embarkation is normally a staggered process that does not cause mobility problems. Cruise ships typically arrive early in the morning (5-10 a.m.) and leave in the afternoon (5-10 p.m.), and only a few ships remain moored at the pier for more than one day. There is, however, a tendency to minimize the time at port to reduce port taxes and to encourage passengers to spend more on board than in the city. The berth allocation problem has been the subject of numerous articles addressing how to determine the best positions of ships on the pier in both time and space (Cordeau et al., 2005; Wang & Lim, 2007). For cruise ships, this is not an issue since the cruise terminals have sufficient berthing capacity. Each terminal hosts a maximum of one cruise ship per day, as previously assigned by the Port Authority. Therefore, there are no physical limitations that force cruise ships to wait to dock.

Mobility problems associated with disembarkation often worsen when more than two cruise ships are disembarking passengers at the same time. Traffic management is necessary on days with more than approximately 15,000 passengers, whether they are embarking or disembarking (Port de Barcelona, 2014). Ferry operations located on the same pier do not interfere with the mobility of cruise passengers, as their schedules do not coincide. The ferries arrival between 22:00 and 23:00, when the cruise ships have already departed.

The growing importance of the cruise industry is highlighted by its status as one of the tourism industry sectors that generate the highest profit, along with lodging and restaurants; however, there is a lack of literature studying the impacts of passenger mobility (Stynes, 1997). As previously explained, the existing literature has generally focused on analysing the economic effects of cruises on the destination, particularly examining cruise passenger expenditure and profiles, to objectively assess whether cruises are beneficial to the global community economy (Henthorne 2000; Río & Cruz, 2008; Brida et al., 2010).

This paper uses the terrestrial mobility data of cruise passengers (passenger flows and modal distribution), which have not yet been addressed in the literature. Some studies have discussed the design of cruise terminals (Fogg, 2001; PIANC, 2016), but they did not specifically address passenger mobility. The data obtained in this study can serve as the starting point for dimensioning the different spaces in a cruise terminal, which has frequently been demanded by the designers of these terminals.

In this context, the aim of this work is to study the impacts of cruise passenger on mobility in ports using data from the Port of Barcelona. This research studies the main explanatory variables, the flow distribution over time, the modal shift of the passengers and the traffic generated by cruise activity.

The rest of this paper is structured as follows. In section 2, the empirical data source and the methodology are explained. Section 3 discusses the empirical results, and section 4 is devoted to the concluding remarks.

2. Data and methods

2.1. Data

The data used in this paper came from a mobility study commissioned by the Barcelona Port Authority in 2011 (most recent data available) for the cruise pier located at *Adossat Pier* (Fig. 2). The study (Doymo, 2011) consisted of fieldwork that included data collected from direct observations of passenger transport mode choice for 9 cruise ships using the port. In 2011, there were 881 calls, and 81 of them were from different vessels. Cruise ships of differing types, capacities, cruise lines and arrival times were chosen to cover most of the representative cases. The representativeness of the sample was analysed using the expression given for finite populations of small size, with a confidence level of 95% and a standard deviation of $p = 0.05$. A sampling error of 13% was obtained, which is acceptable for this analysis. This fieldwork may have the following two limitations: the date the observations were taken and the number of cruise ships taken as a sample.

Although all data were recorded in 2011, these data are considered relevant because no significant changes have occurred since that time. The port infrastructure has remained the same: 4 cruise terminals with the same road access. Since 2011, the volume of passengers at the port has varied each year, but in 2016, the number of passengers was similar to that in 2011 (2,683,584 passengers). Despite the number of passengers remaining stable, the number of calls has decreased because the cruise industry has adopted the economies of scale that have been so successful in other naval sectors (**Kendall, 1972; Papatheodorou, 2006; Tran & Haasis, 2015**). As a result, there are fewer cruise ships with greater capacities. Thus, the total number of passengers is very similar to the one registered in 2011. In addition, the proportion of homeport versus transit calls has barely changed, from 56% of homeport calls in 2011 to 58% in 2016.

The number of samples may not be representative because it is assumed that the same cruise ship results in the same passenger behaviour, which may not always be the case. Depending on the season, the number of passengers and the climatic conditions, passenger behaviour could differ. However, these data should be taken as a first approach to the problem of terrestrial mobility related to cruise ships. Additional studies would be required to extend the results.

The fieldwork was conducted by a team of five people between 13 June and 15 July 2011. One observer at the exit of the pier counted passenger entries and exits in 10-minute periods. In addition, four more observers at the exit of the maritime stations and at the drop-off and pick-up points of the esplanades counted the total number of passengers entering and exiting the terminal in 10-minute periods as well as their selected transport mode: taxi, public bus, shuttle bus, excursion bus or private vehicle. Some other variables were considered such as the number and occupancy of vehicles, queues, efficiency and incidents.

The sampling campaign was performed from the moment that the cruise ship arrived until its departure. Data collection took an average of 11.4 hours per cruise. In these periods, an average of 3,909 passengers entered the terminal, and 3,903 passengers exited the terminal (Table 1). These data are the starting point for the work described in this paper.

Direct observation was selected as the data collection method because it is particularly suited to understanding an on-going behaviour, process or event (Taylor-Powell & Steele, 1996). Additionally, data collection is a reliable and widely used method in the existing literature. For instance, Scherrer et al. (2011) observed visitor behaviour during guided tours of Kimberley Coast (Australia) to examine the potential environmental impacts. Jaakson (2004) observed the space-time behaviour of passengers in 4 cruise ships in the Port of Zihuatanejo (Mexico). Other methods can be used to collect information, and each has its own advantages and weaknesses. Douglas & Douglas (2004) gave questionnaires to cruise passengers on 7 Pacific Island ports of call to evaluate their expenditures. Andriotis & Agiomirgianakis, (2010) and Brida et al. (2012) used surveys to determine cruise passenger profiles in the ports of Heraklion (Crete, Greece) and Cartagena (Colombia) respectively. Finally, De Cantis et al. (2016) used a more modern method that consisted of monitoring cruise passenger flow using an infrared beam counter and subsequently tracking the passengers using GPS devices.

2.2. Methodology

The cumulative curves of the passenger exit flow for the nine studied cruises were plotted. The most relevant variables, such as the periods of maximum demand, variability of the peak hour over time and maximum and average exit rates, were derived from these curves. To obtain greater detail, these variables were studied over shorter periods of time (10 minutes), since the passenger flow fluctuated substantially over time. Subsequently, to determine the passenger exit rates for each cruise, the curves were adjusted using linear regression with $R^2 > 0.9$ (Fig. 4). The curves were grouped by cruise operation type to find repeating patterns that could explain passenger behaviour in terms of leaving the terminal. In addition, to explain the different exit rates, the correlations were analysed using the Pearson correlation coefficient, with the help of the commercial software Minitab, taking a moderate correlation to be $r > 0.4$.

In addition, to quantify the modal distribution of the cruise passengers, the disembarkation data were statistically analysed and validated to obtain the relative percentages of passenger transport mode choice and the average occupancies of the various transport modes.

The ratio of the number of vehicles generated per cruise ship to the number of passengers carried by a cruise was calculated and analysed to determine whether there was any correlation between this ratio and the cruise operation type.

3. Results

3.1. Cruise passenger flow exiting the terminal in a disembarkation operation

The analysis of the passenger exit flow for the nine studied cruises (Table 2 & Fig. 3) shows that disembarkation is a lengthy process that can last between 7 and 12 hours. This finding is in agreement with that of Fogg (2001), who established that the disembarkation process for a home port falls within 12 hours. The maximum demand period, which is defined as the time slot in which the largest number of passengers departs, typically begins one hour after the cruise docks at the pier.

The cruise operation (turnaround, transit or interporting) depends on the passenger flow, which is in accordance with the results from Di Vaio & D'Amore (2011). In turnaround cruises, the period of maximum demand lasts up to four hours, with a peak time between the third and fifth hour depending on the cruise. However, in transit cruises, this period extends over five hours, peaking at the fourth hour (Table 2). This difference occurs because the exit flow of transit passengers is a more staggered and prolonged process than the exit flow of turnaround passengers. In turnaround cruises, passengers have already booked their return journey by plane or train at a certain time, and therefore exit the terminal within a shorter period of time. In addition, in interporting cruises, which are a mixture of the previous two cruise operation types (Lekakou et al., 2009), the maximum demand period is concentrated within approximately two hours. Specifically, the peak demand for MSC Fantasia occurred in the second hour, and that of MSC Splendida occurred in the first hour. These cruises have a later arrival time and more turnaround passengers than transit passengers.

The data suggest that cruise ships arriving at 5 a.m. generally have a four-hour period of maximum demand for the disembarkation process that peaks in the fourth or fifth hour. For cruise ships arriving at 6 a.m., the period of maximum demand lasts five hours, with a peak in the fifth hour. For cruise ships arriving at 7 a.m., the maximum demand period varies from two to five hours with a peak in the second, third or fourth hour depending on the cruise. In addition, for cruise ships arriving at 9 a.m., the maximum demand period only one hour and peaks within that hour. These data show that the later the cruise arrives, the sooner passengers begin to disembark and the earlier the peak hour is.

When designing and managing a cruise terminal, the maximum number of users that the terminal can serve must be determined (PIANC, 2016). The results of this analysis show that, at most, over half of all passengers could disembark in one hour (Table 3). This is the case of the interporting cruises, in which an average of 52% of all passengers disembarked in one hour. On the other hand, transit cruises disembarked 30% of its total passengers in one hour. Turnaround cruises present an intermediate percentage (37%). Considering 10-minute intervals, the maximum passenger flow ranges from 18% in transit cruises (Grandeur of the seas) to 30% in turnaround cruises (Sovereign of the seas). These figures are again in accordance with the previous results. The maximum exit flows in turnaround operations are higher than in the transit operations, since the turnaround passengers end their journey and many of them have already arranged a travel mode to return to their homes.

In most of the cases studied, the flow of passengers exiting the terminal (Fig. 4 & Table 4) occurs linearly in three different stages. In the first stage, which roughly occurs between the first and third hour after the cruise ship arrives, the average exit rate (λ_1) is 13 passengers per minute in turnaround cruises and 9 passengers per minute in transit cruises. The second stage, which occurs between three and four and a half hours, is when most passengers leave the terminal. During this time, in turnaround cruises the exit rate (λ_2) doubles compared to that of the first stage, with an average of 27 passengers per minute. In transit cruises, the pace also increases but slower (15 passengers per minute). In interporting cruises, the first two stages show an exit rate of 37 passengers per minute, which is a high rate. In the third stage, which occurs between four and a half hours until the last passenger has disembarked, the exit rate (λ_3) is very low, between 1 and 2 passengers per minute in the three cruise operation types. Comparing these results with those of the few other studies that have investigated the flow of passengers in different transport modes confirms that passenger disembarkation is a linear process. Molyneaux et al. (2014) indicated that the flow of passengers disembarking from trains follows a piecewise linear function. In the case of airplanes, this process also behaves linearly (Horonjeff, 1969) with an exit rate of between 4 and 39 passengers per minute (Fricke & Schultz, 2008), which is within the range of our results (Table 4). To explain the different exit rates found, a correlation analysis was conducted. This analysis (Table 5) confirmed that the passenger exit flow strongly depends on the type of operation and the arrival time of the cruise ship. This correlation exists only during the first period (λ_1), between one and three hours after the cruise ship arrives. After this time (in the second and third periods), the passenger exit flow is independent of the cruise operation and the arrival time of the cruise ship.

Future demands for high-capacity cruise ships with disembarkations of approximately 5,000 passengers will not significantly increase the passenger flows from maritime stations during peak periods of 10 minutes. When exiting the ship, the passenger must go through different spaces inside the terminal, such as the gangway, boarding corridor, baggage lay down, customs and exit door (PIANC, 2016), which make disembarkation a more staggered process over time. However, a good dimensioning of these spaces, especially the gangway, which is the most critical element of the terminal, will be necessary (Cox & Long, 2004). In addition, the results show that an increase in cruise capacity does not necessarily result in an increase in the maximum flows.

3.2. Modal distribution of cruise passengers in a disembarkation operation

The results obtained during the disembarkation operation of the studied nine cruises from the fieldwork at *Adossat Pier* of the Port of Barcelona (Table 6) show that 35% of all cruise passengers use a taxi, making it the most commonly used transport mode. These results are consistent with those of Hall & Braithwaite (1990) since the Caribbean ports in their study are mostly homeports, resulting in high taxi use. In contrast, in the Port of Zihuatanejo (Mexico), a port of call between the ports of Miami and Los Angeles, few passengers use taxis, and most opt for excursion buses (Jaakson, 2004).

Currently, the Port of Barcelona is considered a homeport because more than half of passengers begin or end their journey in this city. If the modal distribution is differentiated by type of cruise operation, then the use of taxis in turnaround operations increase to an average of 48%. These ports occur at the end of the journey, so passengers are carrying their luggage and usually stay in the city overnight. Therefore, the passengers find it quicker and easier to take a taxi to their hotels instead of using other transport modes as taxis offer a direct route without requiring transfers. In addition to taking a taxi, passengers heading for the airport have the option of taking a transfer bus (25%), which some cruise lines charter to take passengers straight to the airport. For transit cruises, the most frequently used transport mode is the shuttle bus (49%). In these cases, passengers stay in the city for a few hours and leave their luggage on the cruise ship. Additionally, passengers may have previously booked a shuttle bus through a travel agency or on board the ship to take them directly to the area they wish to visit. For interporting cruise operation, the most common transport modes are shuttle buses (35%) and taxis (25%). This is a logical outcome since this operation is a mixture of the previous two modes and includes both passengers who are ending their journey and others who are just calling.

Other significant findings include the following:

- The number of passengers choosing excursion or transfer buses is fairly constant regardless of the cruise operation (13-25%). In ports of call, such as the port of Chios (Greece), the percentage of passengers who opt for excursions is much higher (55%) (Lekakou et al., 2011).

- No passengers in the turnaround operation chose shuttle buses, since they are ending their journey and heading for hotels, the airport or railway stations.

- For various reasons, few passengers choose public buses (8-15%). The first reason is a lack of knowledge; the passengers have not been informed about the existence of a public bus that can take them to the city, and the signage for the bus stop in insufficient and often not appropriately visible. The second reason is finances; although the cost of bus travel is relatively cheap (€3 one way, €4 return), many passengers think that taking a taxi costs less. In reality, taxi rides from the *Adossat Pier* cost €0.98/km with additional charges for the pick-up fee (€2.05) and pier entry/exit (€4.20). The Port Authority needs to encourage the use of public buses to reduce gas emissions and traffic at the pier.

- The number of passengers travelling in private vehicles is low (1-8%), and these are mostly vans from private companies hired by the passengers themselves. The pier does not have long-term parking, and the closest parking area is over 1 km away. In other ports, especially in America, long-term car parks are one of the main sources of income for port authorities. Fogg (2001) estimates that in American ports, between 20 and 30% of the cruise passengers use private parking.

- A significant number of passengers (5-12%) go into the city on foot, which is a key feature of the Port of Barcelona, since the city is located just 1.8 km from the cruise pier. Therefore, in ports close to the destination city, the pavement must be wide, comfortable and safe. In addition, these designs should consider the profiles of cruise passengers: sensitive to long distances and often have difficulties walking (up to 10% of cruise passengers) (Jaakson, 2004).

- The use of the various transport modes does not vary greatly with the cruise operation. Taxis have an average occupation of 3 passengers (Table 7), but despite the need to queue, passengers are increasingly demanding taxis with greater capacity (4+ pax). Although public buses do work at full capacity (40 pax) at certain times, the average number of bus passengers throughout their operating hours is only 10. Chartering large excursion and transfer buses often costs less for cruise lines, even the buses are not used to full capacity (32.4 pax). The average occupancy of private vehicles is over 4 pax as these are often vans hired by the passengers and not their own cars.

- The number of passengers who remain on the cruise ship and do not exit during a cruise call can be significant (Jaakson, 2004). According to Stefanidaki & Lekakou (2014), these passengers do not interact with the local system or population. In the case of the studied cruises, 30% of the total passengers stayed on the cruise ship. By contrast, in the port of call of Cartagena de Indias (Colombia) this percentage decreased to 10% (Brida et al., 2010).

- In terms of the parameters that influence a passenger's transport mode choice, the data show a clear correlation between only the mode choice and the cruise operation. Nevertheless, many other factors such as the distance from the port to destination attractions, the confidence level against the destination, the safety of the destination, and the passenger profile can be considered (De Cantis et al., 2016). These last parameters were not included in this analysis due to the lack of adequate data. As shown in Fig. 5, the number of passengers selecting taxis and those using shuttle buses varies greatly depending on the cruise operation type.

The recent arrival of high-capacity cruise ships will require reinforcing the transport modes and managing traffic with a greater number of personnel. Special consideration should be given to taxis, as this port seeks to become a pure homeport, which mostly uses taxis, rather than a port of call. The reason for this desired shift is that homeports produce a higher economic impact for the city (de la Vina & Ford, 1999; Lekakou et al., 2009; Brida & Zapata, 2009; Pallis, 2015). The trend towards becoming a homeport has been developing in Barcelona since 2011, and in 2016, 58% of cruises were turnaround operations (Port of Barcelona, 2017). As a consequence, the cruise terminals at this port will require a greater number of taxis, since cruise ships that begin or end at the same port (turnaround operations) require more taxis.

3.3. Estimating the traffic generated by a cruise

Estimating the traffic generated by a particular cruise ship is quite difficult since the traffic depends on many factors, such as the cruise operation type, arrival time, and cruise line, as noted previously. Table 7 presents the empirical data from the fieldwork, from which some conclusions can be drawn.

In general, the traffic generated by cruise activity has no direct implications for the city. At most, 881 new vehicles are generated, the process can last for up to 12 hours, and passengers are heading to multiple destinations (airport, train stations, tourist attractions, etc.).

As illustrated in Table 8, turnaround cruises generate more vehicle traffic (15-22%) since more passengers use taxis, which have a smaller capacity than buses. However, for transit cruises, the percentage of vehicles drops to 7% because more passengers choose shuttle buses, which have a greater capacity than taxis. For interporting cruises, as taxis and shuttle buses have similar demand, the percentage of vehicles generated (10-11%) falls between the two previous cruise operation types.

With the expected future trends of this port becoming a homeport and higher capacity cruise ships, traffic is expected to increase even as the overall number of passengers remains constant. This result will occur because passengers will travel by taxi more than by bus and because taxis have smaller capacity.

4. Conclusions

The fundamental contribution of this paper is studying the impact of cruise passengers on mobility within a port area, focusing on the Port of Barcelona. Specifically, this study analyses and predicts the behaviour of cruise passengers on land, that is, understanding how, when and why the flow of passengers occurs, their transport mode choice and the vehicles generated by cruise activity.

The results show that the flow of cruise passengers exiting the terminal greatly depends on the type of cruise operation and the arrival time of the cruise ship. The data show that the later the cruise ship arrives, the sooner passengers disembark, and the less time they take to do so.

Looking more closely at passenger exit flow, this process generally occurs linearly in three different stages. In the first stage (between one hour and three hours after the arrival of the cruise ship), the mean exit rate is 13 and 9 passengers per minute in turnaround and transit cruises respectively.

In the second stage (from three to four and a half hours), the mean exit rate is 27 passengers per minute in turnaround cruises, which is more than twice that in the first stage. In transit cruises, the pace is 15 passengers per minute. In the third stage (from four and a half hours until the last passenger has disembarked), the mean exit rate sharply decreases between 1 to 2 passengers per minute in all cruise operations. These results are in agreement with the conclusions of other studies. For example, in the case of trains, disembarkation is a piecewise linear function (Molyneaux et al., 2014). In airplanes (Horonjeff, 1969), the disembarkation process is linear, with an exit rate within the range of our results (Fricke & Schultz, 2008).

The modal distribution analysis shows that, on average, most passengers choose a taxi (35%), followed by excursion and transfer buses (22%), shuttle buses (19%), public buses (12%) and private vehicles (5%). This distribution is for the particular case of the Port of Barcelona, which is considered a homeport. In addition, a passenger's choice of transport mode strongly depends on the cruise operation type. In a turnaround operation, most passengers (48%) select a taxi. However, in a transit operation, most select shuttle buses (49%). In addition, in an interporting operation, both taxis and shuttles are popular transportation modes, since in this type of operation, some passengers are beginning or ending their journey while others are just calling. Furthermore, 30% of all passengers remain on the cruise ship and do not exit at the Port of Barcelona.

Predicting the road traffic generated by a cruise is very difficult as it depends on many variables. Using the percentages of vehicles with respect to the total number of passengers, the data shows that in turnaround cruises, the percentage of vehicles is between 15% and 22%; in transit cruises, the percentage drops to 7%; and in interporting cruises, the percentage is between 10% and 11%. In terms of mobility, this new traffic has little impact on the overall city traffic. The cruise traffic is small compared with the city traffic and has multiple destinations: airports, railway stations, tourist attractions, etc. However, this traffic does affect the internal mobility of the port, as the traffic is generated at peak hours and on roads with limited capacity.

The future demands of the port entail receiving cruise ships with greater capacity and with turnaround operation. These factors affect port mobility, as the future cruise activity will generate a higher volume of traffic that should be better managed. More turnaround cruises will require a greater number of taxis, which will generate more vehicles on the road and result in queues and long waiting times for passengers. The long-term solutions aim to completely change the current taxi management model, as taxis are responsible for the main mobility problems. One option is a mass transit system, such as a "People Mover" capable of moving a massive number of passengers via tramway or light rail (Vickerman & Beatley, 2004). This system has already been implemented in the Port of Venice as an air train connecting the maritime terminal with the car park (Moretti, 2012). Port Everglades (Florida) is also considering implementing this system in its cruise port to alleviate vehicular congestion (Vickerman & Beatley, 2004). However, this solution requires a substantial infrastructure investment. Another proposed suggestion is the creation of a "Mobility Centre", which is defined as an area far away from the cruise pier where passengers are brought by shuttle buses and can then take a taxi to their destination without a long waiting time.

The results of this research can be applied by port authorities or private operators for the correct dimensioning of a cruise terminal and can thus help to manage port traffic more efficiently. Considering the lack of research on cruise passenger mobility, this article contributes to the body of knowledge by identifying how, when and why mobility problems arise, determining which factors determine the passenger flow, and quantifying the transport modes and the road traffic generated by cruise activity. In addition, this paper considers the future mobility needs of the cruise industry and proposes possible solutions.

Due to the limitations of the data used in this study, the results should be considered a first approach to the problem of terrestrial mobility related to cruise ships. More research is necessary to understand and predict cruise passenger behaviour and to thus improve their mobility within a port.

References

Andriotis, K., & Agiomirgianakis, G. 2010. Cruise visitors' experience in a Mediterranean port of call. *International Journal of Tourism Research*, *12*(4), 390-404.

AQR-Lab. 2015. Impacto de la actividad de cruceros del Port de Barcelona sobre la economía catalana. *Universitat de Barcelona. Institut de Recerca en Economia Aplicada (IREA)*.

Baker, D. 2015. Exploring Cruise Passengers' Demographics, Experience, and Satisfaction with Cruising the Western Caribbean. *International Journal of Tourism & Hospitality Reviews*, *1*(1), 23-31.

Brida, J. G., & Zapata, S. 2009. Cruise tourism: economic, socio-cultural and environmental impacts. *International Journal of Leisure and Tourism Marketing*, 1(3), 205-226.

Brida, J. G., Bukstein, D., Garrido, N., Tealde, E., and Zapata Aguirre, S. 2010. Impactos económicos del turismo de cruceros: Un análisis del gasto de los pasajeros de cruceros que visitan el Caribe colombiano. *Estudios y perspectivas en turismo,* 19(5), 607-634.

Brida, J. G., Pulina, M., Riaño, E., and Zapata-Aguirre, S. 2012. Cruise passengers' experience embarking in a Caribbean home port. The case study of Cartagena de Indias. *Ocean & Coastal Management*, 55, 135-145.

Butt, N. 2007. The impact of cruise ship generated waste on home ports and ports of call: A study of Southampton. *Marine Policy*, 31(5), 591-598.

Caric, H. 2015. Challenges and prospects of valuation - cruise ship pollution case. *Journal of Cleaner Production*, *30*, 1e12.

CENIT. 2016. Cálculo de emisiones de gases contaminantes CO_2, NO_x, PM y SO_x producidos por el tráfico de cruceros en el Puerto de Barcelona.

Commoy, J., Polytika, C. A., Nadel, R., and Bulkley, J. W. 2005. The environmental impact of cruise ships. *World Water and Environmental Resources Congress 2005*.

Cordeau, J. F., Laporte, G., Legato, P., & Moccia, L. 2005. Models and tabu search heuristics for the berth-allocation problem. *Transportation Science*, 39(4), 526-538.

Cox, R., and Long, J. C. 2004. Embarkation/Disembarkation Of Cruise Ship Passengers Between the Terminal and the Ship. *Ports 2004,* ASCE, 10.1061/40727(2004)1.

Cruise Industry News. 2017. Cruise Ship Orderbook. 〈http://www.cruiseindustrynews.com/cruise-news/cruise-ship-orderbook.html〉 (Mar.27, 2017).

Cruise Lines International Association (CLIA). 2015. 2015 Cruise Industry Outlook. Cruising to New Horizons and Offering Travelers More 〈http://www.cruising.org/docs/default-source/research/2015-cruise-industry-outlook.pdf?sfvrsn=2〉 (Mar.14, 2016).

Cruise Lines International Association (CLIA). 2017. 2017 Cruise Industry Outlook. 〈 https://www.cruising.org/docs/default-source/research/clia-2017-state-of-the-industry.pdf?sfvrsn=0 〉 (Mar.27, 2017).

De Cantis, S., Ferrante, M., Kahani, A., & Shoval, N. 2016. Cruise passengers' behavior at the destination: Investigation using GPS technology. *Tourism Management*, 52, 133-150.

De la Vina, L., & Ford, J. 1999. Economic impact of proposed cruiseship business. *Annals of Tourism Research*, *26*(1), 204-207.

Di Vaio, A., & D'Amore, G. 2011. Governance of Italian cruise terminals for the management of mediterranean passenger flows. *Int. J. Euro-Mediterranean Stud*, *4*(1), 119-137.

Douglas, N., & Douglas, N. 2004. Cruise ship passenger spending patterns in Pacific island ports. *International Journal of Tourism Research*, *6*(4), 251-261.

Doymo. 2011. Analysis of the current situation and proposal of future alternatives for road traffic in the access roads to the cruise terminals. *Barcelona Port Authority*, 2011.

Dragovic, B., Tzannatos, E., Tselentis, V., Mestrovic, R., & Skuric, M. 2015. Ship emissions and their externalities in cruise ports. *Transportation Research Part D: Transport and Environment*.

Dwyer, L., & Forsyth, P. J. 1996. Economic impacts of cruise tourism in Australia. *Journal of Tourism Studies*, *7*(2), 36.

European Comission. 2009. Tourist facilities in ports - The environment factor, Directorate-General for Maritime Affairs and Fisheries. 〈 http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/economic_factor_en.pdf 〉 (Mar.28, 2017).

European Commission. 2015. Mapping and Performance Check of the Supply of Accessible Tourism Services (220/PP/ENT/PPA/12/6491) Case Study: Barcelona - Accessible Cruise Destination, Spain.

Ferrante, M., De Cantis, S., & Shoval, N. 2016. A general framework for collecting and analysing the tracking data of cruise passengers at the destination. *Current Issues in Tourism*, 1-26.

Fogg, J. A. 2001. *Cruise ship port planning factors* (No. CI01-115). Florida International Univ Miami.

Fricke, H., & Schultz, M. 2008. Improving aircraft turn around reliability. In *Third International Conference on Research in Air Transportation*.

Gibson, P. 2006. *Cruise operations management*. Elsevier.

Hall, J. A., & Braithwaite, R. 1990. Caribbean cruise tourism: a business of transnational partnerships. *Tourism Management*, *11*(4), 339-347.

Henthorne, T. L. 2000. An analysis of expenditures by cruise ship passengers in Jamaica. *Journal of Travel Research*, 38(3), 246-250.

Horonjeff, R. 1969. Analyses of passenger and baggage flows in airport terminal buildings. *Journal of Aircraft*, *6*(5), 446-451.

Jaakson, R. 2004. Beyond the tourist bubble?: cruiseship passengers in port. *Annals of tourism research*, *31*(1), 44-60.

Kendall, P. M. H. 1972. A theory of optimum ship size. *Journal of Transport Economics and Policy*, 128-146.

Kerswill, M. 2013. Big Ships, Small Towns: The Impact of New Port Developments in the Cruise Tourism Industry. The case of Falmouth Jamaica.

Klein, R. A. 2002. Cruise ship blues: The underside of the cruise ship industry. *New Society Publishers*.

Klein, R. A. 2011. Responsible cruise tourism: Issues of cruise tourism and sustainability. *Journal of Hospitality and Tourism Management*, 18(01), 107-116.

Lekakou, M. B., Pallis, A. A., & Vaggelas, G. K. 2009. Which homeport in Europe: The cruise industry's selection criteria. *Tourismos: An international multidisciplinary journal of tourism*, *4*(4), 215-240.

Lekakou, M., Stefanidaki, E., & Vaggelas, G. K. 2011, February. The economic impact of cruise to local economies. The case of an island. *Athens Tourism Symposium*, 2-3.

London, W. R., & Lohmann, G. 2014. Power in the context of cruise destination stakeholders' interrelationships. *Research in Transportation Business & Management*, *13*, 24-35.

Maragkogianni, A., & Papaefthimiou, S. 2015. Evaluating the social cost of cruise ships air emissions in major ports of Greece. *Transportation Research Part D: Transport and Environment*, *36*, 10-17.

McCarthy, J. 2003. The cruise industry and port city regeneration: The case of Valletta. *European Planning Studies*, *11*(3), 341-350.

Molyneaux, N., Hänseler, F., & Bierlaire, M. 2014. Modeling of train-induced pedestrian flows in railway stations. *STRC Proceedings*.

Moretti, M. 2012. Venice, Italy: Balancing Antiquity and Sustainability. In *Green Cities of Europe* (pp. 129-154). Island Press/Center for Resource Economics.

Pallis, T. 2015. Cruise shipping and urban development: State of the art of the industry and cruise ports. *International Transport Forum Discussion Paper*, 2015-14.

Papatheodorou, A. 2006. The cruise industry: an industrial organization perspective. *Cruise ship tourism*, 31-40.

Polat, N. 2015. Technical Innovations in Cruise Tourism and Results of Sustainability. *Procedia-Social and Behavioral Sciences*, *195*, 438-445.

Poplawski, K., Setton, E., McEwen, B., Hrebenyk, D., Graham, M., & Keller, P. 2011. Impact of cruise ship emissions in Victoria, BC, Canada. *Atmospheric Environment*, *45*(4), 824-833.

Port de Barcelona. 2014. Previsión cruceros 2015. <http://content.portdebarcelona.cat/cntmng/d/d/workspace/SpacesStore/a642cb20-34fd-427d-8d8e-97a7f0732e2e/2015anual_es.pdf> (Mar.14, 2016).

Port de Barcelona. 2017. Estadístiques de tràfic del Port de Barcelona. Dades acumulades desembre 2016. < http://content.portdebarcelona.cat/cntmng/d/d/workspace/SpacesStore/e3476a6c-47d5-4e8c-a57f-7aaae44963d2/PortBcnTrafic2016_12_ca.pdf > (Mar.28, 2017).

PIANC, WG. 152. 2016. Guidelines for Cruise Terminals. *Report of PIANC InCom WG 152.*

Río, M. C., & Cruz, M. T. K. 2008. Perfil y análisis del gasto del crucerista: El caso de Bahías de Huatulco (México). *Cuadernos de turismo*, (22), 47-78.

Sanz-Blas, S., Buzova, D., & Carvajal-Trujillo, E. 2015. Investigating the moderating effect of information sources on cruise tourist behaviour in a port of call. *Current Issues in Tourism*, 1-9.

Scherrer, P., Smith, A. J., Randall, M., & Dowling, R. 2011. Environmental and cultural implications of visitor access in the Kimberley region, Australia. *Australian Geographer*, *42*(3), 257-271.

Stefanidaki, E., & Lekakou, M. 2014. Cruise carrying capacity: A conceptual approach. *Research in Transportation Business & Management*, *13*, 43-52.

Stynes, D. J. 1997. Economic impacts of tourism: a handbook for tourism professionals. *Urbana, IL: University of Illinois, Tourism Research Laboratory*, 1-32.

Sun, X., Feng, X., & Gauri, D. K. 2014. The cruise industry in China: Efforts, progress and challenges. *International Journal of Hospitality Management*, *42*, 71-84.

Taylor-Powell, E., & Steele, S. 1996. Collecting evaluation data: Direct observation. *Program Development and Evaluation. Wiscounsin: University of Wisconsin-Extension*, 1-7.

Torbianelli, V. 2012. The local economic impact of cruises: From figures to the active policies of the European Harbour cities. *Pomorstvo: Scientific Journal of Maritime Research*, *26*(1), 139-150.

Tran, N. K., & Haasis, H. D. 2015. An empirical study of fleet expansion and growth of ship size in container liner shipping. *International Journal of Production Economics*, *159*, 241-253.

Vickerman, M. J., and Beatley, D. K. 2004. Port Everglades New International Cruise Terminal and Airport People Mover Connection: Development Strategy for the Largest Cruise Terminal Complex on the US East Coast. *Ports 2004,* ASCE, 10.1061/40727(2004)3.

Wang, F., & Lim, A. 2007. A stochastic beam search for the berth allocation problem. *Decision Support Systems*, 42(4), 2186-2196.

Table 1
Cruise ship data collection.

Cruise ship	Terminal	Cruise operation	Pax entering	Pax exiting	Cruise line	Arrival day & time
Sovereign of the Seas	A	Turnaround	3,376	2,658	Royal Caribbean	25/06/2011 7:00
Carnival Magic	D	Turnaround	4,241	5,534	Carnival Corporation	10/07/2011 5:00
Brilliance of the Seas	B	Turnaround	2,618	2,625	Royal Caribbean	24/06/2011 5:00
Liberty of the Seas	B	Turnaround	4,772	4,980	Royal Caribbean	02/07/2011 5:00
Norwegian Epic	A	Turnaround	5,039	4,347	Star Cruises	03/07/2011 5:00
Grandeur of the Seas	A	Transit	2,423	2,383	Royal Caribbean	20/06/2011 6:00
Independence of the Seas	B	Transit	4,377	4,456	Royal Caribbean	11/07/2011 7:00
MSC Fantasia	B	Interporting	4,196	4,201	MSC	11/07/2011 7:00
MSC Splendida	B	Interporting	4,139	3,944	MSC	15/07/2011 9:00

Table 2
Variables for passenger exit flow at the terminal.

Cruise ship	Cruise operation	Period of maximum demand (h)	Peak hour (h)	Max pax per hour (pax/h)	Max pax in 10 minutes (pax/10 min)	Mean pax per hour (pax/h)	Mean pax in 10 min (pax/10 min)
Sovereign of the Seas	Turnaround	1st to 4th	3rd	1,092	329	266	55
Carnival Magic	Turnaround	1st to 5th	4th	1,868	371	503	86
Brilliance of the Seas	Turnaround	1st to 5th	5th	933	264	219	43
Liberty of the Seas	Turnaround	1st to 5th	4th	1,798	486	453	88
Norwegian Epic	Turnaround	1st to 5th	5th	1,611	373	363	65
Grandeur of the Seas	Transit	2nd to 7th	4th	772	136	184	37
Independence of the Seas	Transit	1st to 6th	4th	1,207	254	319	60
MSC Fantasia	Interporting	1st to 3rd	2nd	2,245	575	601	106
MSC Splendida	Interporting	1st to 2nd	1st	1,993	551	439	75

Table 3

Maximum exit flows in one-hour periods and 10-minute intervals

Cruise ship	Cruise operation	Max pax per hour (pax/h)	%	Max pax in 10 min (pax/10 min)	%
Sovereign of the seas	Turnaround	1,092	41%	329	30%
Carnival Magic	Turnaround	1,868	35%	371	20%
Brillance of the seas	Turnaround	933	36%	264	28%
Liberty of the seas	Turnaround	1,798	36%	486	27%
Norwegian Epic	Turnaround	1,611	37%	373	23%
Grandeur of the seas	Transit	772	32%	136	18%
Independence of the seas	Transit	1,207	27%	254	21%
MSC Fantasia	Interporting	2,245	53%	575	26%
MSC Splendida	Interporting	1,993	51%	551	28%

Table 4
Passenger exit rates by cruise

Cruise ship	Cruise operation	Arrival time	Pax disembarking	λ_1 (pax/min)	λ_2 (pax/min)	λ_3 (pax/min)
Sovereign of the Seas	Turnaround	7:00 am	2,658	18	18	2
Carnival Magic	Turnaround	5:00 am	5,534	15	31	3
Brillance of the Seas	Turnaround	5:00 am	2,625	8	18	1
Liberty of the Seas	Turnaround	5:00 am	4,980	18	38	2
Norwegian Epic	Turnaround	5:00 am	4,347	8	29	2
Grandeur of the Seas	Transit	6:00 am	2,383	6	12	2
Independence of the Seas	Transit	7:00 am	4,456	13	19	2
MSC Fantasia	Interporting	7:00 am	4,201	36	36	1
MSC Splendida	Interporting	9:00 am	3,944	39	39	1

Table 5
Correlations between passenger exit rates and the cruise operation, arrival time and number of passengers on cruise ships

Passenger exit rate	Cruise operation	Arrival time	Number of pax
λ_1 (pax/min)	0.738	0.737	0.246
λ_2 (pax/min)	0.297	0.180	0.714
λ_3 (pax/min)	-0.547	-0.332	0.501

Table 6
Mean modal transport percentages by cruise operations

% Pax in transport modes	Turnaround	Transit	Interporting
Taxi	48%	10%	25%
Excursion & transfer bus	25%	13%	24%
Shuttle bus	0%	49%	35%
Public bus	13%	15%	8%
Private vehicle	8%	1%	3%
On foot	6%	12%	5%
Total	100%	100%	100%

Table 7
Mean occupancy of transport modes

Transport mode	Mean occupancy (pax)
Taxi	3.0
Excursion & transfer bus	32.4
Shuttle bus	25.8
Public bus	9.9
Private vehicle	4.8

Table 8
Ratios between cruise passengers and vehicles generated

Cruise Ship	Cruise Operation	Pax disembarking	Total vehicles	Ratios Veh/Pax (%)
Sovereign of the Seas	Turnaround	2,658	410	15%
Carnival Magic	Turnaround	5,534	881	16%
Brillance of the Seas	Turnaround	2,625	583	22%
Liberty of the Seas	Turnaround	4,980	795	16%
Norwegian Epic	Turnaround	4,347	849	20%
Grandeur of the Seas	Transit	2,383	169	7%
Independence of the Seas	Transit	4,456	314	7%
MSC Fantasia	Interporting	4,201	424	10%
MSC Splendida	Interporting	3,944	441	11%

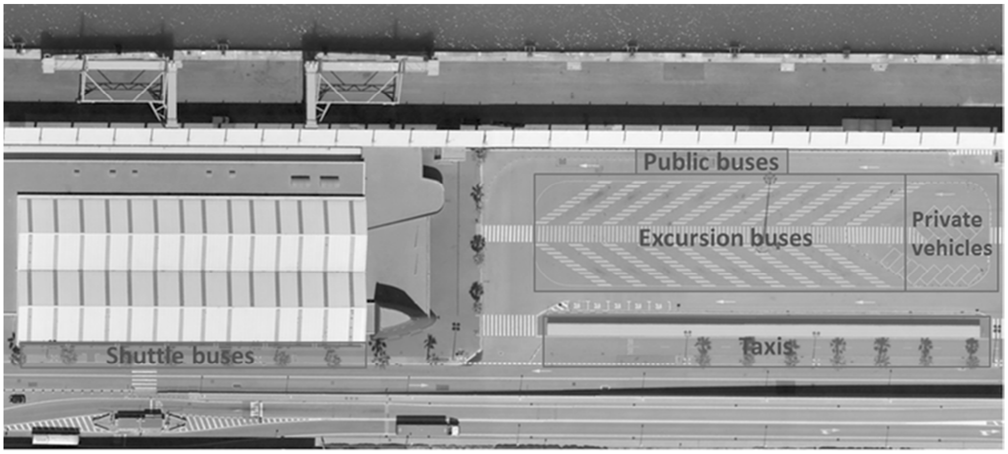

Fig. 1. Modal transport distribution in a cruise terminal

63x28mm (300 x 300 DPI)

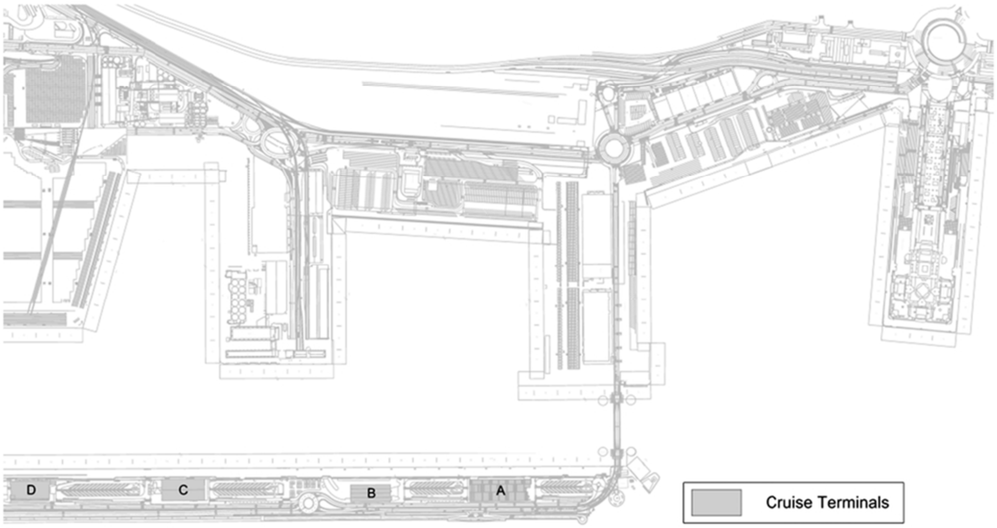

Fig. 2. Cruise terminals in the Adossat Pier of the Port of Barcelona

80x43mm (300 x 300 DPI)

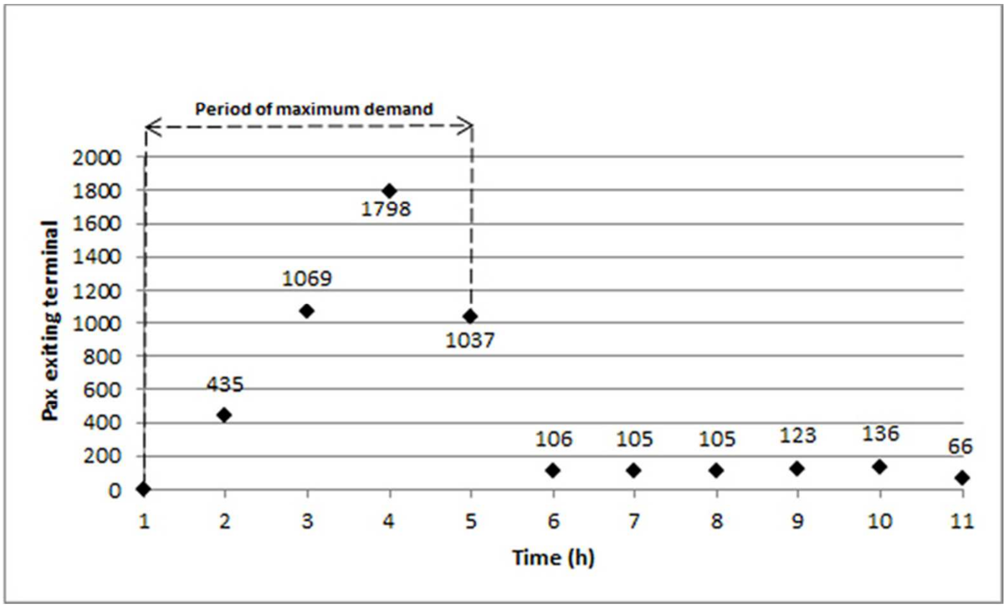

Fig. 3. Passenger exit flow at the terminal for cruise ship Liberty of the seas

63x38mm (300 x 300 DPI)

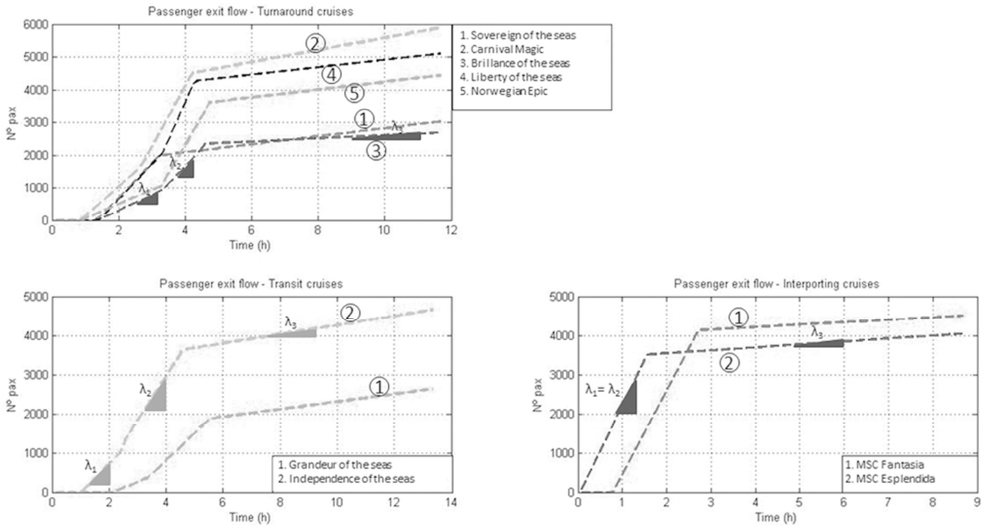

Fig. 4. Passenger exit flow by cruise operation

87x45mm (300 x 300 DPI)

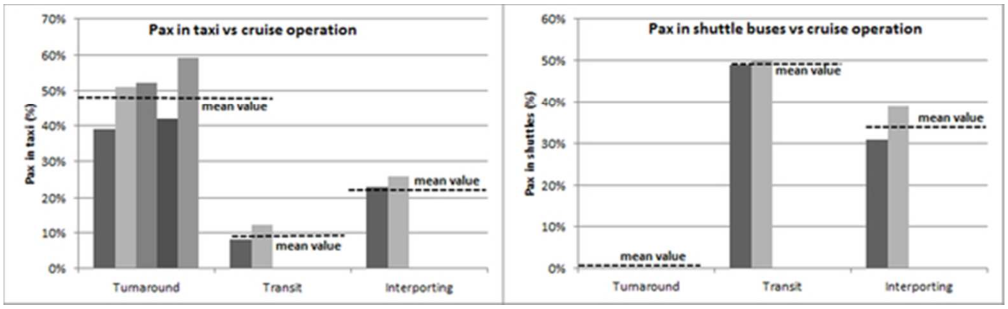

Fig. 5. Plots of taxi and shuttle bus transport modes against cruise operation

51x15mm (300 x 300 DPI)