The Southampton system: a new universal standard approach for port-city classification

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ABSTRACT

The most widely-used current system for classifying port-cities is limited to container ports, excluding other types of cargo and passengers. This limits the usefulness of research findings and policy recommendations. A new system is proposed that includes passengers and all cargo types. In order to compare passenger numbers with cargo, the weight of ships from a sample of recent ship calls to Southampton was used to calculate the average cargo tonnage and passengers per tonne of ship. This led to the finding that 10 tonnes of cargo tonnage are equivalent to 1 passenger. This finding was validated with data from other ports and used as the basis for a new universal system (‘The Southampton System’), combining passenger numbers and cargo tonnage on one axis with urban population on another in a $4 \times 4$ matrix, creating 16 groupings of port-cities. The developed system was tested using data collected from 301 ports from around the world. These ports were successfully grouped, including ports that have not been included in previous systems due to a lack of containers. The Southampton System provides an effective and broader method for port-city classification, enabling more effective future study into, and policy recommendations for, port-cities.

KEYWORDS

Port-city; classification; the Southampton System; cargo tonnage; passengers

1. Introduction

A port is defined as a place that has the facilities for ships to load or unload, and a city is defined as an inhabited place of greater size, population or importance than a town or village (Merriam-Webster 2019). It should thus be relatively simple to create a definition of what constitutes a port-city. However, there is a lack of consensus on exactly how port-cities should be defined and classified.

Port-cities have a key role in international trade and provide essential services to the local, regional and national economies. Port-cities experience different challenges and opportunities when compared with inland cities, due to the presence of the port. Large port-cities have also been shown to experience higher levels of economic growth than inland cities, with the port contributing a large amount of a city’s gross domestic product (GDP), such as 13% and 7.6% in Rotterdam and Shanghai, respectively (Adomaitis 2014). Port-cities can boost manufacturing and growth of port-related industries, contributing jobs to the local area. They can also be popular start-and end-points and destinations for tourist activities, such as cruises. The presence of the port may bring additional opportunities in areas such as employment, renewable energy, circular economy, culture and identity.
Alongside the benefits created by a port, there are a range of negative aspects, such as pollution, traffic congestion, severance and visual blight. Ports can create varying forms of environmental pollution, such as air, water, noise, light, soil, thermal and biological pollution (e.g. alien invasive species). Within a port-city, the air emissions created by the port can form a large percentage of total city emissions. A good example of this is Hong Kong, where port activities were estimated to contribute 54% of SO₂ and 33% of NOₓ in terms of emissions by weight annually within the city (OECD 2013). This all makes port-cities very different from inland cities.

The last centuries have been characterised by a dramatic increase in the number of people living in cities, with the world’s urban population increasing from 751 million in 1950, to 4.2 billion in 2018, with 55% of the world’s population living in urban areas (United Nations 2018). This trend is due to continue, with 68% of the world’s population expected to live in urban areas globally by 2050 (United Nations 2018). Alongside this trend of urbanisation, has been a faster rate of growth in coastal areas, with the majority of growth taking place in coastal cities (Adomaitis 2014). These trends have fuelled the expansion of port-cities.

Establishing sustainable cities and communities is one of the 17 United Nations Sustainable Development Goals (SDGs) (SDG number 11). Port-cities are vitally important to efforts to encourage sustainability. It is therefore important to gain a greater understanding and critical evaluation of port-cities, what their requirements and challenges are, how they differ and how they can be better utilised to produce more benefits and fewer negative impacts. As a strong focus is placed on understanding the environmental impacts of ports and sustainability, a system to effectively group port-cities by their size and potential impacts is needed.

At present, there is no effective way to categorise port-cities. The most widely used system in the literature (Ducruet and Lee 2006), is used exclusively for grouping ports by container traffic. This excludes ports without containers and fails to include other types of cargo, as well as passengers. This limits the definition of Port-City to a certain type of cargo port. Consequently, many studies into port-cities are deficient or restricted by this definition, which limits their findings and practical utility. As the need for sustainable development in port-cities increases, a broader and more suitable way to classify what is and what is not a port-city is required.

In this paper a quantitative approach to determine this classification was adopted based on data collected from over 300 Port-Cities world-wide and data on port traffic at Southampton, which was then validated using data from eight other Port-Cities.

2. Background

Ducruet (2011) proposed that port-cities should be defined as any urban settlement that contains port and maritime activities. Chen and Lam (2018) stated that a port-city is an integration of port and city systems. These serve as good basic definitions to differentiate port-cities from non-port-cities. However, studies into port-cities have often chosen more specific definitions, depending on the metrics used to evaluate port-city status. Port-cities were defined by Armen (1972) as cities in which the port was the main source of economic activity, excluding many cities where the port is no longer the main economic driver in the city, such as London. More recent work such as Ducruet and Lee (2006) has focused only on port-cities with container traffic.

The systems used to classify ports and port-cities fall into three broad categories; Time-series, Functional and Hierarchical (Table 1). These systems can also be separated into national systems, such as the UK’s major and minor system (Department for Transport 2019), regional systems such as the port-city Interface model (Hoyle 1989) and systems designed to be used internationally such as Ducruet and Lee (2006) Port-city typology.

Time-series, or generational, models are able to capture how the port and port-city has developed, and how it may develop in the future. Bird’s Anyport model (1963) is an early example of this; it describes how ports may evolve over time, expanding from an initial location and eventually developing specialised areas. This model also helps to explain the changing relationships between
Table 1. Existing classification systems for ports and port-cities across a range of scales.

| Port and Port-City Classification systems | National | Regional | International |
|------------------------------------------|----------|----------|---------------|
| Time-series                              | Anyport Model (Bird 1963)—Based on UK port evolution | Port-City Interface Model (Hoyle 1989)—Based on Western ports. Asian Hub Port-City Model (Lee, Song, and Ducruet 2008) COREALIS (2018)—Based on European Ports | UNCTAD Model (1993). Anyport model with regionalisation stage (Notteboom and Rodrigue 2007) |
| Functional                               | Major and Minor distinctions (US Department of Defence 2005, Ministry of Transport of the People’s Republic of China 2019, Department for Transport 2018a) | Port-City Typology (Ducruet and Lee 2006) | |

port and city, showing how during the specialisation phase, old and disused port land may be redeveloped and repurposed. This model was expanded by Notteboom and Rodrigue (2007) with the addition of a regionalisation stage. The port-city interface model created by Hoyle (1989) offers more detail, illustrating six developmental stages that port-cities pass through, along with the expected characteristics of such a port-city. Hoyle’s (1989) system was based around western port-cities, and was therefore of limited use beyond these. To address this, the Asian Hub Port-City model was created by Lee, Song, and Ducruet (2008), to illustrate the six corresponding developmental stages port-cities in Asia have been observed to pass through. The UNCTAD Port Development Model (1993) considers the key trends driving port development during four generational stages, with a fifth stage proposed by Lee and Lam (2016). Whilst these types of models are useful when studying the historical evolution of ports and port-cities and are available across a range of scales, they are of limited use when considering how present-day port-cities may vary and need to develop in future.

It is possible to group ports and port-cities by function, such as the COREALIS project (2018), which produced nine different types of container ports. These are Dominant, Superior, Intermediary, Versatile, Ordinary, Developing, Specialised, Industrial and Peripheral. This system allows container ports to be grouped based on their shipping network and inland networks.

Hierarchical systems are commonly used by governments, such as the widely used major and minor system. Since 2000, the UK Government has defined a major port as a port that handles over 1,000 kilotonnes of cargo annually (Department for Transport 2018a), with this value having been 2,000 prior to 2000. The US Department of Defence (2005) defines a major port as a port capable of handling 100 kilotonnes a month, which would give an annual value of 1,200 kilotonnes per year. China has 34 major ports all of which exist in cities handling over 50,000 kilotonnes per year (Ministry of Transport of the People’s Republic of China 2019). This shows how a simple minor or major distinction does not work at a global level due to the varying sizes of ports and the varying importance of these ports to their respective countries. Different types of tonnes are also used across the world. A US Tonne (short tonne) is equivalent to 907.18 kg, a metric tonne is equivalent to 1000 kg and a British tonne (long tonne) is equivalent to 1016 kg (Britannica 2020). This makes comparisons more difficult, however, it can still be possible as shown by AAPA (2016), which ranks ports together despite different forms of tonnage being used. A port handling 10,000 kilotonnes annually may be of great importance to a small country, whereas a similar sized port in China is considered minor. Both of these ports would create considerable impacts for the cities in which they are located.

Another approach used for hierarchical classification is Ducruet and Lee (2006) classification of port-cities that uses container traffic on one axis and urban population density on the other to
create nine different groups of port-cities, in order of rank. This allows port cities to be grouped based on size and volume of port traffic in containers.

There are numerous available systems for classification of port-cities. A new, clearer and more functional approach to sustainable development in port-cities internationally is needed. A sustainable approach must consider environmental, economic and social factors, the three pillars of sustainable development. Some of the key costs and benefits created by port-cities are presented in Table 2.

Most of these costs and benefits are related to either the size of the port activity, or the size of the urban population, or both. These existing systems are unable to consider all of these factors, due to the fact they all neglect key areas. The time-series models all reflect changes to infrastructure and port development, but crucially do not relate to the size of the impact, or the size of the affected population. Hierarchical systems focusing on major and minor ports fail to consider the size of the city and other types of activity not measured in cargo tonnage or twenty-foot equivalent units (TEU). The system which gets closest to being able to consider the overall size of the impact of the port and the overall size of the impacted population is the system created by Ducruet and Lee (2006) (Figure 1), which also appears to be the most widely used in the literature. This system has been used by organisations such as the OECD, in The Competitiveness of Global Port-Cities: Synthesis Report (OECD 2013), as well as other academic articles, such as Chen and Lam (2018).

The size of the port activity, and the size of the urban functions, is expressed by Ducruet and Lee (2006) as centrality, representing the urban functions, and intermediacy, representing the size of port activity. Container traffic expressed in TEU is used as a measure of intermediacy and urban population used as a measure for centrality.

Ducruet and Lee (2006) typology is created by a matrix, splitting port-cities into nine distinct groups, for small, medium and large city sizes and port traffic volumes. This system provides a good framework to assess port-cities by their container traffic. It is simple enough to be used with easily available data and doesn’t create too many groups to be practical, which is an important strength. However, it fails to consider other types of cargo such as general cargo, dry bulk, liquid bulk and Ro/Ro (roll on/roll off—ships designed to allow wheeled cargo to be driven on and off a ship on their own wheels or using a platform vehicle). It also fails to include passengers, which is an important limitation. Using the UK as an example, container traffic makes up only 39.2% of inward and 24.8% of outward traffic in UK ports (Department for Transport 2018b). This shows that container volume is not the most effective way to classify port-cities and excludes the majority of port activity. Empirical port and city studies are often done separately (Chen and Lam 2018), and this system has helped enable an increase in ports and cities being studied together. However, in studies using this

**Table 2. Costs and benefits of port-cities (adapted from OECD 2013).**

| Environmental | Economic | Social |
|---------------|----------|--------|
| Costs         |          |        |
| Environmental pollution (Air, Water, Light, Soil, Noise) | Opportunity costs. Land use | Security threats (Smuggling, terrorism, people trafficking etc.) |
| Soil pollution | Cost of infrastructure Traffic congestion | Changing relationship between port and city (relating to issues such as automation). |
| Degradation of environmental sites | | Impact on human health |
| Traffic congestion | | Traffic congestion |
| Land use | | |
| Benefits      |          |        |
| Renewable energy opportunities | Local employment Value added Industrial development Maritime Centres Waterfront development Investment | Culture and Identity Provision of goods and services Employment |
| Circular economy opportunities | | |
system the findings are limited to container ports, due to the focus of the system. This illustrates a key problem at the heart of many port-city studies, which is a lack of a common framework that can be used to include all types of port-cities and separate them into meaningful groups for further investigation.

The problems of this system can be illustrated using Plymouth in the UK as an example. With an urban population of 259,200 (City Population 2019) and a local government authority, it is clearly defined as a city under any available definition of a city. With 433,000 international ferry passengers (Department for Transport 2018c), 2,384,000 annual cargo tonnage (Department for Transport 2019) and over 500 years of maritime and naval heritage, Plymouth is considered a port under any available definition of a port. It would seem logical that Plymouth should be classified as a port-city. Nevertheless, it is not considered a port-city under the system proposed by Ducruet and Lee (2006), due to the absence of containers from its port activity (ABP 2019a). This shows a disconnect between the common understanding of what a port-city is and the academic studies concerning them, demonstrating clearly the limitations of this system for port-city classification and why a new system is needed.

Chen and Lam (2018) stated that general global recommendations for sustainability policy in port-cities are yet to be developed. It may not be possible to develop such policies if studies continue to use a system that is capable of representing only one specific metric of cargo ports. Many issues relating to sustainability in port-cities cannot be solved without a broader view of port activity. Sustainability should seek to balance social, economic and environmental issues. One activity within some port-cities which has been criticised for this balance is cruise tourism. Cruise ships have been shown to produce fewer local economic benefits than container ships (OECD 2013), contributing up to 25% of waste in the global merchant fleet despite making up less than 1% of the fleet (Butt 2007) and produce harmful air pollution. Maragkogianni and Papaefthimiou (2015) calculated cruise ship air pollution creates health impacts with a cost of €5.3 per passenger per port call. Using the average cruise ship passenger capacity of 3000 (Roberts

Figure 1. Matrix showing port-city typology. Adapted from Ducruet and Lee (2006)
et al. 2018), this would create €15,900 of health impacts per visit to the port. This illustrates the importance of considering all types of port traffic when creating sustainability policy for port-cities.

An improved classification must be able to consider a greater range of cargo types, must include passengers and must be able to accommodate all types of port-cities that could theoretically exist, rather than container ports only. It should remain simple enough to be practically usable, allowing port-cities to be quickly grouped using freely available and accessible data. This study is a first attempt to find a direct comparison between passengers and cargo in order to incorporate them both into a new system for port-city classification that is able to include a greater range of port types. The developed system (“The Southampton System”) is tested using data collected on port-cities around the world to present how they are distributed, and illustrate the inclusion of port-cities that were excluded from the system in Ducruet and Lee (2006).

The city of Southampton was selected as a test case for the new system. This is because it is one of the UK’s largest cargo ports, the UK’s largest cruise port, and it is widely used by ferries and a wide variety of leisure craft, meaning that the vessels found in this port city are broadly representative of a wide variety of ship types.

3. Methodology

The aim of this paper is to produce a universal standard classification system for port cities by using quantitative methods. Vessel traffic service data (VTS) from Southampton port were used to find a direct comparison between cargo traffic and passenger traffic. The comparison was verified with data from a range of port cities around the world. This has allowed the creation of a new classification system incorporating both cargo and passenger volumes, which was then tested with publically available data on port-cities.

Firstly, an appropriate measure of cargo traffic was identified. Cargo tonnage was chosen as a better measure of cargo traffic than TEU (twenty-foot equivalent unit—an approximate unit of cargo capacity used to describe the capacity of container ships/terminals) as it includes all forms of cargo and not just containers. A method was devised to compare cargo tonnage with passengers. This was done using the gross tonnage and deadweight tonnage of cargo and passenger ships. Gross tonnage represents the overall internal volume of the vessel, whereas the deadweight tonnage represents the maximum additional weight the ship is able to carry. Data were collected on a range of ships that have visited the port of Southampton on the 28 November 2019, or ships due to visit in the future using VTS data (ABP 2019b). The UK’s major-port tonnage by cargo type (Department for Transport 2018b) was used to calculate the percentage of each ship type within UK annual major-port tonnage. This was used alongside the collected VTS data to create a representative sample fleet of UK cargo ships.

The percentage each type of ship would contribute to a fleet of 20 ships was calculated, and then rounded to the nearest whole number of ships within each group (Appendix A), creating a final sample fleet of 21 ships. This number was chosen to make it comparable with the number of passenger ferries used in the study, which is limited by the size of the fleet. The most recent ship calls from these types of ships in the port of Southampton were then selected using VTS data (ABP 2019b). The gross tonnage of these vessels was used alongside the deadweight tonnage to calculate how many tonnes of cargo can be added for each tonne of the ship’s volume on average, using the mean value across all ships. To illustrate this calculation for one vessel, the container ship COSCO Vietnam has a deadweight tonnage of 102,875, which was divided by the ship’s gross tonnage of 91,051. This gives a value of 1.13 tonnes of cargo per 1 tonne of the ships internal volume. The same process can then be repeated using passenger vessels, replacing deadweight tonnage with passenger numbers in the calculation to provide a comparison.

Gross tonnage and passenger data for passenger ships were collected using scheduled cruise ships in the port of Southampton from VTS data (ABP 2019b), alongside data of the local ferry fleet
International ferry data were collected from the Port of Dover (P&O ferries 2019) since Southampton does not offer this service. The gross tonnage for ferries was used alongside maximum passenger numbers, to calculate how many passengers can be added for each tonne of the ship’s internal volume. The values for different types of passenger ships can then be compared directly with cargo tonnage, producing a potential way to include both of them on the same axis, and include a greater range of ports within the classification system.

The findings are validated by comparing the values from Southampton with values calculated in the same way from other port-cities (Qingdao, Vancouver, Istanbul, Shanghai, Busan, Le Havre, Liverpool and Portsmouth) assembled from Marine Traffic (2020).

Once passenger numbers and cargo tonnage were matched, a new matrix was produced using a choice between cargo tonnage or passenger numbers on one axis, and urban population on the other. These were done using orders of magnitude in order to offer greater differentiation among the smaller to medium sized port-cities which make up the majority of world port-cities, and also in order to group some of the larger port-cities together where the differences in size are very large.

Key measures of port activity (cargo tonnage, ferry passengers and cruise passengers) were collected alongside city population statistics. Where necessary TEU was converted into cargo tonnage using a value for the maximum potential weight per TEU. This value is 21,600 kg per TEU (Roberts et al. 2018); this is not as accurate as having recorded cargo tonnage values but allows sufficient understanding of the freight volume. Cruise passenger numbers were estimated when necessary from recorded cruise ship calls in port, using an average number of passengers per vessel of 3,000 (Roberts et al. 2018). This was required for many of the ports in Asia, where ship calls not passenger statistics are recorded.

Ports were selected for the classification system based on lists of the world’s largest ports and data availability. The largest passenger and cargo ports in the world were used using freely available lists. For the smaller ports, additional data were collected for specific countries. These countries were selected due to ease of use, such as data published in English (UK, USA, Australia, Greece, Germany), or data which could be translated reliably with available resources (China, Korea). Some countries and world regions lack data. Data of this type are often published by government authorities. This means the collected data for this report may be biased in favour of countries with strong institutions, which enables effective data collection and publication. It is very difficult to find published data for certain world regions, such as Africa and South America (excluding the very largest ports)—for the list of ports and data sources see Appendix B. Selected ports were chosen to demonstrate the effectiveness of the new system, as these would all be considered to not be port-cities using the system created by Ducruet and Lee (2006). These are ports and cities of varying sizes, which do not have container terminals.

Table 3 illustrates examples of non-container ports located in settlements with a population of greater than 10,000 people. Their distribution will be illustrated using the new classification matrix. These ports are included as they are not categorised as port-cities under the system created by Ducruet and Lee (2006) due to a lack of containers.

4. Results

Twenty-one ships were chosen as the most recent of each type to visit the port of Southampton, assembled into a sample fleet representing the UK’s percentages of each cargo type (Appendix C). This produced an average gross tonnage of 48,180 and an average deadweight tonnage of 53,853. It is then possible to divide the deadweight tonnage by the gross tonnage to discover how much cargo tonnage 1 tonne of ship is able to carry. This gives a value of 1.118 tonnes of cargo per tonne of ship, from a sample of ships that ought to represent the average across all UK cargo shipping.

Data on the next 10 cruise ships to visit the port were collected alongside the local ferry service fleet from Southampton and international ferry fleet data from the port of Dover. The gross tonnage was collected alongside passenger numbers, which can then be used to calculate the number of
passengers per tonne of ship. Using a sample of cruise ships chosen to create the average gross tonnage and passenger numbers from the port of Southampton produced a mean gross tonnage of 109,272 and a mean passenger number of 2,764 (Appendix D). This was used to calculate the number of cruise passengers per tonne of ship (0.025).

The gross tonnage and passenger numbers of Southampton’s local ferry fleet was calculated (Appendix E). This gives a value of 0.188 passengers per tonne of ship for local passenger ferries. The international passenger fleet operated by P&O at the port of Dover was also used (Appendix F). This gives a value of 0.048 passengers per tonne of ship for international ferries. Table 4 shows the average tonnes of cargo and passenger numbers for cruise, international ferry and domestic ferries per 1 tonne of ship. This can then be used to directly compare cargo tonnage with passengers. Multiplying the cargo tonnage value by 8.5 gives a value of 10 cargo tonnes for 8.5 tonnes of ship. This allows passenger numbers to be compared with 10 tonnes of cargo tonnage. This gives an average for passenger ships of 0.72 passengers per 10 cargo tonnes. As domestic ferries may be more common in ports than cruise ships, the true value as an average value for passengers may be higher, therefore a value of 1 passenger per 10 cargo tonnes is proposed as a suitable value. This will make comparisons easier. The amount of fuel the ship needs to use to move is based on the weight of the ship, and cruise ships for example contain all of the infrastructure required to make people’s stays there comfortable (bedrooms, bathrooms, sewerage etc). It is important to bear this in mind when considering the weight of ship per person. International and domestic ferries may carry cars associated with the passengers, as well as the other required infrastructure for the passengers’ trips.

These data can be grouped in orders of magnitude, and considered alongside urban population data in orders of magnitude to produce a new system for port-city classification. This system is able to consider a wide range of types of cargo and the equivalent values for passengers. The population axis was expanded to 4 groups in order to accommodate the growth in megacities.

The same method was followed for data from a selection of port cities (Appendices G, H, I, J, K, L and M). Table 5 shows the values for different passenger types when compared with cargo tonnage in a range of port-cities. The values are close to those generated from Southampton shown in Table 4. This demonstrates the universal applicability of this system and the suitability of using 1 passenger as an equivalent to 10 tonnes of cargo.

### Table 3. Selected ports that do not fit into the existing system by Ducruet and Lee (2006).

| Port          | Urban population | Annual Cargo tonnage | Annual Passengers | Containers |
|---------------|------------------|-----------------------|-------------------|------------|
| Plymouth      | 263,000          | 88,000                | 430,000           | None       |
| Swansea       | 179,485          | 520,000               | NA                | None       |
| Falmouth      | 21,797           | 125,000               | 19,470            | None       |
| Penzance      | 21,200           | 15,000                | 36,450            | None       |
| Teignmouth    | 14,700           | 460,000               | NA                | None       |
| Corpus Christi| 325,733          | 80,000,000            | NA                | Low volumes|
| Green Bay     | 104,057          | 2,087,390             | NA                | None       |
| Coos Bay      | 16,680           | 1,500,000             | NA                | None       |
| Harwich       | 13,699           | NA                    | 1,000,000         | None       |
| Grimsby       | 88,000           | 1,100,000             | NA                | None       |
| Brownsville   | 175,023          | 11,300,000            | NA                | None       |

### Table 4. Average amount of cargo, cruise, international and domestic ferry passengers per 1 tonne of ship, and per 10 tonnes of cargo.

|                  | Cargo tonnage (Southampton) | Cruise passengers (Southampton) | International ferry passengers (Southampton) | Domestic ferry passengers (Southampton) |
|------------------|-----------------------------|---------------------------------|---------------------------------------------|------------------------------------------|
| Mean value per 1 tonne of ship | 1.118                      | 0.025                           | 0.048                                       | 0.188                                   |
| Mean value per 10 tonnes of cargo | NA                        | 0.21                           | 0.39                                        | 1.53                                    |
Table 5. Average passenger numbers per passenger type when compared with cargo tonnage in a range of port-cites.

| Cargo tonnage (Using Qingdao, Vancouver, Busan, Le Havre, Shanghai) | Cruise passengers (using Qingdao, Istanbul, Vancouver, Busan, Le Havre, Shanghai) | International ferry passengers (using Qingdao, Busan, Le Havre, Liverpool, Portsmouth) | Domestic ferry passengers (using Istanbul, Vancouver, Liverpool, Portsmouth) |
|---|---|---|---|
| Mean value per 1 tonne of ship | 1.12 | 0.02 | 0.04 | 0.19 |
| Mean value per 10 tonnes of cargo | NA | 0.22 | 0.41 | 1.68 |

Table 6 illustrates the new universal classification system and the groupings this creates. It is able to differentiate ports based on urban population, cargo and passenger numbers, producing a potential 16 types of port-cites. The urban population axis has Town, City, Metropolis and Megacity groupings and the port traffic axis has micro, small, medium and large groupings. Table 6 shows the distribution of port-cities from the collected data sets within the Southampton System, including examples for each populated group. The port-cities are spread across the groups with only 3 groups having no port-cities. These are types of port-cities that could theoretically exist, however they are not found in the collected data. The example port-cities not categorised by Ducruet and Lee (2006) system shown in Table 3, are successfully categorised using this new system.

The Southampton System for port-city classification is illustrated in Figure 2, along with graphic representations for each newly created port-city type. This illustrates the increase in city size and port traffic along each axis.

5. Discussion

The method for comparing passengers and cargo tonnage provides a way to include cargo and passengers on the same axis. This makes classification easier by keeping the number of axis to 2 and avoiding the creation of an impractical number of groups. This is the first classification system for port-cities to successfully find a way to include passenger numbers which makes it a significant improvement on the system used by Ducruet and Lee (2006). At present the inclusion of passenger numbers alongside cargo in port-city studies is very limited. This system will enable greater inclusion of this section of port traffic in research into port-city related topics.

The Southampton System is able group a larger range of port-cities, from micro-port towns such as Penzance and Falmouth up to Large-Port megacities such as Shanghai and Tianjin. Containing 4 groupings for megacities also allows it to anticipate the growth in megacities and ensures this system’s utility for the foreseeable future, whilst also being able to include small and micro ports that have been ignored in many studies. The groups with no port-cities in at present could contain port-cities if the data set is expanded, and may be of greater significance in the future as urban population continues to grow. The system is still unable to consider value-added by port services such as bunkering, ship building and ship repair, which may contain port activity not expressed in cargo tonnage or passenger numbers. However, the system does improve on existing systems used within academia and industry and provides a more complete view of what constitutes a port-city.

Plymouth, Swansea, Falmouth, Penzance and Harwich are all examples of ports that were not classified as port-cities under the previous classification system. The Southampton System gives them the designations of Small-Port city (Plymouth), Small-Port Town (Harwich), Micro-Port City (Swansea) and Micro-Port Town (Penzance and Falmouth). This outcome seems more accurate than saying they are not port-cities of any form as using only container traffic would do. Ports such as Galveston which receive high volumes of passengers are also placed into a higher grouping than they would have been if only cargo tonnage or TEU had been considered. Galveston’s 3,387 kilotonnes of cargo per year would have given it the designation of a small-sized port; however,
Table 6. The new classification system—The Southampton System.

| Classification | Large-Port Town | Large-Port City | Large-Port Metropolis | Large-Port Megacity |
|----------------|-----------------|-----------------|-----------------------|---------------------|
| 100,000 Kilotonnes + Or 10 Million passengers + | Number in group: 8 Examples | Number in group: 13 Examples | Number in group: 28 Examples | Number in group: 4 Examples |
| Or 1 Million Passengers to 9.9 Million | Calais, Sao Luis (Itaqui), Dover, Perama | Helsinki, Antwerp, Chiba, Santos | Dalian, Yokohama, Busan, Rotterdam | Shanghai, Tianjin, Guangzhou, Shenzhen |
| 10,000 Kilotonnes to 99,999 Kilotonnes | Number in group: 25 Examples | Number in group: 58 Examples | Number in group: 38 Examples | Number in group: 5 Examples |
| Or 1 Million Passengers to 9.9 Million | Helsinborg, Felixstowe, Galveston, Holyhead, Harwich | Southampton, Lisbon, Amsterdam, Valparaiso, Corpus Christi, Brownsville | London, Brisbane, Zuhai, Montreal | Manila, Karachi, Tokyo, Lagos |
| 1,000 Kilotonnes to 9,999 Kilotonnes. Or 100,000 Passengers to 999,999 Passengers | Number in group: 39 Examples | Number in group: 28 Examples | Number in group: 10 Examples | No Ports in data-set |
| 100 Kilotonnes to 999 Kilotonnes. Or 10,000 Passengers to 99,999 Passengers. | Port Talbot, Newport, Albany, Coos Bay, Grimsby | Plymouth, Bristol, Manchester, Aberdeen, Green Bay | Fukuoka, Copenhagen, Belgrade, Adelaide | No Ports in data-set |
| Urban Population | 10,000 to 99,999 Urban Population | 1 Million to 9.9 Urban Population | 10 Million + Urban population | 539 |
its 1.7 million annual cruise passengers allow Galveston to be considered a medium-sized port, which is more befitting of the 10th largest cruise port in the world since 1.7 million cruise passengers per year will create a whole range of infrastructure requirements and positive and negative impacts which are just as important to consider as those created by container carriers. The Southampton System allows this to be considered.

Our system should allow future studies to study a greater range of port-city types, compare and contrast between groupings and make recommendations specific to each group. This is important if sustainability policy is to be created and applied to all types of port-cities globally, as suggested by Chen and Lam (2018). The new system will enable research to cover a broader range of port-city types, ensuring that findings are not limited to container ports.

The additional port-cities used in the calculations were chosen as some of the largest ports internationally with easily accessible data (Qingdao, Vancouver, Shanghai, Busan, Le Havre, Istanbul). In addition, Liverpool and Portsmouth were chosen as smaller port-cities within the UK, to provide a national comparison with Southampton. These port-cities were chosen to help verify the system. The calculations from Southampton (Table 4) are very similar to the results created using data from the other ports-cities in this study (Table 5). This consistency between port-cities shows that the system can be applied to varying sizes of ports, as well as being applicable internationally.

From the perspective of port and city authorities, the Southampton System will make it easier for ports and cities to find which group their port-city is in since it only requires easily accessible data. This may enable authorities to learn from the examples of other port-cities within the same groups, sharing knowledge and ideas. It may also allow ports to gain a better understanding of what issues
to expect as their port traffic and/or urban populations rise or fall, and the port-city moves into a new group within the system.

6. Conclusions

A new practical system for classifying port-cities has been successfully developed and tested: The Southampton System. A selection of global port-cities have been classified and tested using this new system. Directly comparing passenger numbers with cargo tonnage allows the developed system to address the weaknesses of previous work which has failed to include passengers. Using cargo tonnage instead of TEU has enabled this system to improve on the existing systems by including all cargo types as well as passenger numbers, and provides a wider categorisation of port-cities.

The Southampton System is able to include port-cities that have previously been excluded under previous systems, such as Plymouth. The new system is easy to use, creates a practical number of groups and is able to consider a greater range of sizes than previous systems. By expanding the system put forward by Ducruet and Lee (2006) which used a $3 \times 3$ matrix, to $4 \times 4$, the Southampton System is able to include micro-ports. This allows the system to classify mega-cities, which are set to increase in number in the future, ensuring the system’s continued utility. The Southampton System will allow research to consider a wider range of port-cities than are included in many recent studies, providing a useful framework for future research.

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