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The relations between the dry port characteristics and regional port-hinterland settings: findings for a global sample of dry ports

Lam Canh Nguyen[1,2], Theo Notteboom[3,1,4,5]

[1] *Faculty of Applied Economics, University of Antwerp, Antwerp, Belgium*
[2] *Vietnam Maritime University, Hai Phong, Vietnam*
[3] *Center for Eurasian Maritime and Inland Logistics (CEMIL), Shanghai Maritime University, Shanghai, People's Republic of China*
[4] *Maritime Institute, Faculty of Law, Ghent University, Ghent, Belgium*
[5] *Antwerp Maritime Academy, Antwerp, Belgium*

Corresponding author: Theo Notteboom

Abstract

This paper aims at defining generic characteristics of dry ports by carrying out an analysis using a large sample of dry ports from around the world. The dataset includes details on 107 inland terminals worldwide. All dry ports in the database have been selected from studies in the extant literature before being shortlisted to fit our research scope. Data collected includes terminologies used, actors driving the development, terminal throughput, total area, services provided and the relation with the corresponding seaport(s). Using statistical analysis, the paper examines how dry port parameters are influenced by (1) a different terminal set up, like sea-driven and land-driven development, developed and developing system, dry port functions; (2) specifications of the seaport with which the dry port is connected, i.e. seaport traffic, connectivity, utilization, etc. and (3) the transport leg linking dry ports and seaports. The findings could be applied to the planning and development of inland nodes from the perspectives of different stakeholders.

Keywords: dry port, seaport, inland terminal, statistics, sample analysis, hinterland

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1. Introduction

Globalization, the massification of maritime transportation and the scale increases in vessel size are putting a huge pressure on seaports and their corresponding hinterland transport networks. Inland nodes have a key role to play in advancing port-hinterland connectivity. In spite of being used interchangeably with terminologies like inland terminals, freight village, ICD, inland port and other notions, a dry port has its own distinguished characteristics in view of establishing a closer integration between seaports and hinterlands. The concept of dry port revolves around three main facets: (1) an intermodal terminal facility, as a dry port is a result of cargo unitization; (2) a strong link to seaports using high capacity, frequent and reliable inland waterway, rail and or road services; and (3) a service offering which is interchangeable with seaports, such as customs services, cargo storage or value added services. The concept has been applied in different countries, both developed and developing ones, under various names, but the ultimate purpose is similar: improving the accessibility between seaports and inland trade zones, promoting a modal shift to rail and/or barge and relieving the constraints at gateway seaports.

Extant literature discusses the characteristics of dry ports (see section 2.2 of this paper), but most insights are based on specific case studies of individual dry ports or a small regional/local group of inland nodes. Our research aims at defining generic characteristics of dry ports by carrying out an analysis using a large sample of dry ports from around the world. The dataset used in this paper includes details on more than one hundred inland terminals worldwide. All inland nodes included in the database comply with the three facets of dry ports mentioned above. Data collected includes terminologies used, actors driving the development, terminal throughput, services provided, and the relationship with the corresponding seaport(s). By carrying out statistics analysis, we aim to clarify how dry port parameters are influenced by (1) different terminal set up, such as sea-driven vs. land-driven development, developed and developing system, level of functions, etc.; (2) specifications of the seaport with which the dry port is connected, i.e. seaport traffic, connectivity, utilization, etc. and (3) the transport leg linking dry ports and seaports. In the conclusion, we discuss how the findings from the analysis could be applied to the planning and development of inland nodes from the perspectives of different stakeholders.

2. Literature review and hypothesis formulation

2.1. Terminologies

There is no consensus on the terminology used for inland nodes worldwide. Various terms have been used in different situation as mentioned by Notteboom & Rodrigue (2009) and Cullinane et al. (2012). Although sharing the similarity of integrating an off-dock terminal on site, such terms were developed differently due to temporal and spatial dimensions (Notteboom et al. 2017). In the United States, inland port is the popular term used for inland locations situated along rail-based or road-based land bridge corridors. The same term is also used in Europe but more in the context of river ports with inland waterway access. In many countries in Asia and Africa, the term ICD (inland container depot or inland clearance depot) is commonly found at off-dock terminals, although many of them have gone beyond the sole functions of a container depot and customs clearance point. Other related terms, such as interporti in Italy, plateformes logistiques in France, GVZ in Germany, freight village and logistics park, all refer to the main functions of value added logistics activities in such locations. The term dry port is getting more popular worldwide but its definition is still controversial.

Recently, UNESCAP (2013a, b) gave very broad definitions of the term dry port to refer to any inland location providing services similar to the ones offered by seaports, except for transhipment from/to sea-going ships. Economic Commission for Europe (2001) narrowed the use of the term to inland terminals with a direct link to one or more seaports. Roso et al. (2009) used the term dry port to describe a more advanced concept: a dry port should be intermodal and ideally connect to one or more seaports using high capacity traffic modes, such as rail transport or barges. In this research, we include all dry ports under different terminologies but limit ourselves to container terminals only. In the next section, we carry out a descriptive analysis to see which terminologies are most commonly used.

2.2. Dry port classification

Dry ports could be classified according to different dimensions. Roso et al. (2009) classified inland nodes as close, mid-range and distance dry ports in accordance with the distance to seaports and the position of inland locations along the supply chain. These insights are similar to the concepts of satellite terminals, transloading and load centers as introduced by Notteboom and Rodrigue (2009). In short, close dry ports or satellite terminals are located close to the seaport with a strong link between on-dock and off-dock terminals. They act as extensions of seaports with the purpose of dealing with problems at seaport terminals, such as land shortage, congestion or local environmental issues. A mid-range dry port or transloading terminal is set in the middle point between a seaport and its end-market and works as a consolidation point for different rail services. Such terminals are mostly found at country or state borders, as indicated by Beresford et al. (2012). These dry ports can also be inserted along long-distance transport corridors, such as in the context of the Belt and Road initiative (Wei, Sheng, and Lee 2017). Distant dry ports or load centers are situated in the proximity of the end markets, such as consumption areas or export-based industrial zones to consolidate or deconsolidate cargo from/to such market.

Notteboom & Rodrigue (2009) also classify dry ports according to a set of functional dimensions: (1) the number of modes served at the terminal (unimodal, bimodal, trimodal); (2) the primary function such as depot, warehousing, distribution, and value added services; (3) terminal size; (4) type of cargo handled; and (5) the openness of the node (i.e. multi-user vs. single user facilities).

Monios & Wilmsmeier (2012) introduced a classification based on the actor driving terminal development: land-driven vs. sea-driven. The former type of dry port is developed by a land player, such as a local government or rail company. The latter is developed by maritime-related actors like seaport authorities, terminal operators and shipping lines. This classification shares similarities with city-based and seaport-based dry ports introduced by Beresford et al. (2012).

The orientation of the dry port's cargo flow forms an additional element relevant to dry port classification. Based on the orientation of the cargo flow, a dry port might be classified as a maritime-oriented node or a land-oriented one. The former type refers to dry ports with a strong connection with seaports via a dedicated transport corridor. The cargo base of the latter type is mainly found in other inland locations. According to Roso et al. (2009) and Economic Commission for Europe (2001), an advanced dry port should have a connection to the seaport, which fits into the maritime-oriented category. Additionally, dry ports might be classified as domestic when the cargo flow does not go outside the country, or international.

UNESCAP (2006) provides some insights on how inland nodes can be classified based on their functions. The lowest level involves an inland node consisting of a container yard and a container freight station (CFS) for container handling and stuffing and stripping activities. The terminal could evolve to the next level, i.e. an ICD (Inland container depot) that also includes facilities for customs clearance, empty container depot and other container services. The next level includes facilities that offer logistics and other value added services. The highest level in the proposed typology is an industrial zone for goods assembly, (postponed) manufacturing and processing with integrated on-site terminal(s).

< insert figure 1 about here >

The above dimensions for the classification of inland nodes help to restrict our research to the target group and to analyse the differences between groups of dry ports. In this paper, we focus on maritime-oriented dry ports which have a connection to at least one seaport. We also limit the analysis to inland container terminals of at least ICD level. In other words, small-scaled inland nodes with only a container yard and CFS are not considered in this research.

2.3. Hypotheses

This research aims at finding how dry port parameters are associated with (i) different terminal set ups, (ii) the served seaports and (iii) the transport leg between dry ports and seaports. Based on the literature review and our understanding of the current dry port system, five hypotheses are formulated and tested in the remainder of the paper.

a. Hypothesis 1: Developed countries are likely to have more sea-driven dry ports than developing countries.

Finding the preferable direction for development is imperative for countries which have a dry port system that is still in its infancy stage. It gives a clue on how the network will develop and which parties will play a significant role in such development. In developing countries like Vietnam, the government works as a facilitator of dry port development with the purpose of boosting national trade and integrating it with other transport planning. If the land-driven model is predicted as the favourable model in developing countries, such governments should pay more attention to the land-based player, like the local government or inland transport companies. If the current system in the world shows that the sea-driven model is more popular, more attention should be paid to maritime parties, like terminal operators, port authorities or shipping lines.

There are different arguments used in extant literature addressing this topic. Ng and Gujar (2009) and Ng and Cetin (2012) use the case study of India to support this hypothesis. They argue that inland terminals in developing economies are more likely to be land-driven as they have been established to serve export-based industrial zones. Globalization and containerization made that many supply chains with labour-intensive activities were outsourced to developing countries, thereby triggering the growth of industrial zones in such economies and a growing demand for more efficient logistics to move cargo seaward. Land-based actors such as governments or railway companies typically play a key role in developing dry ports in the proximity of export-based zones. Nguyen and Notteboom (2017) also support the argument that dry ports in developed economies are likely to be developed by maritime-based players. However, Monios and Wang (2013) found that land-driven dry ports are also popular in more developed economies. Our paper aims at clarifying this controversial issue by testing the given hypothesis.

b. Hypothesis 2: A structural relationship exists between seaport specificities and dry port characteristics.

As synthesized by Nguyen & Notteboom (2016a), developing inland terminals is a possible solution for relieving seaports from land shortages and congestion. A seaport with congested terminals would benefit from connecting to a dry port by shifting land-intensive activities such as storage to inland nodes. Therefore, seaport-related actors have an incentive to develop a sea-driven dry port. Examples include the case of Genoa port (Caballini and Gattorna 2009) or terminal operator ECT in Rotterdam with its "extended gate" concept (Veenstra, Zuidwijk, and van Asperen 2012). In contrast, ports without land limitations do not have that motivation as they might lose substantial parts of their activity when logistics and value added services move to dry ports (Roso and Lumsden 2009). Monios and Wilmsmeier (2012) also agree seaports still prefer that such activities are performed onsite if they have abundant space. Therefore, seaports are likely to see a reduction in capacity utilization when more cargo is shifted to dry ports.

Most of the dry port traffic comes from or is going to its serving seaport. Van Klink and van Den Berg (1998) argued that seaports are in an excellent position to stimulate intermodal transport, where dry ports and transport legs are included. The dry port parameter is determined by competition and complementary with its connected seaports. Evidence of competition between gateway seaports and inland locations for logistics activities were discussed in Notteboom & Rodrigue (2009). Monios (2011) also pointed to an increasing strategic conflict between inland terminals and port-centric logistics. Veenstra et al. (2012) concluded that seaports will lose part of their role as logistics nodes for the hinterland and revert back to their core business of cargo handling and transhipment. They also predicted that customs and other inspection activities would move to inland nodes. While truly port-related activities like cargo handling cannot be moved elsewhere, the location of distribution facilities and value added services might be moved to dry ports due to space limitations, high land prices, congestion, environmental problems and shortage of industrial premises at seaports. Similarly, Roso and Lumsden (2009) argued that ports without land limitation might lose a substantial part of their profits when moving storage activities to a dry port. Therefore, seaport specificities should be associated with the corresponding dry port parameters.

c. Hypothesis 3: A relationship exists between the drivers of dry port development and its parameters/characteristics.

As discussed in the case of China (Monios and Wang 2013), land driven inland ports are more focused on logistics. They are likely to be equipped with facilities for distribution and processing and, in many cases, are parts of industrial zones. In contrast, sea driven dry port size is relatively small with the main task of improving seaports' accessibility.

As land driven dry ports are developed to serve economic zones, i.e. export based industrial areas or import-based market, there is not a strong relation between them and specific seaports. These dry ports are free to choose where the cargo is shipped seaward, so the number of connected seaports can be high. In contrast, sea driven terminals are developed by maritime-related actors, such as seaport authorities or deep-sea terminal operators. Therefore, they mainly serve their seaport with the purpose of relieving congestion and improving hinterland accessibility. That results in a limited number of served seaports of such terminals.

In terms of the location, land driven dry ports could be far away from seaports as their main customers are industrial zones. Sea driven dry ports are also not limited to their proximity, but the distance to the dry ports might play a role in this case. The closer the dry port is, the better control the maritime-related actors have over their off-dock terminals. It also implies lower transaction costs and a better utilization of dry ports.

d. Hypothesis 4: A relationship exists between dry port parameters/ characteristics and the transport leg between dry ports and seaports.

In the advanced concept of dry port, Roso et al. (2009) emphasized the importance of having strong links between seaports and the dry port, preferably by rail. Veenstra et al. (2012) also argued that such transport leg should play an imperative role in extending sea terminals' gate to inland locations. Additionally, the modal shift from road to rail (and barge, where available) is another reason to promote dry port development. Therefore, we test how the transport leg influences the dry port parameters.

e. Hypothesis 5: A relationship exists between dry port parameters/characteristics and the functional set up of the dry port.

As discussed earlier, dry port functions could start from the ICD level with the facilities of container yard, CFS and depot. It might evolve to a higher level of logistics centers and value added services, and even an industrial zone with goods processing and manufacturing. Such level of activity is expected to be associated with other parameters such as dry port traffic, total area or number of served seaports. This test helps to understand the characteristics of a dry port based on the logistics area in which it is integrated. For example, does a dry port, which is part of a logistics zone, have a high throughput and connect to more seaports?

3. Data collection

3.1. Selecting the sample group of dry ports

In order to test our hypotheses, we collected data on a sample of 107 dry ports worldwide using a sampling technique. Probability sampling techniques such as random sampling is not suitable for this research as obtaining the sampling frame (the complete list of all dry ports worldwide) is not practical. Overall, the data availability on dry ports is very limited and difficult to access.

The dry port selection process followed a number of steps. First, we used search engines (i.e. library sources such as Web of Science and Google Scholar) to filter extant literature related to dry ports. The selection process resulted in a documented population of dry ports in operation. The case studies described in literature provide some relevant information for the data collection stage. After obtaining a long list of dry ports collected from literature, we shortlisted the terminals which fit into our research scope, thereby focusing on (1) container terminals, which (2) have connections to seaports and (3) provide functions of at least ICD level. We also examined other sources, such as online news items and magazine articles, and contacted dry port operators (where possible) to get an updated status and recent data on the selected dry ports.

The case studies were collected from Roso (2008), Notteboom & Rodrigue (2005), Roso & Lumsden (2009), Roso et al. (2013), Rodrigue et al. (2010), StratMos (2009), FDT (2007), Monios and Wang (2013), Notteboom & Yang (2016), Beresford et al. (2012), UNESCAP (2015), Witte and Wiegmans (2015), Ng and Gujar (2009), UNESCAP (n.d.), UNESCAP (2011), Caballini and Gattorna (2009), Werikhe & Zhihong (2015), Port Report Africa (2014), Jeevan et al. (2015), Wilmsmeier et al. (2015), Veenstra et al. (2012), Hanaoka and Regmi (2011), Garnwa et al., Roso and

Lumsden (2010), Korovyakovsky and Panova (2011), Bergqvist (2013), Monios and Wilmsmeier (2012), Cronje et al. (2009), Nguyen and Notteboom (2016a), Nguyen and Notteboom (2016b), and Wang et al. (2018).

We limited the sample group to only maritime-oriented dry ports, where the majority of terminal traffic goes to/from seaports. Land-oriented dry ports are not included. We also restrict our sample group to only container terminals with a minimum level of ICD as defined by UNESCAP (2006). Small terminals equipped with only a CFS and container yard are not considered in the sample.

3.2. Sample group profile

The sample group contains 107 dry ports from 34 nations. About 7.5 percent of the group is from Africa, 50.5 percent from Asia, 3.7 percent from Australia, 35.5 percent from Europe and 2.8 percent from North & South America. Figure 2 shows the location of the sample group. 70 dry ports are from developing countries, while 37 come from developed countries. Within the sample group, there are five cases located in landlocked countries.

< *insert figure 2 about here* >

3.3. Identification and operationalization of the variables

The constructs in our hypotheses were measured using a set of variables, summarized in Table 1. Dry port parameters include the dry port's annual throughput, dry port comparative traffic (the ratio of dry port throughput to its dominant seaport traffic), the total area of the dry port, the number of seaports served and the distance to the served seaport(s). Seaport specifications are operationalized using the seaport's annual throughput, seaport connectivity and seaport/terminal utilization degree. The data was collected from different secondary sources, including port websites, annual report, academic literature and media articles, etc. The status of developed or developing countries are classified by United Nations and are coded into a binominal variable.

< *insert table 1 about here* >

4. Methodological implementation and empirical findings

The appropriate method selection process for each situation was based on Field (2009). SPSS version 24 software was used to compute the outcomes.

4.1. Estimation of dry port parameters

This section estimates the parameters of the whole population by descriptive analysis of the sample group. A total of 15 different terminologies were used in the sample group. The most popular terms include dry port, ICD, inland port, inland terminal, logistics park and logistics center. Other terms less frequently found include CFS, distriport, GVZ, industrial park, logistics zone, rail hub, interporto, logistics platform and special economic zone (each with only 1 or 2 observations). The frequency of terminologies used is presented in Table 2.

< *insert table 2 about here* >

In the sample of 105 valid observations, 52.4 percent concerns a sea driven dry port while in the remaining 47.6 percent we deal with a land driven dry port.

In terms of available transport modes, the bimodal dry port (road and rail/barge) is the most common, accounting for 74.3 percent of the total. It is followed by unimodal terminals (only road service) with 20 percent. Only 5.7 percent of the dry ports cover all three modes (trimodal).

The total area of dry ports seems to follow a skewed distribution (figure 3) where small dry ports are abundant. About half of the dry ports have a total area below 45 ha while two thirds are smaller than 100 ha. The average size of dry ports is 197.81 ha.

The average number of seaports served by a dry port is two. The mode (or the most frequent observation) is one with 48.2 percent. About two third of the dry ports are connected to two or fewer seaports. Out of the sample, 96.3 percent of dry ports serve up to 4 seaports. The maximum number of served seaports is 6. The central of tendency of this parameter is visualized in Figure 4.

The distance to the seaports also follows a skewed distribution with fewer observations for the further distances (Figure 5). The average distance between dry port and seaport is 424.64 km. While the closest dry port could be situated just a few km from the seaport, the furthest located inland node in the sample group is at a distance of 1741 km from the seaport. About 50 percent of the dry ports are located less than 300 km from the seaport. More than 90 percent of dry ports are located within a 1000 km radius from the seaport.

The average annual dry port throughput (Figure 6) equals about 172,000 TEU. However, the vast majority of the terminals has a much smaller throughput with about half of the observations below the 70,000 TEU threshold. The highest throughput is 3.6 million TEU in the case of Duisport (Germany).

The average value of dry port comparative traffic is 5 percent (Figure 7). This is based on a sample of 92 dry ports for which data on this variable was available. Roughly 50 percent of the dry ports only serve less than 1.7 percent of seaport traffic. About 90 percent of the dry ports have less than 16.44 percent of seaport traffic. The highest observation is 30.33 percent in the single case of Duisport (Germany) while the lowest number is close to zero.

Figure 8 presents the results on the dry port activity level following the UNESCAP typology presented in figure 1. The most popular functional type is the logistics center level with 67.6 percent out of 105 observations, followed by the ICD level with 27.6 percent. Only 4.8 percent of the cases reach the level of an industrial zone.

< insert figures 3 to 8 about here >

4.2. Hypotheses testing

a. Hypothesis 1: Developed countries are likely to have more sea-driven dry ports than developing countries.

This hypothesis was tested using a Chi-square test between two binominal variables: nation status (developed vs. developing) and the dry port driver (land driven vs. sea driven). Figure 9 shows the clustered bars for the two variables. The p value of 0.412 shows no statistical significance between nation status and the dry port driver. Therefore, we refute hypothesis 1.

< insert figure 9 about here >

b. Hypothesis 2 refers to the relationship between the dry port parameters (i.e. throughput and the comparative traffic, distance to seaport, total area) and the seaport specifications (i.e. seaport throughput, seaport connectivity, seaport/terminal utilization degree). As could be seen in earlier figures, these variables show a skewed distribution pattern. As the assumption of normal distribution is violated, we applied the Spearman's correlation coefficient to check if there are relations between these variables. Spearman's test firstly ranks the data, then checks the correlation between those ranks by using the Pearson's equation. Table 3 shows the test results.

The main results are as follows.

First, there is a negative correlation between seaport connectivity and the comparative traffic of a dry port in terms of its dominant seaport traffic, which is moderate and statistically significant ($p < 0.001$, rs = - 0.524).

Second, a dry port connects to a seaport with higher throughput is likely to be smaller in comparative traffic with seaports. The relation is strong and statistically significant ($p < 0.001$, rs = - 0.605).

< insert table 3 about here >

Third, an increase of comparative traffic of dry ports goes hand in hand with a decrease in terminal utilization. The relation is moderate and statistically significant ($p < 0.001$, rs = - 0.524).

Fourth, there is a weak positive relation between seaport utilization and the distance between the dry port and the seaport ($p = 0.048$, rs = 0.192). In other words, seaports with dry ports in the close vicinity are more likely to see a lower utilization degree.

Fifth, an increase of seaport size in terms of throughput goes hand in hand with an increase of the total dry port area. The relation is moderate and statistically significant ($p < 0.001$, $r_s = 0.504$).

Sixth, an increase in the seaport/terminal utilization degree coincides with the larger total dry port area. The relation is weak and statistically significant ($p = 0.011$, $r_s = 0.263$). In other words, if a seaport shows a higher capacity utilization, it is likely to connect to larger dry ports.

We do not find any significant relation between annual dry port throughput and the set of seaport variables. But annual dry port throughput is significantly associated with its total area ($p = 0.008$, $r_s = 0.297$).

c. Hypothesis 3 reads 'There exists a relationship between the drivers of dry port development and its parameters/characteristics'. We test if the driver of dry port (sea driven or land driven) has an influence on the dry port characteristics (i.e. total area, annual throughput, comparative traffic, level of activity, number of served seaports, distance to seaport).

As indicated in Figures 3 to 8, all the continuous variables follow a skewed distribution and are not normally distributed. Therefore, one might apply either Wilcoxon rank-sum or Mann-Whitney test in such situation. The logic behind that is to rank all the dry ports in the order of total area (smallest area gets rank 1, and the next lowest one gets rank 2, etc.). Then we sum up the rank of each group of drivers and compare them with each other. In this research, Mann-Whitney is used to test all the continuous variables and to obtain the results as shown in Table 4.

Next, the effect size r from the z score is produced by SPSS and the number of observations by the formula of Rosenthal (1991). This exercise leads to the following findings:

(1) Sea driven dry ports are located significantly closer to the seaport(s) than land driven ($p < 0.001$). The effect size is small to medium ($z = -3.556$; $r = -0.344$).

(2) Land driven dry ports are serving significantly more seaports than sea driven dry ports ($p < 0.001$). The effect size is medium ($z = -5.491$; $r = 0.53$).

(3) The size of sea driven dry ports is significantly larger than land driven ones ($p = 0.039$). The effect size of the size of the dry port terminal is small to medium ($z = -2.061$; $r = -0.21$).

(4) The dry port driver (sea driven or land driven) is not significantly related to the annual throughput of the dry port ($p = .493$).

(5) The comparative traffic of land driven dry ports is not significantly different from the sea driven ones ($p = .995$).

< insert table 4 about here >

Next, the relationship between the dry port driver and the activity level (i.e. the UNESCAP typology) is examined. Figure 10 visualizes the number of each dry port group (sea driven and land driven) per activity level. As the activity level of a dry port is an ordinal variable, Chi-square is used to test the relation between the two variables. The result is insignificant ($p= 0.554$).

< insert figure 10 about here >

d. Hypothesis 4 reads ‘A relationship exists between dry port parameters/characteristics and the transport leg between dry ports and seaports’.

It is tested whether the transport mode linking the dry port and the connected seaport is associated with the dry port parameters (i.e. throughput, the comparative traffic, number of served seaports, distance to seaports and total area). As the number of transport modes is coded as a nominal variable (1 = unimodal, 2 = bimodal, 3 = trimodal), and the assumption of normal distribution is violated, we applied the non-parametric Kruskal-Wallis H test. The method is based on a rank-based nonparametric test. It is similar to the Mann Whitney test to allow for a comparison of more than two independent groups. The test results are shown in Table 5 and can be interpreted as follows:

(1) The comparative traffic of unimodal terminals (mean rank of 29.43) is significantly ($p = 0.048$) lower than for bimodal and trimodal terminals. The comparative traffic of bimodal (mean rank of 48.07) is slightly higher than for trimodal (mean rank of 46).

(2) The annual dry port volume of trimodal terminals (mean rank 65.33) is significantly ($p = 0.039$) higher than for bimodal terminals (mean rank 45.54) and unimodal dry ports (mean rank 33.61).

(3) In a significant way ($p = 0.028$), trimodal terminals (mean rank 81.42) serve more seaports than bimodal terminals (mean rank 52.59) and unimodal terminals (mean rank 46.4).

(4) The distance to the seaport is not significantly different between unimodal, bimodal and trimodal terminals ($p = 0.405$)

(5) The total area is significantly different depending on the number of modes served ($p = 0.006$). Trimodal terminals have the largest size (mean rank = 81.17),

followed by unimodal terminals (mean rank = 46.03) and bimodal terminals (mean rank = 44.56).

< *insert table 5 about here* >

e. Hypothesis 5 reads ‘A relationship exists between dry port parameters/characteristics and its functional set up’. The relationship between the level of activity of the dry port (UNESCAP typology) and the dry port parameters (i.e. number of served seaports, dry port throughput and comparative traffic) is tested. Again, the Kruskal-Wallis test is used:

(1) There are significant differences (p = 0.016) in dry port connectivity among dry ports with different activity level: Industrial zones serve the highest number of seaports (mean rank = 77.2), followed by logistics centers (mean rank = 55.64) and ICDs (mean rank = 42.36).

(2) In a significant way (p = 0.004), industrial zones have the highest throughput (mean rank = 73.33), followed by logistics centers (mean rank = 48.74) and ICDs (mean rank = 31.79).

(3) Also in a statistically significant way (p = 0.021), industrial zones have the highest comparative traffic (mean rank = 54.33), followed by logistics centers (mean rank = 49.35) and ICDs (mean rank = 32.58).

5. Discussion

First, there is no significant evidence that dry ports in developed countries are more likely to be developed by maritime-related actors, i.e. seaport authority or terminal operators. Also, contrary to what is stated in some of the extant literature, we found no evidence that developing countries have a higher proportion of land-driven dry ports than developed countries. This implies that the dry port facilitator should pay attention to both maritime parties and land-based actors in developing the inland node system, regardless whether he/she is dealing with developed or developing economies.

Secondly, the dry port parameters are significantly related to the specificities of the seaports it serves. The negative relation between the comparative traffic of dry ports and seaports and the seaport parameters (i.e. throughput and connectivity) uncovers the fact that in the current system, dry port size and seaport size do not necessarily match. This could be explained by the fact that one big seaport is likely to connect to a large number of small inland locations, instead of a few large dry ports. This finding might give the planner insight on how a dry port system should be distributed. If such a system is serving a big seaport, it is likely to contain a large number of small dry ports, instead of having few large dry ports. In contrast, for smaller seaports, the system will contain fewer dry ports with a more pronounced size relationship to the related seaport. Also, dry ports in nations with a lower liner connectivity index are likely to be larger in terms of the comparative traffic with seaports.

Furthermore, the connection to dry ports with larger comparative throughputs goes hand in hand with a reduction in the seaport/terminal utilization degree. Also, a closer distance between dry ports and seaports is likely to coincide with a lower seaport utilization degree. Furthermore, the dry port area is likely to be larger in the case it connects to a seaport with a higher throughput or a higher utilization level. These findings imply that the planning of larger dry ports located closer to the seaport is likely to reduce seaport congestion.

The dry port parameters are significantly associated with the development driver. Sea driven terminals are likely to be closer to the seaports they serve and also serve fewer seaports than land driven dry ports. This is an expected result because land-driven dry ports are mainly supporting the local industry, so they should be located in the proximity of such production zones, instead of close to seaports. Sea-driven terminals are developed to support seaports in terms of capacity expansion and market catchment. Additionally, sea driven dry ports are likely have a bigger size than land driven terminals. These findings help to understand the development pattern of the dry port system based on the parties that trigger the project.

The transport mode connecting dry ports and seaports is another factor associated with dry port parameters. Trimodal terminals are significantly larger in size and traffic and serve more seaports than bimodal ones. Unimodal dry ports serve the fewest number of seaports and have the least traffic. This finding shows the importance of intermodality in the inland transport network. More accessibility to railways and inland waterways is likely to bring more traffic to inland nodes.

Finally, the level of dry port activity following the UNESCAP typology significantly influences the dry port parameters. Dry ports at the highest activity level (industrial zones) are likely to be larger in size and traffic, and they also serve more seaports. They are followed by logistics centers and ICD level.

6. Conclusions

This paper analysed the relationships between dry port parameters and (1) terminal set up, (2) the seaport(s) served and (3) the transport leg connecting the dry port to the corresponding seaport(s). Five hypotheses were formulated and tested using data on a sample group of 107 dry ports. One hypothesis was rejected while the remaining four hypotheses were accepted.

Our findings show correlations between dry ports and the seaports they connect to, the transport link and the terminal set up. More insights are provided on how the dry port pattern might develop based on regional port-hinterland settings. The results contribute to the literature on dry port characteristics and create a foundation for further research. Our findings are meaningful for different stakeholders in the industry. The dry port developers might be maritime-based players, like terminal operators or port authorities, and land-based parties, like local governments or transport companies, regardless of the development status of the nation. When developing transport plans at a macro-level, government agencies should carefully consider the characteristics of seaports and dry ports, the direction of development and the level of activity of the dry ports, as this research has demonstrated they are related to each other. Maritime-related actors should understand how dry port parameters and specific characteristics of the seaport(s) are intertwined. For example, if a seaport is having a congestion problem, one might think of developing or cooperating with a larger dry port located in the vicinity of the seaport. Connecting to more inland terminals is another way to benefit from the dry port concept. The finding also points to the importance of intermodality in developing the dry port system.

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Table 1. Identification and operationalization of the variables

No	Variable	Variable Operationalization and units	Nature
1	Nation status	1 = developed countries 2 = developing countries We follow the classification of United Nations (2016).	Binominal
2	Dry port driven	1 = sea driven 0 = land driven	Binominal
3	Mode link to seaports	1 = unimodal (only road) 2 = bimodal (road + rail or inland waterway) 3 = trimodal (road, rail, inland waterway)	Nominal
4	Dry port area	Total paved area (in ha) for dry port activities	Continuous
5	Number of served seaports	We count the seaports that directly link to the dry port with substantial cargo flow	Discrete
6	Seaport throughput	Number in '000 TEU, collected for recent years. This criterion is used as a proxy of seaport size in order to examine the relation between seaport specifications and dry port parameters.	Continuous
7	Seaport utilization	We take the proxy of the utilization degree of the busiest container terminal in the port, measured in percentage	Continuous
8	Seaport connectivity	We use the Liner Connectivity Index of the nation as proxy	Continuous
9	Distance to seaports	We use the distance between the dry port and the dominant seaport (the one with majority of cargo flow to/from the dry port), measured in km	Continuous
10	Dry port throughput	Measured in '000 TEU and collected for recent years. In case only data of terminal capacity is available, we assume that the dry port is working at 100% utilization. This criterion is used as another proxy for the size of a dry port in order to examine the relation between dry port specifications and other hinterland settings.	Continuous
11	Dry port comparative traffic	Describes the comparative size of dry ports and their dominant seaports in terms of the amount of cargo handled. We use the following proxy: (dry port throughput x 100%)/ throughput of the dominant seaport. Measured in percentage.	Continuous
12	Dry port activity level	The dry port activity level is classified: 1 = ICD level (terminal with CFS, container yard, depot, customs facility) 2 = Logistics and other VAS (ICD level with addition of a surface of at least 5000 m2 of covered warehousing space 3 = Industrial zone (level 2 with addition of area for manufacturing and processing)	Ordinal

Source: Authors

Table 2. Frequency of terminologies used in the sample group

Terminology

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	dry port	29	27.1	27.1	27.1
	ICD	25	23.4	23.4	50.5
	inland port	16	15.0	15.0	65.4
	inland terminal	16	15.0	15.0	80.4
	Logistics park	6	5.6	5.6	86.0
	logistics center	4	3.7	3.7	89.7
	distriport	2	1.9	1.9	91.6
	rail hub	2	1.9	1.9	93.5
	CFS	1	.9	.9	94.4
	GVZ	1	.9	.9	95.3
	Industrial park	1	.9	.9	96.3
	interporti	1	.9	.9	97.2
	logistics platform	1	.9	.9	98.1
	logistics zones	1	.9	.9	99.1
	Special Economic Zone	1	.9	.9	100.0
	Total	107	100.0	100.0	

Source: Authors, using SPSS 24

Table 3. Correlation table

Correlations

			annual dry port traffic ('000TEU)	percentage of seaport traffic	Liner connectivity index 2016	seport throughput ('000 TEU)	sea terminal utilization	Dis to the dominant seaport(km)	total area (ha)
Spearman's rho	annual dry port traffic ('000TEU)	Correlation Coefficient	1.000	.679**	-.006	.115	-.119	-.059	.297**
		Sig. (2-tailed)	.	.000	.953	.277	.262	.580	.008
		N	91	91	91	91	91	91	78
	percentage of seaport traffic	Correlation Coefficient	.679**	1.000	-.524**	-.605**	-.524**	-.061	-.071
		Sig. (2-tailed)	.000	.	.000	.000	.000	.563	.537
		N	91	91	91	91	91	91	78
	Liner connectivity index 2016	Correlation Coefficient	-.006	-.524**	1.000	.778**	.477**	.120	.451**
		Sig. (2-tailed)	.953	.000	.	.000	.000	.217	.000
		N	91	91	107	107	107	107	94
	seport throughput ('000 TEU)	Correlation Coefficient	.115	-.605**	.778**	1.000	.646**	.125	.504**
		Sig. (2-tailed)	.277	.000	.000	.	.000	.201	.000
		N	91	91	107	107	107	107	94
	sea terminal utilization	Correlation Coefficient	-.119	-.524**	.477**	.646**	1.000	.192*	.263*
		Sig. (2-tailed)	.262	.000	.000	.000	.	.048	.011
		N	91	91	107	107	107	107	94
	Dis to the dominant seaport(km)	Correlation Coefficient	-.059	-.061	.120	.125	.192*	1.000	.028
		Sig. (2-tailed)	.580	.563	.217	.201	.048	.	.792
		N	91	91	107	107	107	107	94
	total area (ha)	Correlation Coefficient	.297**	-.071	.451**	.504**	.263*	.028	1.000
		Sig. (2-tailed)	.008	.537	.000	.000	.011	.792	.
		N	78	78	94	94	94	94	94

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Authors, using SPSS 24

Table 4. Mann-Whitney test for the two groups of dry ports

Ranks

	driven (1=sea, 2= land)	N	Mean Rank	Sum of Ranks
Dis to the dominant seaport(km)	1	55	43.63	2399.50
	2	52	64.97	3378.50
	Total	107		
number of served seaports	1	55	39.07	2149.00
	2	52	69.79	3629.00
	Total	107		
total area (ha)	1	48	53.18	2552.50
	2	46	41.58	1912.50
	Total	94		
anual dry port traffic ('000TEU/year)	1	47	47.85	2249.00
	2	44	44.02	1937.00
	Total	91		
percentage of seaport traffic	1	47	46.02	2163.00
	2	44	45.98	2023.00
	Total	91		

Test Statistics[a]

	Dis to the dominant seaport(km)	number of served seaports	total area (ha)	anual dry port traffic ('000TEU/year)	percentage of seaport traffic
Mann-Whitney U	859.500	609.000	831.500	947.000	1033.000
Wilcoxon W	2399.500	2149.000	1912.500	1937.000	2023.000
Z	-3.556	-5.491	-2.061	-.691	-.008
Asymp. Sig. (2-tailed)	.000	.000	.039	.489	.994
Exact Sig. (2-tailed)	.000	.000	.039	.493	.995
Exact Sig. (1-tailed)	.000	.000	.020	.246	.498
Point Probability	.000	.000	.000	.001	.002

a. Grouping Variable: driven (1=sea, 2= land)

Source: Authors, using SPSS 24

Tables 5. Kruskal-Wallis H test between link mode groups

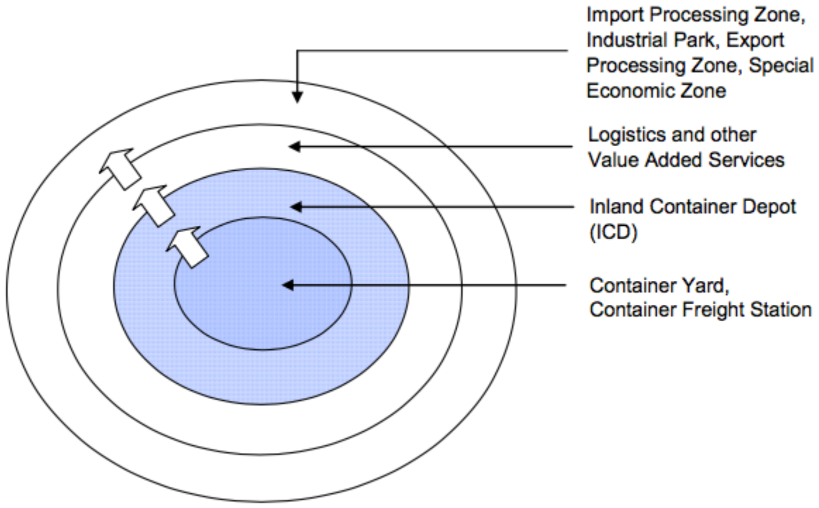
	link mode (1=uni,2=bi, 3=trimodal)	N	Mean Rank
percentage of seaport traffic	1	14	29.43
	2	69	48.07
	3	6	46.00
	Total	89	
anual dry port traffic ('000TEU/year)	1	14	33.61
	2	69	45.54
	3	6	65.33
	Total	89	
number of served seaports	1	21	46.40
	2	78	52.59
	3	6	81.42
	Total	105	
Dis to the dominant seaport(km)	1	21	45.07
	2	78	54.83
	3	6	57.00
	Total	105	
total area (ha)	1	16	45.03
	2	71	44.56
	3	6	81.17
	Total	93	

Test Statistics[a,b,c]

	percentage of seaport traffic	anual dry port traffic ('000TEU/year)	number of served seaports	Dis to the dominant seaport(km)	total area (ha)
Chi-Square	6.070	6.474	7.116	1.808	10.283
df	2	2	2	2	2
Asymp. Sig.	.048	.039	.028	.405	.006
Exact Sig.			.024		
Point Probability			.000		

Source: Authors, using SPSS 24

Figure 1. Dry port function evolution



Source: UNESCAP (2006)

Figure 2. The locations of the dry ports in the sample group

Source: Authors, created by batchgeo.com

Figure 3 - Dry port area

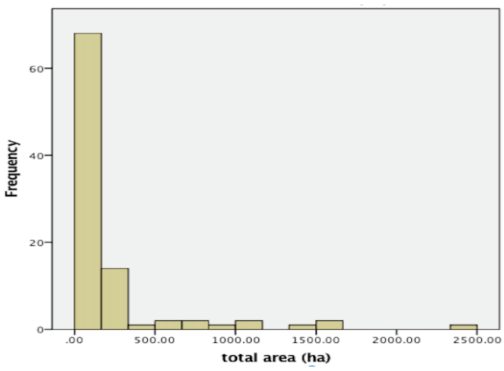


Figure 4 - Number of served seaports

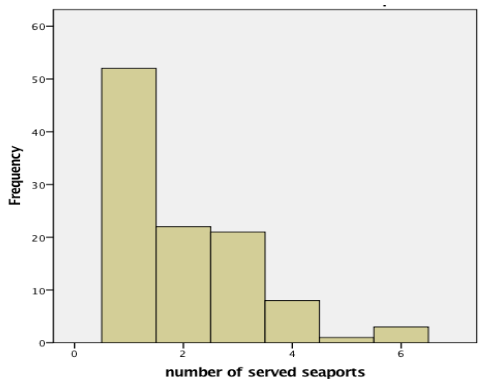


Figure 5 - Distance to seaports

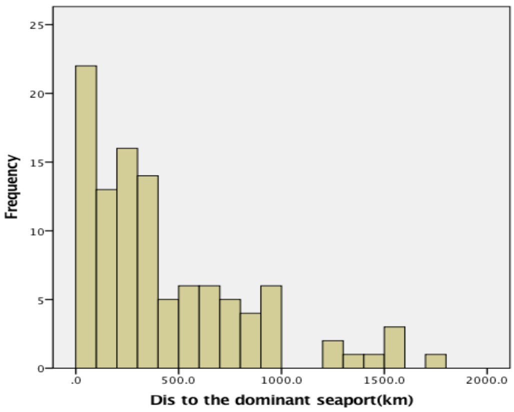


Figure 6 - Annual dry port traffic

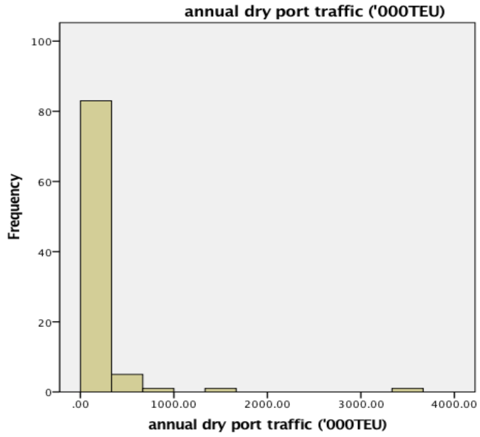


Figure 7 - Dry port comparative traffic (as percentage of seaport)

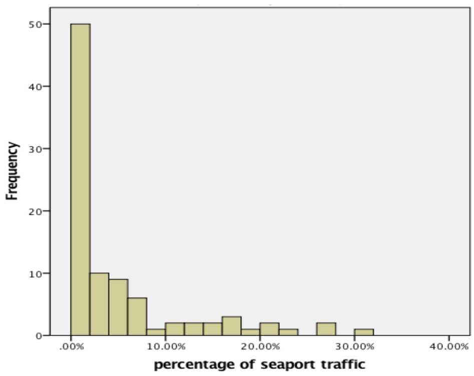
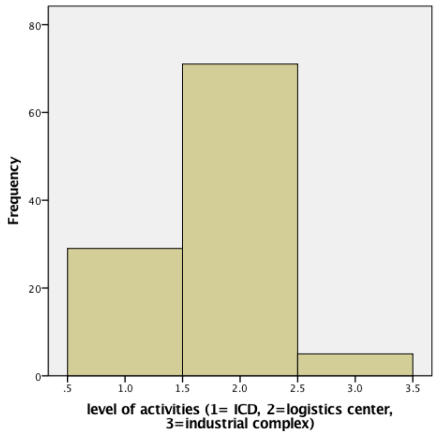
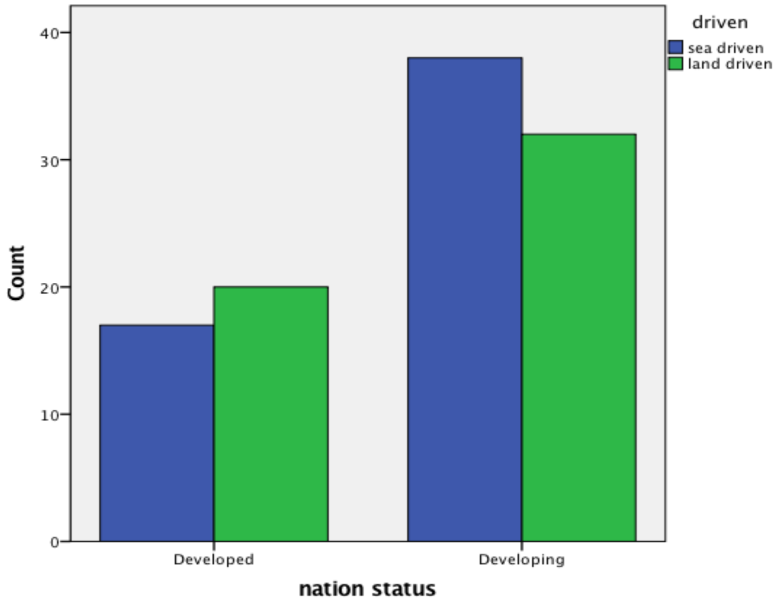


Figure 8 – Level of dry port function



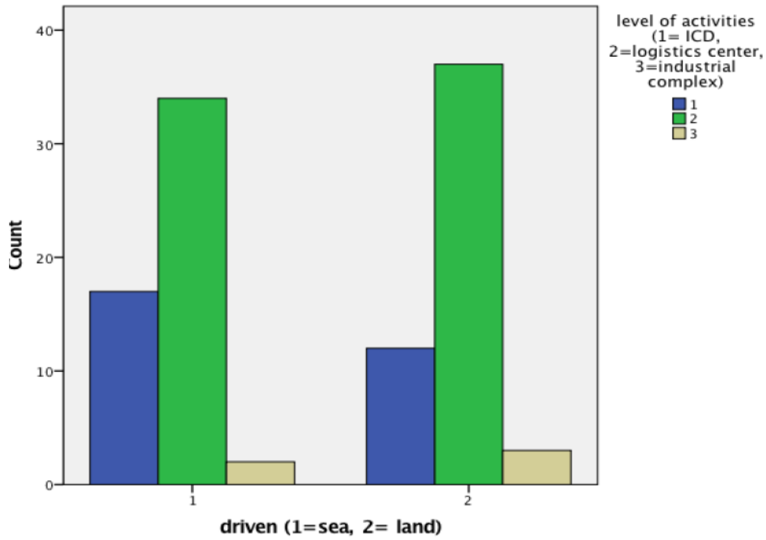
Source: Authors, using SPSS 24

Figure 9. Cluster bar



Source: Authors, using SPSS 24

Figure 10. Dry port activity level in terms of sea driven and land driven development



Source: Authors, using SPSS 24