An analysis of the CSR portfolio of cruise shipping lines

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Comparing onsite and offsite rail access for dry port developments – a benchmark study in China

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Abstract
While large dry ports with high throughput are more likely to have onsite rail access, the question is more difficult for small and medium sites, which may not have sufficient throughput for rail viability. Thus whether a new dry port development should be located with or without direct rail access is a major concern at the proposal stage. This challenge is a current concern in many developing countries experiencing a surge in dry port demand. The aim of this paper is to develop a model that can identify at what level of demand the onsite configuration becomes the better option.

The model calculates the equilibrium point in total costs between onsite and offsite dry ports, which varies according to changes in land price, operational productivity and modal split. Taking China as an example case, findings suggest that the land cost plays a vital role in the decision of an onsite or offsite configuration. The modal split of the cargo using the dry port, which is greatly affected by shipping distance to seaports and shipper preference, also shows a strong effect on the decision.

Keywords: dry port; intermodal transport; intermodal terminal; inland port; rail freight transport; transport economics; transport cost; on-dock; off-dock; modal shift

1 Introduction

According to the early definitions of the dry port concept (UNCTAD, 1982, 1991), a dry port was considered synonymous with an inland clearance depot (ICD), ideally also providing supporting logistics services such as containerisation. The overriding goal was to improve access to global trade lanes for inland (often landlocked) locations. At this time the transport mode connecting dry ports with seaports was not specified. While high capacity transport modes such as rail or inland waterway could be advantageous, the primary goal was to reduce costs by saving time, delays and fees in the port, with the added potential for other related services such as intermediate storage, processing and repacking.

In more recent times, where modal shift and port congestion have become important issues in developed countries, dry ports are more likely to be connected to seaports by rail and/or inland waterway (Roso et al., 2009). Yet in developing countries where customs clearance at a seaport can take several days, customs reform is ongoing and this activity remains one of the key reasons for passing containers through a dry port, even if using road transport. Examples include Tanzania (Roso and Lumsden, 2010), India (Ng and Cetin, 2012), Malaysia (Chen et al., 2016) and Vietnam (Nguyen and Notteboom, 2019). Of the 18 dry ports in China analysed by Monios and Wang (2013), 7 were rail-connected, 3 had rail connections less than 10km away, while 8 used road transport under customs bond to connect to seaports. Given that many dry ports in developing countries are not rail-connected, if shippers desire to send their cargo by rail then an additional road shunt is needed between the dry port and the intermodal terminal. Yet this issue has not been addressed in any academic studies.

This study compares the cost profile of a dry port located adjacent to a rail terminal with a dry port without a rail connection. Whether the dry port should be designed and constructed with onsite rail access or instead the containers should be shunted to a nearby intermodal terminal is in fact not as simple as it seems. The former can be limited by the available space or expensive land near rail terminals, while the latter may cost less but comes with the disadvantages of lower efficiency and additional transport and transhipment costs. The trade-off between investment and utilization benefit for developing a dry port therefore becomes more complicated when taking into account the local economy (e.g. imports and exports, trade structure, operating and capital costs, etc.) and indirect factors (e.g. land productivity, geographical location, supporting policy, dominant transport modes, etc.). This paper aims to support the decision-making process of investors facing the choice of whether a new dry port should be located adjacent to a rail terminal or not. The methodology is based on an Input-Output model which assesses the economic benefit of the two types of dry port configurations under different productivity ratios as well as changing modal split ratios. The aim of this paper is to develop a model that can identify at what level of demand the onsite model becomes the better option, which is not a static decision but is reflected in an equilibrium point between the two models that changes according to changes in land price, operational productivity and modal split.

The remainder of this paper is structured as follows: Section 2 provides a literature review regarding the technical and operational features of the two types of dry port as well as previous studies on the economics of dry pot and terminal development. The choice of China as an empirical case, the theoretical framework and the Input-Output model are explained in Section 3 and the empirical application to four Chinese cities is presented in Section 4. Finally, conclusions are drawn in Section 5 regarding the applicability and generalisability of the model.

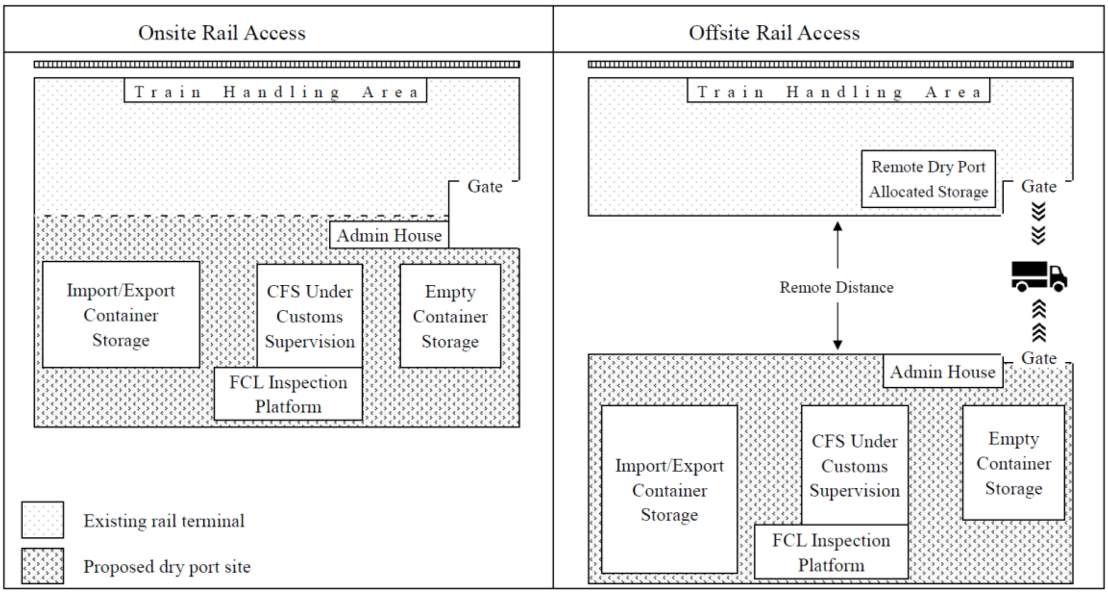
2 Dry port types and developments

2.1 Defining dry ports and identifying the two types

This paper uses the following dry port definition provided by the United Nations: "dry ports are specific sites to which imports and exports can be consigned for inspection by customs and which can be specified as the origin or destination of goods in transit accompanied by documentation such as the combined transport bill of lading or multi-modal transport document" (UNCTAD, 1991: 2).

The conceptual layouts of the two proposed types of dry ports defined by UNCTAD (1991) are illustrated in Figure 1. The first case, in which the dry port is co-located with a rail terminal, would ideally be developed within the grounds of an existing rail terminal or adjacent area. This strategy generally requires less land but necessitates a higher land cost. As all cargo handling activities are integrated onsite, fewer loading and discharging movements are required per shipment, thus reducing dwell time (Ashar, 1991). In contrast, the second type is a dry port development without a rail terminal nearby, which benefits from cheaper land and shunts cargo by road to and from an existing rail terminal. The shunting distance will vary but is generally between 25 and 50 km (Nierat, 1997). Under this model, it is nevertheless assumed that there is a certain size of storage area within the existing rail terminal allocated particularly for the inventory of traffic flows via the dry port. Its size correlates with the designed capacity of the remote dry port and the dwell time ranges from a few hours to one day.

Figure 1: Conceptual layouts of dry ports: connected to a rail terminal (left) vs distant location (right)



Source: Adapted from UNCTAD (1991)

As large dry ports with high throughput are much more likely to include an onsite rail connection (although even in these cases it is not always certain that all dry port shippers will utilise rail), this paper focuses on small to medium dry ports in a range up to 100,000 TEU annual throughput. Dry ports exceeding this level are generally located in regions with either a geographical and rail infrastructure advantage or a high cargo generating ability. For example, Xi'an International Inland Port, Kuming Tengjun International Inland Port and Yiwu International Inland Port are the three major dry ports in China. The first two are strategically located in key cities along the OBOR route and designed with a capacity of 3.1 and 1.2 million TEU, respectively, while Yiwu is a major manufacturing centre in China with more than 1 million TEU exported every year.

2.2 Economic analysis of dry port and inland terminal developments

Previous studies of dry port and terminal development have tended to focus on the intermodal terminal, as the complexity and specific engineering needs require large investments, and sufficient scale is needed to reach economic feasibility and provide a return on investment. Bergqvist et al. (2010) identified the key influencing factors on such developments as profitability, the role of funders, the need for a political entrepreneur, suitable location and the presence of large local shippers. The key issue of providing sufficient flows is strongly linked to the dry port's relationship with seaports (Notteboom and Rodrigue, 2005; Wilmsmeier et al., 2011; Nguyen & Notteboom, 2018). Yet, even with a potential for container flows from one or more seaports, the economics of the terminal itself relate to the initial capital investment, design size, operational model and ability to obtain economies of scale.

Tsamboulas and Kapros (2003) developed an investment evaluation model for rail-connected freight villages, based on construction and operating costs, a variety of public and private investments and expected revenues. Panova and Hilmola (2015) analysed investment appraisal calculations of dry port projects under PPP models in Russia using a deterministic model of net cash flows based on investment, financial and operational cash flows. Koh (2010) developed planning models for inland container terminals and proposed a heuristic algorithm for the purpose of evaluating alternative investment plans. Kozan (2000) considered the transhipment cost not only with regard to operational management, but also with regard to the investment in facilities. In addition, the choice of equipment will depend on container throughput, physical operating space, track layout, etc. Wiegmans et al. (1999) analysed the cost structure of inland terminals, based on capital and operating costs, and showed that the cost per container handling lowers as throughput increases. Ballis and Golias (2002) evaluated the effect on handling costs of different terminal configurations, and identified the key parameters as length and utilisation of transhipment tracks, train and truck arrival behaviour patterns, type and number of handling equipment, mean stacking height in the storage area and the terminal access system and procedure. Similarly, Wiegmans and Behdani (2018) analysed the investment and cost structure of intermodal terminals and identified the impact on handling costs, demonstrating that extra-large terminals have the lowest average handling costs.

As noted above, the majority of research on inland freight facilities has focused on intermodal terminals, either as pure rail-road handling terminals or integrated within a larger inland port or dry port. This situation reflects the fact that research interest, particularly in developed countries, has been on the intermodal connection to reduce emissions and congestion through modal shift. By contrast, the focus in this paper is on dry ports as locations for inland customs clearance with, in some cases, related storage and intermediate logistics services. These containers will then continue to the port under customs bond, either by road or rail. Those containers being transported by rail will require road transport between the dry port and a nearby intermodal terminal, a topic that has not been considered thus far in the intermodal literature. The comparison between dry ports with and without onsite rail access is analogous to on-dock or off-dock rail terminals used by seaports, the former indicating a rail terminal within the port and the latter requiring road shunting to an external rail terminal (e.g. containers passing through the ports of Los Angeles and Long Beach use both types to access the US rail network – Leachman and Jula, 2012).

Therefore a clear research gap exists regarding the comparison of an onsite and offsite configuration when proposing a dry port development. The key issue is the equilibrium point between the higher cost and operational productivity of land adjacent to an existing rail terminal and the cost advantage of cheaper land in a remote location, even with the additional road transport cost. As already pointed out in many previous studies (e.g. Tabari et al., 2008; Alberto, 2010; Li et al., 2011; Özcan et al., 2011), land cost is a crucial factor in site selection. A model is needed to calculate the trade-off between these inputs and determine at what level of demand it is better to absorb the extra transport cost incurred by the offsite configuration rather than locating the dry port next to a rail terminal which would raise fixed costs. Previous research has already revealed the negative influence of the first/last mile between the intermodal terminal and the shipper on the likelihood of choosing intermodal transport (Morlok, et al., 1995; Macharis and Bontekoning, 2004; Bergqvist and Monios, 2016). In this case, a second road movement is introduced between the dry port and the rail terminal in addition to the first/last mile from the warehouse or factory to the dry port. While two road movements seems inefficient to operators in developed countries, such practice is common in developing countries (Monios and Wang, 2013).

3 Methodology

3.1 The Chinese dry port system and justification of case selection

While China is in many ways a unique country, its growing system of dry ports (some rail-connected and some not) is a common model used in many developing countries, as noted in the introduction. Using China as a case provides a single network of sites with similar conditions that allows comparison between sites, thus providing a suitable opportunity for analysis of the two dry port types and development of the equilibrium model.

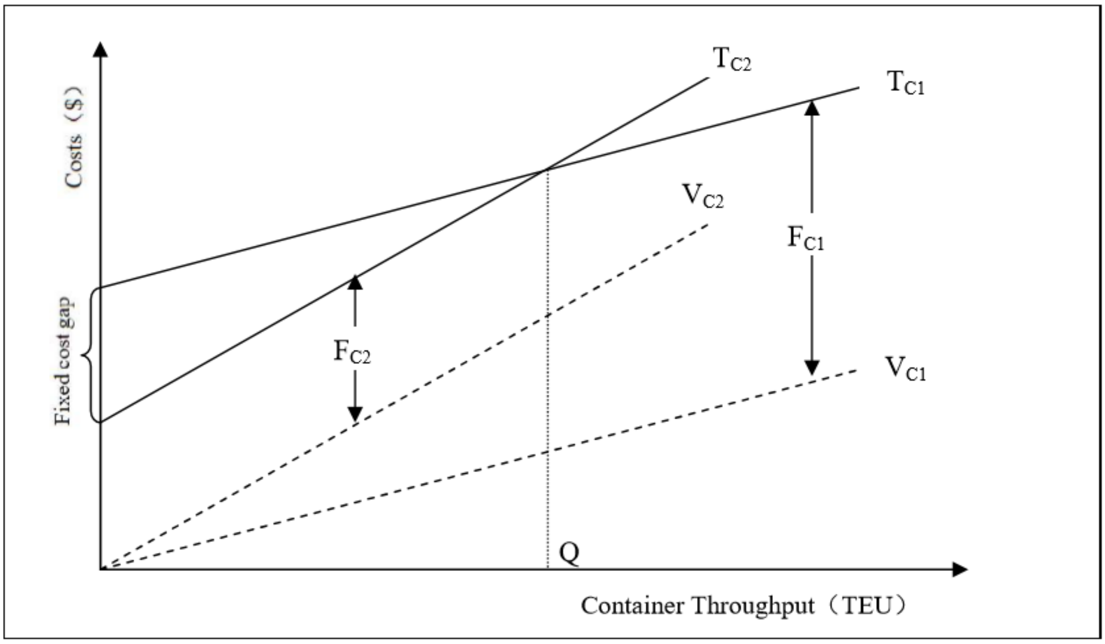
There has been a great expansion of the Chinese dry port system over the past decade, and this tendency is expected to continue due to the recent Chinese national strategy for promoting intermodal freight transport. For example, whereas the first Chinese dry port was established in Beijing in 2002 by the port of Tianjin, now there are more than 25 either solely or jointly developed by this one seaport alone and the port of Ningbo has developed 10 dry ports compared to 5 in 2013. Over 45 inland cities, other than those with traditional geographical advantage (e.g. Xi'an, Wuhan and Zhengzhou), are actively developing their own dry ports for promoting local economic development. Due to the previous and ongoing government support (China NDRC and MoT, 2018; China State Council, 2018), it is expected that, in the very near future, significant investments will be made developing new dry ports in China. Thus it is important to understand the relative merits of the two models.

The emerging dry port network in China has drawn the attention of scholars over the last decade (e.g. Hanaoka & Regmi 2011; Lu & Chang 2013; Zeng et al., 2013) and now the focus is not solely on the system perspective but on the different types and service models of these dry ports. Beresford et al. (2012) found that a lack of logistics capacity had been a restricting factor on trade in China, and Monios and Wang (2013) identified that freight transport in China remained fragmented, with many small companies, lack of consolidating locations and equipment availability for establishing intermodal solutions. Li et al. (2015) concluded that dry port development in China should evolve from the pursuit of scale to increasing efficiency. While great efforts and large investments have been made upgrading the capacity and quality of the rail infrastructure network to support intermodal flows, Monios and Wang (2013) found that many dry ports did not have their own onsite rail connection and instead either used road transport or shunted containers to nearby rail terminals. As a consequence of these challenges, modal shift from road to rail was constrained and the vast majority of cargo heading to Chinese ports remained on road.

3.2 Investment inputs for dry port development and operations

As mentioned above, the two compared options are whether to co-locate the dry port next to a rail terminal where land costs are much higher but more productive, or locate in a cheaper area without a rail terminal and those customers wishing to use rail will need to pay for an additional road shunt and handling costs to access the rail terminal. The model developed in this paper exhibits interactions between the required cost inputs (i.e. sum of the initial capital expenditures and operational costs) of a dry port and its transport demand as indicated by the annual container throughput (Jachimowski, 2018). By doing so, the cost scenarios of each case can be quantitatively drawn and the junction of curves represents the threshold value when the cost input of onsite and offsite access achieve equilibrium (see Figure 2).

Figure 2: Cost structure of dry port development and operations



Source: drawn by authors

Accordingly, the total cost (T_C) of a dry port development and operations at a given capacity consists of fixed costs (F_C) including land purchasing, site construction, equipment investment and other capital expenditures, and variable costs (V_C) such as cargo handling and transportation, wages, fuel and utility expenses:

$$T_c = F_C + V_c \quad (1)$$

3.2.1 Fixed costs

Land cost – container loading and unloading area

According to ESCAP (2017), the required size of the loading area is determined by the daily traffic flow and can be calculated according to the following formula:

$$S_{op} = \frac{P \cdot (1+K) \cdot s_1}{T} \quad (2)$$

P: designed container throughput per year (TEU)

K: reserve capacity safety factor for periods of peak demand in the whole dry port (%)

T: total operating days of dry port (days)

s_1: allocated area for loading and discharging a standard 20-foot container (m^2).

Land cost – container yard (CY) area

Container storage requirements depend on many factors, typically including throughput, handling equipment, stacking height, safety factor and dwell time (UNCTAD, 1979). According to CSAC (2000), the required size can be calculated using the following formula:

$$s_{cy}=\frac{P\cdot(1+k_1)\cdot t_1\cdot s_2}{T} \quad (3)$$

k_1: reserve capacity safety factor for periods of peak demand in CY (%)

t_1: dwell time at CY (days)

s_2: projected area per 20-foot container for storage (m^2).

In practice, the projected area per 20-foot containers is determined by:

$$s_2=\frac{G}{g\cdot H\cdot h} \quad (4)$$

G: average net weight per 20-foot container (tonnes)

g: storage weight per unit size of container storage yard (tonnes/m^2)

H: the number of stacking layers

h: ratio of average to maximum stacking height.

Land cost – container freight station (CFS) area

A container freight station is a common feature of many seaports and dry ports for the purpose of stuffing and unstuffing of LCL (less than container load) traffic. In this way container handling activity is streamlined and congestion is minimised (Kybart, 1985). By following the principle of UNCTAD (1979) and the design code published in CSAC (2000), the required size of the CFS can be computed as the following:

$$S_{CFS}=\frac{\alpha\cdot P\cdot(1+k_2)\cdot(1+a)\cdot t_2\cdot G\cdot s_3}{T\cdot u} \tag{5}$$

α: the percentage of containers passing through the CFS (%)

k_2: reserve capacity safety factor for periods of peak demand in the CFS (%)

a: access factor to allow for circulation and operational areas in the CFS

t_2: average transit time of consignment (days)

s_3: required area for stockpiling per tonne of cargo (m^2/tonne)

u: area utilisation rate of CFS.

Land cost – other areas

The remaining areas of a dry port typically include the administrative office, parking, container repairing and cleaning, maintenance, etc. In practice, the size of the administrative office area is generally proportional to the designed capacity (Wiegmans and Behdani, 2018), while most support services (e.g. container repairing and cleaning) and other maintenance activities are provided outside the terminal due to the high price of land close to the terminal area. Therefore, following Ashar (1991), it is assumed in this study that the occupied area of CY and CFS account for 80 per cent of the total required size of a dry port while the remaining 20 per cent is for administrative office, parking and other support services.

Handling equipment

For a small to medium size dry port at any given capacity, there won't be any significant difference between the two proposed types of dry port regarding the demand for loading equipment and other superstructure. Therefore, the cost of this section is temporarily defined as X.

Road vehicle costs for dry ports without rail access

For Chinese dry ports using offsite rail access, it is common that the road shunt is performed by dedicated vehicles belonging to the dry port. The fixed element of the cost mainly consists of the costs of truck purchasing, insurance, depreciation, etc. The calculation of the total costs for this expenditure as defined by CSAC (2005) is summarised in the following formula:

$$F_{shunting} = \frac{P \cdot k \cdot d_t}{2T \cdot t_3 \cdot v \cdot \tau} \cdot \left[c_{vehicle}\left(1 + D_p\right) + c_{insurance} \right] \quad (5)$$

d_t: shunting distance between the dry port site and the rail terminal (km)

v: road vehicle shunting speed (km/h)

t_3: daily operating hours of the shunting services (h)

τ: vehicle loading rate (%)

$c_{vehicle}$: purchase cost per vehicle ($)

$c_{insurance}$: annual insurance cost per vehicle ($)

D_p: average depreciation cost factor (%).

3.2.2 Variable costs

Following the same rationale as above, it is assumed that most of the operating costs for the two dry port types at the same designed capacity are generally the same. This value is temporarily defined as Y. However, the offsite design involves an additional road transport movement and extra loading and discharging. In consequence, the additional variable costs for the offsite design depend on the actually transported volume and consist of the spending on fuel consumption, wages, maintenance costs, etc. (Wang, 2013). The modal split figure is essential to this calculation because cargo going by road between the dry port and seaport is not relevant to the comparison of onsite vs offsite rail terminal.

$$V_{shunting} = \frac{(c_{fuel}+c_{wage}+c_{maintanence})\cdot d_t \cdot Q \cdot m}{2\cdot(1+v\cdot t_3\cdot T+d_m)} \quad (7)$$

$$Q = P \cdot U \quad (8)$$

Q: the actual container throughput per year (TEU)

U: the utilisation rate of the designed capacity

m: modal split ratio, percent of rail distribution (%)

c_{fuel}: fuel cost per kilometre ($/km)

c_{wage}: annual wage per driver ($/year)

$c_{maintanence}$: annual average maintenance cost per vehicle per year ($/year)

d_m: total distance per maintenance required (km).

3.3 Input equilibrium and performance indicators of onsite and offsite model

The required capital input for developing a dry port is affected by both the designed capacity and actual handling volume. Comparing only a total figure for different dry port capacities would be overly static, thus it is necessary to take a more dynamic approach to the analysis. Therefore, it is necessary to quantitatively assess the input equilibrium between the two proposed designs. The formulae for calculating the equilibrium point are the following:

$$T_{c1}=T_{C2} \quad (9)$$

and in detail:

$$x \cdot S_{On} + X + Y = y \cdot S_{Off} + X + Y + F_{shunting} + V_{shunting} \quad (10)$$

x: annual land cost for onsite configuration

y: annual land cost for offsite configuration

S_{On}: total land size of onsite configuration

S_{Off}: total land size of offsite configuration

X: cost of handling equipment and superstructure on an annual basis

Y: annual operational cost of the dry port.

Note: fixed costs for land purchase, terminal facilities and road transport vehicles are converted into annual costs based on a lifespan of 20, 20 and 10 years, respectively.

Alternative dry port configurations could lead to a significant change in operational performance and investment effectiveness due to their variation in terms of dwell time and stock density. In order to further explore the details of the equilibrium, operational productivity and land investment effectiveness are utilised as indicators revealing the potential influence factors and, in consequence, the impact on the investment decision.

Operational productivity has a long tradition as a performance indicator in the port sector (e.g. Silberholz et al., 1991; Beškovnik and Twrdy, 2011, Wilmsmeier et al., 2013; Chang and Tovar, 2017) and occasionally for inland terminals (Wiegmans and Witte, 2017). It is generally measured as the ratio between the output and the main terminal facility components utilised. For instance, TEU/yard acre, TEU/crane-hour, vessel calls/berth, etc. In this study, dry port operational productivity is measured by assessing the throughput per container stock yard m^2:

$$p_O = \frac{Q}{S_{CY}} \tag{11}$$

where p_O refers to the dry port's operation productivity.

Additionally, land cost effectiveness is also a major concern for the investment strategy. Similar to the above, it is measured by the ratio between the dry port annual throughput and the cost of land at the market price on a yearly basis:

$$p_L = \frac{Q}{S \cdot C_{land}} \tag{12}$$

where p_L refers to the dry port's land productivity.

4. Results and analysis

4.1 Cost equilibrium between onsite and offsite model

By applying the cost formulae in Section 3 to the data in the appendix, the fixed and variable costs can be calculated as shown in Table 1.

Table 1: Breakdown of total costs for developing a dry port

Cost sections			Onsite	Offsite
Fixed costs	Land purchasing	Loading & discharging	$0.11 \cdot P \cdot x$	$0.13 \cdot P \cdot y$
		Container yard	$0.49 \cdot P \cdot x$	$0.66 \cdot P \cdot y$
		Container freight station	$0.24 \cdot P \cdot x$	$0.45 \cdot P \cdot y$
		Other area	$0.21 \cdot P \cdot x$	$0.31 \cdot P \cdot y$
	Building construction & handling equipment		X	X
	Shunting transport vehicle purchasing		0.00	$0.33 \cdot P$
Variable costs	Dry port operation cost		Y	Y
	Shunting transport & extra loading		0.00	$13.44 \cdot P \cdot U \cdot m$

The total cost equilibrium between onsite and offsite configurations can then be resolved into the following equation:

$$\frac{1.05P \cdot x + X}{20} + Y = \frac{1.55P \cdot y + X}{20} + 0.33P + Y + 13.44P \cdot U \cdot m \qquad (13)$$

which can be further processed as:

$$1.05x - 1.55y - 6.60 = 268.80Um \qquad (14)$$

$x - y > 0$

$U \in [0,1]$

$m \in [0,1]$

Formula 14 reveals that the overall cost equilibrium between the two proposed dry port configurations is ultimately influenced by the land price gap (x-y), the site throughput indicated by the capacity utilization rate (U), and the modal split ratio (m). In other words, there exists a trade-off between the cost of extra shunting transport services and the variation in the land price gap regarding an onsite vs offsite configuration. The formula shows that the given capacity (P) of a proposed dry port shows no effect on the investment decision where there is no particular constraint on space availability. This is because the fixed costs of the occupied land area and operating facilities including shunting vehicles are proportional to the given capacity in both onsite and offsite cases. In addition, site operating cost (Y) might decrease along with the increase of designed capacity (i.e. scale return as highlighted in previous research). However, comparing onsite vs offsite at the same designed capacity, the facilities requirements and site operating costs would not be significantly different.

4.2 Empirical application to Chinese cities

4.2.1 Case data on the four cities

In order to verify formula 14 and reveal the interactions between the land price gap and the extra transport cost, four Chinese cities were selected to carry out the experimental tests, namely Qinhuangdao, Shijiazhuang, Tianjin and Beijing. As shown in Table 2, Qinhuangdao represents a small (by Chinese standards) inland city with a total GDP of $18 billion and 3 million population, while Beijing is the capital of China and its GDP in 2018 was more than $364 billion and its population is about 7 times higher than Qinhuangdao. Correspondingly, the area sizes of the two cities are vastly different, from 791,000 ha to more than 1.5 million ha. The cities of Shijiazhuang and Tianjin are added to represent the middle tier of Chinese cities, even though there was a significant gap in terms of their GDP outputs in 2018. The former is the capital of Hebei province with a strategic geographical location and the latter is one of the four municipal cities designated by the Chinese government as having outstanding economic development.

It is not surprising that the industrial land price varies across each of the four cities, expanding along with the increasing size of the city as well as other corresponding parameters. The city of Qinhuangdao, as the representative of a small city with relatively lower economic development, shows a $38 gap between the minimum and maximum industrial land price per square meter. The gap is expanded to $45 when examining the city of Shijiazhuang, further to $127 for Tianjin, and finally the largest of $1,607 for Beijing. Thus the more active the economic development in a city, the higher the land price gap between the core and suburban areas.

Table 2: Information about the four sample Chinese cities in 2018

City	Qinhuangdao	Shijiazhuang	Tianjin	Beijing
Area size (ha)	791,300	1,446,400	1,196,645	1,614,054
Population (million)	3,134	10,952	10,816	21,542
GDP (million $)	17,960	83,090	250,030	364,340
Min. industrial land price per m^2 ($)	39	77	59	50
Max. industrial land price per m^2 ($)	77	112	186	1,657
Price gap ($)	38	45	127	1,607

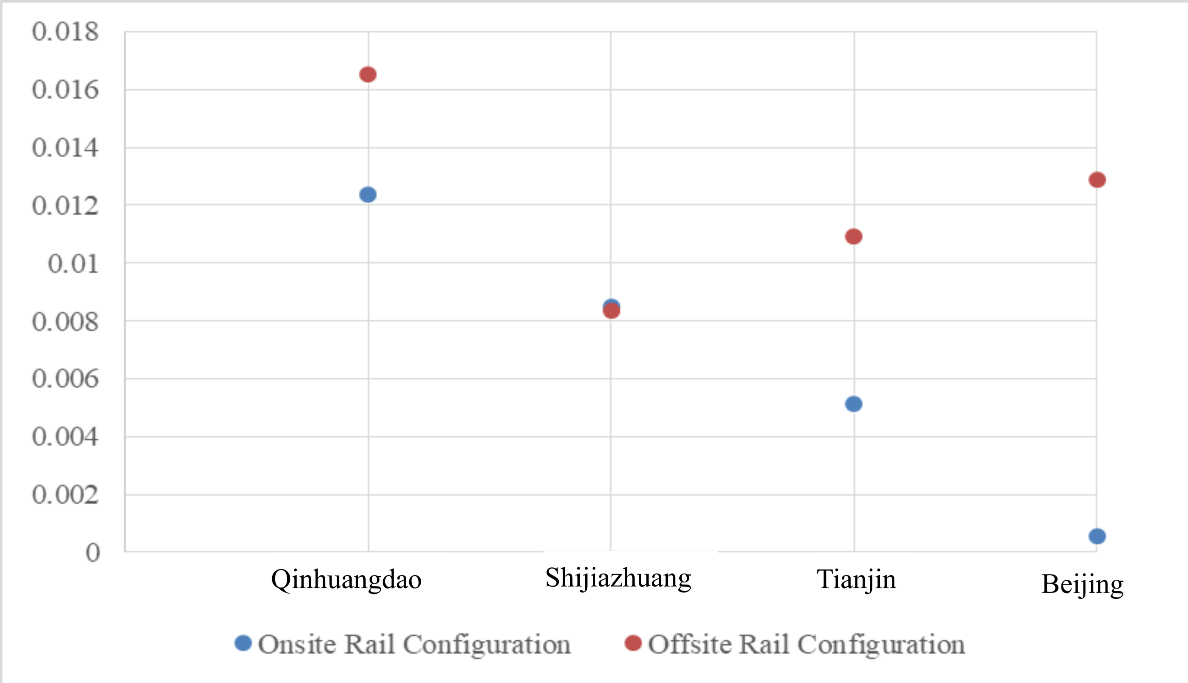
Source: NBSC (2019)

4.2.2 Comparing onsite and offsite configurations

Within the context of this research, the investment input between onsite and offsite configurations is mainly adjusted by the variation of the price gap at the corresponding locations, while the output varies by the land cost effectiveness and the maximum throughput that can absorb the negative impact of the extra shunting transport cost.

Figure 3 presents the application of formula 12, in which the land cost effectiveness is measured by the ratio between the dry port annual throughput and the cost of land at the market price on an annual basis. The results reveal that a lower land cost produces a higher land cost effectiveness. For example, for the offsite configuration, the city of Qinhuangdao holds the highest land cost effectiveness of 0.0165 at the cheapest land cost of $39, while Shijiazhuang shows the lowest effectiveness of 0.0084 with the most expensive land at the remote location. Meanwhile, except for the city of Shijiazhuang, this advantage becomes more significant as the land price gap increases. The city of Shijiazhuang being an example of a medium size city in China, its land price at the cheapest location is not as low as the smaller city Qinhuangdao while its land price gap is not as significant as in the large and ultra large cities with more developed economies. As a result, the land cost section of the dry port investment in Shijiazhuang is even more effective with an onsite rail configuration. Thus, the figure shows that a lower land cost generally brings a higher land cost effectiveness, but it requires a smaller price gap to maintain the advantage of the offsite configuration at the cheaper remote location compared to the onsite model.

Figure 3: Land cost effectiveness in selected cities



Source: authors

Table 3 presents the results of the equilibrium calculation identifying the threshold container throughput to achieve a cost advantage of the offsite configuration over the onsite model based on a 100,000 TEU design capacity. For a dry port located in Qinhuangdao, when the rail modal share is only 25%, the offsite model has a cost advantage over the onsite up to a throughput of 20,600 TEU. Anything above that level of throughput makes the onsite option more attractive. As rail share increases, so do the additional transport costs, thus the throughput level at which the offsite model can maintain its advantage decreases. If 100% of cargo uses rail then the offsite model only has a cost advantage if total throughput is very low, around 5,150 TEU. This result is mainly due to the low land price gap. If the dry port were to be operating at its theoretical maximum of 100,000 TEU, then the offsite model would only remain competitive with the onsite model at a rail share of 5.15%.

Table 3: Maximum container throughput for cost advantage of offsite configuration (TEU)

Rail mode share	Qinhuangdao	Shijiazhuang	Tianjin	Beijing
100%	5,150	0	36,250	616,730
75%	6,870	0	48,330	822,310
50%	10,300	0	72,490	1,233,460
25%	20,600	0	144,990	2,466,920

Source: authors

Note: results subject to a design capacity of 100,000 TEU

The city of Shijiazhuang is a very different example, where the offsite configuration shows no cost advantage at any level of modal share. Given the minimum and maximum land price of \$77 and \$112 respectively, the annual land purchasing cost for a 100,000 TEU capacity dry port with the offsite design is \$59,675, which is already higher than the onsite model at \$58,870. This result is attributed to the lower operational efficiency of the offsite configuration which requires a larger amount of land, even though it is cheaper per m^2. At Tianjin, the offsite model is only attractive up to an annual throughput of 36,250 TEU when all containers need to be distributed by rail. As rail share declines, the offsite model becomes more attractive, even beyond its designed capacity of 100,000 TEU when the modal split drops below around 35%. The top tier city of Beijing shows an absolute cost advantage for the offsite configuration at all levels of modal split, due to the very large land price gap. Even with the additional shunting costs of moving 100% of the dry port cargo to a rail terminal, the offsite model retains a cost advantage until the throughput passes a theoretical level of 620,000 TEU, more than 6 times higher than the designed capacity of 100,000 TEU.

4.2.3 The impact of the modal split ratio on operational productivity and capacity utilisation

The previous section revealed the importance of both land price and modal split ratio on the dry port costs in the onsite and offsite models. This section investigates the impact of the modal split ratio on the operational performance of the dry port at a given level of investment, as this relationship affects not only the dwell time and hence operational efficiency of the onsite rail configuration, but also the additional shunting transport movement being performed as part of the internal operational activities at the offsite dry port.

Operational productivity in this study is defined as the ratio between actual terminal throughput and operational container stock yard size (formula 11). As shown in Table 4, the two proposed configurations have the same operational productivity when all containers are distributed by road transport. In other words, the demand for the container yard and all other technical features are the same because they are both doing the same task, with all traffic flows both in and out moving via road. However, the operational productivities of the two proposed configurations diverge as the modal split ratio changes. For example, the ratio for the onsite model increases from 66 to 110 with 100% rail share. In contrast, the offsite option becomes less and less productive as the rail share increases, from 66 to 41, due to the increase of shunting costs to access the rail terminal.

Table 4: Operational productivities of dry port configurations by modal split scenarios

Modal split ratio	Road (100%) ←			→ Rail (100%)
	m=0.00	m=0.25	m=0.50	m=0.75	m=1.00
Onsite	66.00	73.33	82.50	94.29	110.00
Offsite	66.00	57.39	50.77	45.52	41.25

Source: authors

The next step is to consider how the modal split affects the utilisation rate of the offsite model. Table 5 calculates the utilisation rate of the case cities, assuming their highest land price gaps. Shijiazhuang has the lowest capacity utilisation rate with all modal split scenarios, and can only achieve full utilisation when the modal split ratio approaches 0. The reason, as mentioned earlier, is that even though land at the offsite location is cheaper per m^2, this configuration is less operationally efficient hence requires more land and is more expensive even before the additional transport costs are added. The city of Tianjin has the highest result among these three cities – at 100% rail share it uses 59% of its capacity, and once the modal split drops below 50% its utilisation rate achieves almost 120%. The city of Qinhuangdao is a typical smaller city with a balanced interaction between capacity utilisation and rail modal split ratio, achieving 35% utilisation when rail share drops below 15%, but as rail share increases its utilisation drops quickly.

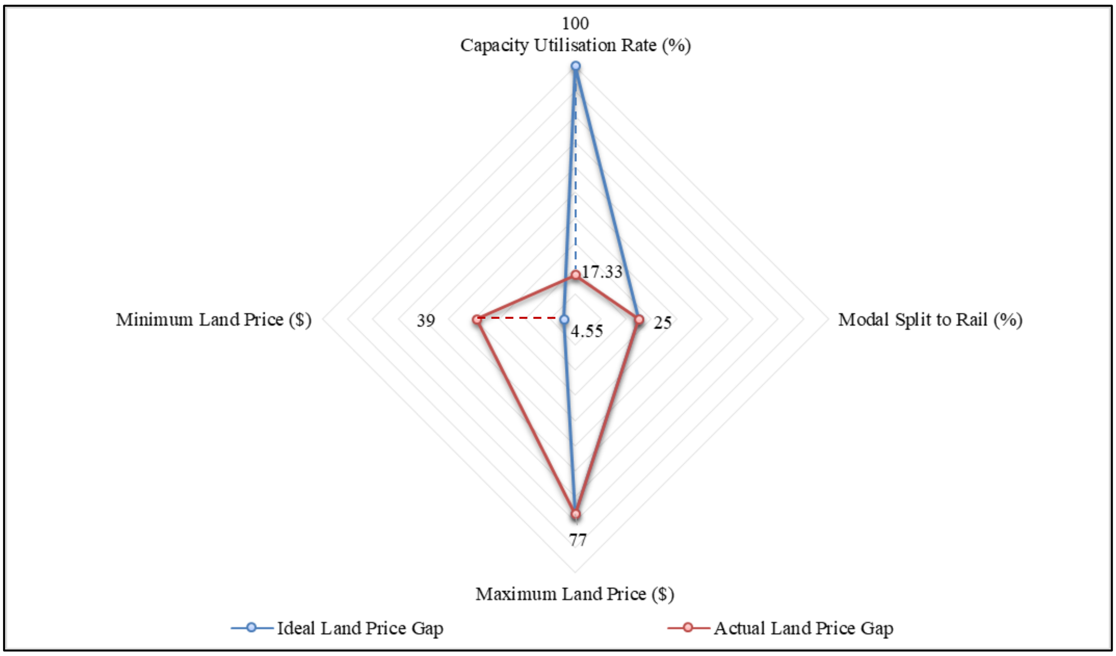
Table 5: Capacity utilisation rate (%) of offsite configuration at the maximum land price gap in selected cities

	m=1.00	m=0.75	m=0.50	m=0.25	m=0.04	m=0.01
Qinhuangdao	4.33	5.78	8.67	17.34	100.00	-
Shijiazhuang	0.78	1.04	1.56	3.13	-	100.00
Tianjin	59.21	78.94	118.42	236.83	-	-

Source: authors

In practice, however, while increased modal shift to rail is desirable, it is potentially more desirable for the developer that the new offsite dry port achieves a high utilisation, which, all else being equal, would require a change in costs. The trade-off here can also be calculated using the same model. For example, for the offsite configuration in the city of Qinhuangdao to retain its cost advantage and full utilisation as modal shift increases from 4% to 25%, the minimum land price needs to drop from \$39.00 to \$4.55 per m^2. Otherwise, the utilisation would drop significantly, from 100% to 17% (graphically represented in Figure 4). In reality, it is quite common in China that the land is provided free by the city or sold at the minimum legal price, with additional subsidies. These strategies could also be applied in other cases and compared using the model applied in this paper.

Figure 4: Dynamics between land price gap and site performance indicators in Qinhuangdao



Source: authors

The results in Table 5 assume the maximum land price gap, but there is a relationship between variations in this input and variations in the modal split ratio. The earlier case analysis showed that in Beijing the offsite model is competitive with the onsite model at all levels of modal split, due to the high land costs for an onsite model. Table 6 shows how this result might change if the land price gap changes. By following the modal split scenarios, the offsite configuration would have an absolute cost advantage in Beijing at decreasing levels of modal split when the price gap is higher than 94, 158, 222, and 286, respectively. This means that a higher modal share for rail (thus requiring more road transport movements to the terminal) requires a lower price gap, and a higher price gap can be permitted when less cargo needs to travel to the rail terminal. However, this result is largely theoretical in the case of Beijing given that the current land price gap there is $1,607.

Table 6: Threshold price gap ($) at the full utilisation rate of capacity

	m=1.00	m=0.75	m=0.50	m=0.25
Beijing	94	158	222	286

Source: authors

5 Conclusion

This paper aimed to compare two dry port models – one developed adjacent to a rail terminal (onsite) and one located at a distance that would involve road transport to access the rail terminal (offsite). The former model has higher land costs while the latter introduces both additional transport and handling costs and reduced efficiency in the container yard due to these movements. Thus the goal of this paper was to examine first the trade-off between land and transport costs in the two models, and then to investigate how they change according to operational productivity and modal split. This was done by applying an Input-Output analysis to identify at which levels the onsite and offsite models achieve equilibrium. Resolving the equations showed that the design capacity does not affect the outcome of the onsite vs offsite model, and thus the key influences are land price, modal split and operational productivity. The model was applied to four Chinese cities to investigate the results at different land prices.

The first result concerns the trade-off between land and transport costs in influencing the equilibrium point between onsite and offsite models. Where land price is very expensive (e.g. Beijing), the offsite model is always cheaper than the onsite, because the additional transport costs of moving containers from the dry port to the rail terminal will never be more than the increase in land cost from an offsite to onsite location. For Shijiazhuang, the opposite was true, with the onsite model always being more attractive than offsite. The other two sites presented a range, showing that as rail modal share and thus transport costs increase, the onsite model becomes more attractive, with the actual level depending on the relative land price in the two cities. For example, with 100% of dry port containers needing to travel to the rail terminal, in Qinhuangdao the offsite model retains its cost advantage only up to a throughput of 5,150 TEU, at which point it is worth building an onsite dry port, whereas at Tianjin the offsite model retains its advantage up to 36,250 TEU. As rail share decreased, the offsite model remains attractive at progressively higher throughput levels.

The second question was to interrogate the result according to changes in operational productivity (the offsite model being less efficient) and modal split. The results showed that the efficiency advantage of the onsite model increases substantially as rail modal share increases, which means that the capacity utilisation of the offsite model declines. At full rail share, Qinhuangdao and Shijiazhuang dry ports showed very low capacity utilisation, requiring that rail share become quite low before their rate increased. By contrast, a dry port at Tianjin had more than half capacity utilised at 100% rail share, increasing as the rail share declined. Finally, these results themselves vary if the land price gap changes. Table 6 showed a relationship between land price gap (between most and least expensive locations) and modal split. A higher share of dry port cargo using rail (thus requiring more road transport movements to the terminal) requires a lower price gap for the offsite model to achieve equilibrium, whereas a higher price gap can be permitted when less cargo needs to travel to the rail terminal.

From the public perspective, investing in a dry port generally comes with two objectives: full utilization rate of the designed capacity (i.e. effective investment) and promoting cargo flows to be transported by rail or inland waterway. For a city planning to develop a dry port, the investor should already be roughly aware of the transport modal shares of the local cargo. The model developed in this paper can be used to modify the cost inputs (e.g. changes in land price due to subsidies from the city) and compare different levels of modal split and capacity utilisation. Using the minimum and maximum land price in a city, the previous section demonstrated how the model can calculate the maximum capacity utilization rate at the corresponding level of modal split ratio to maintain the cost advantage of the offsite design. For example, the offsite model in Qinhuangdao exhibits a cost advantage only at a maximum 4% rail share when the capacity was fully utilized (100%). When the modal split increased to 25%, the offsite design lost its advantage if the capacity utilization rate remained at 100%. To maintain this cost advantage for the offsite configuration (for example, when it is desirable to retain the offsite model due to constraint on space availability near the rail terminal), the investor could either reduce the designed capacity at the alternative location (as long as it can meet the local minimum demand) or ask for subsidies to reduce the fixed costs. Such subsidies are seen quite often in China, e.g. by providing free land or a tax reduction. The methodology in this paper can be used to calculate the relationships and trade-offs between these key factors. Thus this research is not only beneficial for investors in supporting their financial decision regarding dry port development, but also helpful for government or related public bodies to promote modal shift strategies through actions such as cheap land provision, subsidies, tax reduction, etc. This model can be applied in any country where a decision is taken between a rail-connected dry port and an offsite model, which includes many developing countries.

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Appendix: Parameters and Variables

Table 7: Parameters and data used in the study

Parameters	Definition	Onsite	Offsite
P	Designed capacity	Variable	Variable
Q	Actual container throughput	Variable	Variable
U	Utilization rate of dry port capacity	Variable	Variable
X	Expenditures of building construction and equipment facilitations on the annual basis	Assumed constant	Assumed constant
Y	Annual operational cost of proposed dry port configurations	Assumed constant	Assumed constant
T	Operating days per annum	330 days	330 days
t_1	Dwell time of CY	3 days	5 days
t_2	Average transit time of consignment (CFS)	2~3 days	3~5days
t_3	Daily operating hours of the shunting services	12 hours	12 hours
K	Reserve capacity safety factor for periods of peak demand of whole dry port (%)	20%	40%
k_1	Reserve capacity safety factor for periods of peak demand in CY (%),	10%~30%	30%~50%
k_2	Reserve capacity safety factor for periods of peak demand in CFS	10%~30%	30%~50%
G	Average net weight per 20 foot container	11~13 tonne /TEU	11~13 tonne /TEU
g	Storage weight per unit size of CFS	0.26 tonne/ m^2	0.26 tonne/ m^2
H	The number of stacking layers	3	3
h	Ratio of average to max stacking height	0.6-0.7	0.85~0.95
α	The percentage of containers pass through CFS	60%	60%
a	Access factor to allow for circulation and operational areas in the CFS	0.4	0.4
u	Area utilisation rate of CFS	60%~70%	60%~70%
S	Occupied land area of dry port	Variable	Variable
s_1	Allocated area for loading and discharging a standard 20 foot container	30 m^2	30 m^2
s_2	Projected area per 20 foot container for storage	Variable	Variable
s_3:	Required area for stockpiling per ton of cargo	1 ~2 m^2/tone	1 ~2 m^2/tone
d_t	Shunting distance between dry port site and existing rail terminal	0	25 Km
d_m	Total distance per maintenance required	N/A	5000
v	Road vehicle shunting speed	N/A	60 km/h
τ	Vehicle loading rate (%)	N/A	80%~90%
D_p	Average depreciation cost factor (%)	N/A	5%

$c_{vehicle}$	Purchasing cost per vehicle ($)	N/A	28848
$c_{insurance}$	Annual insurance cost per vehicle ($)	N/A	1028
c_{fuel}	Fuel cost per kilometre ($/km)	N/A	0.995
c_{wage}	Annual wage per driver ($/year)	N/A	12766
$c_{maintanence}$	Annual average maintenance cost per vehicle per year ($/year)	N/A	216
x	Annual land cost for onsite configuration	variable	variable
y	Annual land cost for offsite configuration	variable	variable
m	Modal split ratio to rail distribution (%)	100, 75, 50, 25	100, 75, 50, 25

Source: CASC (2000, 2005); ESCAP (2017); NBSC (2019)

Note: Investments in land purchasing, terminal facilities and shunting transport vehicles are assumed on the basis of a life span of 20, 20 and 10 years, respectively.