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Strategic locations for logistics distribution centers along the Belt & Road: Explorative analysis and research agenda

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Abstract:

Since the inception of China's Belt and Road Initiative (BRI) in 2013, the associated infrastructure and transport and economic corridor developments have been widely addressed in the research field of transportation, logistics and supply chain management. Such developments open windows of opportunity for accommodating trade flows in new or upgraded intermediate hub nodes and gateway locations along the BRI corridors. This paper aims to propose *strategic* locations for global logistics distribution centers (LDCs) along the Belt and Road from the viewpoint of China, considering regional economic and trade blocks, maritime transport routes, China's overseas port developments, China Railway Express services, trade conflicts between China and US, and deteriorated mobility of resources and human power caused by COVID-19. We present a set of strategic locations for establishing LDCs by analyzing qualitative and quantitative facility location factors supported by the findings in the existing literature. Eight locations for global LDCs are identified in the Sub-Saharan region, Sri Lanka, the Middle East, Northern Oceania, Southern Europe, Northern Europe, and key dry hub port locations in Minsk, Belarus and Northeast Asia along the Silk Road Economic Belt. Furthermore, we present a research agenda with applicable methods.

Keywords: Belt and Road Initiative, Logistics distribution center, New Maritime Silk Road, China Railway Express, Supply chain management.

1. Introduction

Since its inception in 2013, China's Belt and Road Initiative (BRI) has gained wide attention from several academic disciplines such as international relations, political science, transportation, logistics, and supply chain management. More than 700 journal papers[1] written in English in the fields of transportation, logistics, and supply chains have been published over the last eight years specifically dealing with the 21st Century Maritime Silk Road (MSR) and Silk Road Economic Belt (SREB) in the BRI, including some literature review papers (e.g., Lee et al. 2018a; Lee et al., 2020d; Wang et al., 2020a and 2020b) and special issues of international journals (e.g., Lee et al., 2016; ; Lee et al., 2018b; Cullinane et al., 2018; Lam et al., 2018; Chhetri et al., 2020; Lee et al., 2020a; Lee et al., 2020b; Lee et al., 2020c). The literature review papers applied a systematic approach with text mining techniques to reveal key topics and keywords in the context of the BRI in a visual way. Lee et al. (2020d) and Wang et al. (2020a) summarized research trends in transportation, logistics, and supply chains under the BRI. In particular, Lee et al. (2018a) and Lee et al. (2020d) highlighted research methods applied for such BRI studies. Thürer et al. (2020) highlighted research agenda from the viewpoint of global supply chain management by a comprehensive BRI literature review. The extant literature on the BRI reveals that no study so far has addressed the issue of *strategically* locating global logistics distribution centers (LDC) along the Belt and Road (B&R) from China's viewpoint. In other words, the strategic implications of LDC's in the context of the BRI have gained little attention in extant literature.

Since 2013, China has implemented the BRI through transport infrastructure investments such as in seaports, airports, railways, pipelines, and highways along the Belt and Road or B&R (Clarkson, 2020). China Railway Express (CR Express) services between China and Central Asia/Europe have developed strongly in tandem with subsidies from local governments (Yang, Sun, Lee, 2020; Ng et al., 2018; Wei and Lee, 2021; Zhang et al., 2020). Container volumes carried by China-Europe services increased from 13,200 TEU in 2013 to 1,135,000 TEU in 2020. This growth has been accommodated by large investments in rail tracks and multimodal terminals such as Khorgos on the Kazakh-Chinese border. Zhou et al. (2021) investigated the local and global centrality of "multimodal transport hubs", comprising of air, maritime and rail transport in the context of BRI and concluded that these hubs could promote international trade along the B&R while the potential development of hub ports in Africa could develop "the connectivity of the BRI for better international trade efficiency" (p.16). However, their study deals with global multimodal transport networks in terms of the "Air Silk Road Initiative"[2], MSR and SREB, while not elaborating on possible locations for global LDCs in tandem with multimodal hub ports. We argue that such LDCs can have strategic value to successfully implement and achieve China's sustainable economic growth.

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[1] As of January 2021, more than 700 BRI-related papers in association with keywords such as shipping, container port, air, railway, highway, logistics, and supply chains have been published in the journals of Web of Science and Scopus.

[2] On Air Silk Road Initiative, see Zhou et al. (2021, p. 2) and "What is the Air Silk Road Initiative?", The Aviation Industry Corporation of China, https://www.avic.com/en/aboutus/overview/index.shtml. (Accessed 26 March 2021).

This paper attempts to fill this gap by proposing strategic locations for global LDCs in the context of the BRI. In this paper, we define an LDC as a facility that performs consolidation, warehousing, packaging, decomposition, and other logistics functions associated with the global or regional distribution of freight. They can also perform light manufacturing activities such as assembly and labeling. Their main purpose is to provide value-added services to global supply chains passing through the global freight network, and in doing so, to contribute to the regional and local economy through job creation and the lowering of logistics costs. The scope of LDCs in this paper focuses on containerized cargo flows and assembly and production lines associated with global supply chains. Major LDCs are usually located adjacent to first-tier seaports, airports or dry ports having good connectivity and accessibility with maritime and inland transportation networks and regional markets. For example, the majority of the main distribution centers in Europe (also called European Distribution Centers or EDCs) are located within 200km distance from major gateway ports such as Rotterdam, Antwerp and Hamburg (Rodrigue and Notteboom, 2010; Graham et al., 2019).

The term "strategic location" is used partly because this study has been conducted from the Chinese perspective, considering the BRI, and partly because it does not present a quantitative method using empirical data to determine optimal LDC locations. In a further study with a more quantitative approach, the term "optimal location" of LDCs could be more appropriate in line with the terminology and wide array of methods applied in the vast literature on optimal facility location (see for a review, Melo et al., 2009). Studies on the optimal location of a distribution center have been based on several factors, such as labor cost and quality, rent of land and buildings, logistics costs, the legal environment, taxes and incentives, geographical location in association with market accessibility and transportation connectivity, country and financial risks, and so on. These factors are typically considered from a firm's perspective using questionnaire surveys and quantitative and qualitative analysis techniques (Yeung et al., 2001; Bhatnagar et al., 2003; Lee and Wilhelm, 2010; Jiang et al., 2021). Findings from the literature on the optimal location of a distribution center cannot be directly used as a reference for the strategic location of LDCs in this study, because the former is based on a firm's perspective while this paper follows a country's perspective in the context of the BRI. Therefore, this paper attempts to explore strategic locations for global LDCs by analyzing qualitative and quantitative factors with the help of the findings extracted from existing literature. This study also proposes a research agenda for further analysis of strategic locations of LDCs with reference to applicable research methods. Figure 1 shows our research framework.

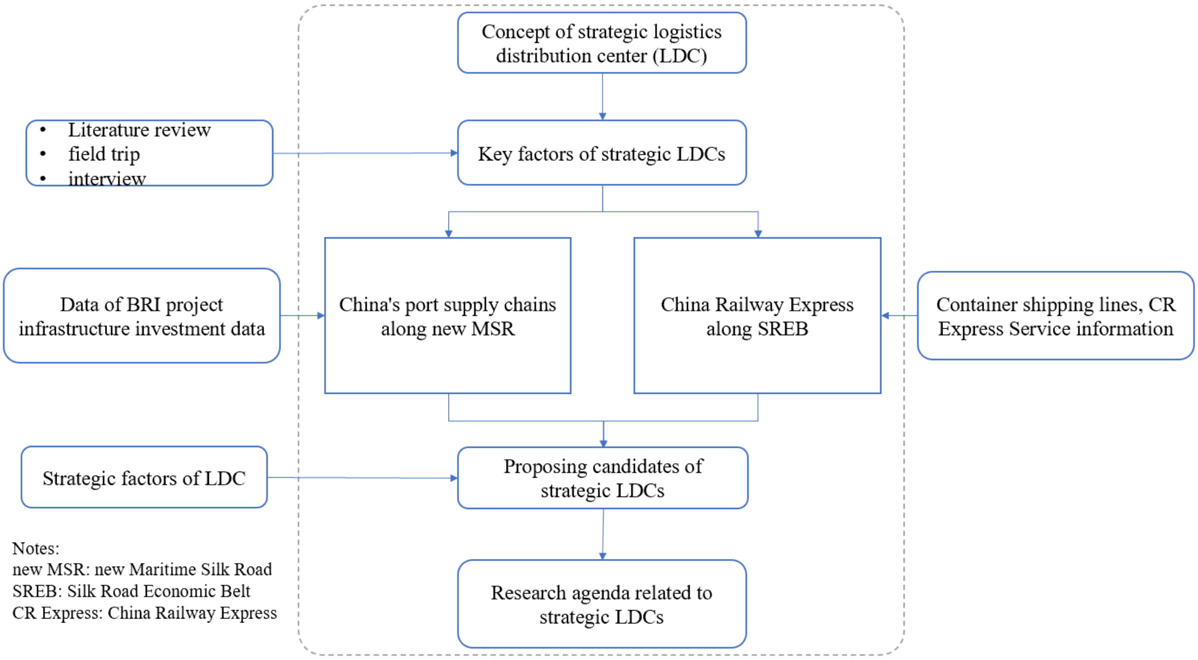
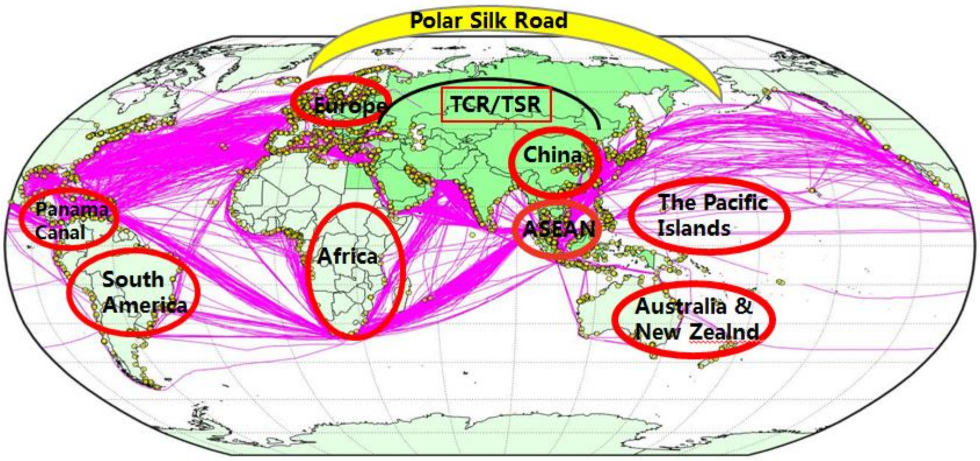


Figure 1. Framework of this study.

The paper is structured as follows. Section 2 explores key factors in proposing strategic LDCs in the context of the BRI, referring to existing literature. Section 3 proposes candidate locations for LDCs grounding on the discussion in Section 2. Discussions and implications of the proposed strategic locations of LDCs and a research agenda related to the global LDCs are addressed in Section 4. Finally, Section 5 concludes this paper with research limitations.

2. Key factors in proposing strategic LDCs in the context of the BRI

This section explores key factors which should be considered when proposing strategic LDCs along the B&R. As far as the transportation network is concerned, the BRI consists of the B&R, i.e., connecting China to the rest of the world by land and by sea. The former is represented by the China Railway Express (CR Express) and the latter by the MSR. In this paper, we consider the "*New MSR*" proposed by Lee et al. (2018b), which has expanded the scope of MSR (See Figure A1). The New MSR covers a larger area than the MSR, including also South Africa, South America, Oceania and the Pacific. In addition to the B&R, the Chinese government announced China's Arctic Policy in January 2018 (State Council Information Office, 2018), which includes the so-called *Polar Silk Road*. Therefore, China has three main surface transport networks (Figure 2).



Source: Lee et al. (2020).

Notes: TCR - Trans-China Railway; TSR -Trans-Siberian Railway. The New MSR connects China to Europe, Africa, South America, ASEAN, The Pacific Islands, Australia and New Zealand. (See also Figure A1).

Figure 2. Three main surface transport networks connecting China to the world.

Maritime transport along the New MSR and rail transport along the SREB are having an impact on multimodal transportation, global logistics and supply chain management (Lee et al., 2020d). The infrastructural and operational development of economic and transport corridors in light of the BRI promotes connectivity and accessibility along the B&R (Figure A1) and, therefore, paves the way for the emergence of (new) global LDCs. On the other hand, trade conflicts, such as between China and the US, have started to cause a decoupling of production lines in China and new protectionism of high technology. As a result, alternative production locations and reshoring options are to be envisaged, which open windows of opportunity for new LDC locations along the B&R. Furthermore, the outbreak of COVID-19 in December 2019 has limited the globally free movement of resources and human power thereby disrupting global production lines and supply chains (Choi, 2021; Chowdhury et al., 2021; Notteboom et al., 2021; Kwon, 2020). Such developments increase the significance of strategic LDCs locations in the context of the BRI.

The choice of strategic locations of LDCs from China’s perspective is influenced by China’s overseas port development, China’s settlement of free trade agreements (FTA) (Table A1), and China’s leading regional economic blocks, e.g., Regional Comprehensive Economic Cooperation (RCEP), Shanghai Cooperation Organization (SCO), Brazil-Russia-India-China-South Africa (BRICS), and China + ASEAN (Figure A3). Since the inception of the BRI in 2013, China has actively supported the development of international organizations led by China and FTA to efficiently implement the BRI. These organizations meet on a regular basis even during the COVID-19 pandemic. Container cargo flows have increased over the past decade in association with China’s BRI infrastructure investment along the New MSR and the development of China’s regional economic blocks.

Table 1 shows the BRI project investments from January 2013 to August 2020 by investment sector. Out of the three main sectors, the infrastructure sector represents 984 projects out of a total of 1,128 investments in 113 countries. Seaports, airports, railways, highways and roads, and pipelines are part of the transportation sub-sector covering 343 projects.

Table 1. Types of BRI project investment in the world, 2013-2020.

Sector	Number of Project
Infrastructure	**984**
Power Plants	416
Property	152
Transportation	343
Others	73
Capital Investment	**102**
Building Materials	36
Energy & Chem.	46
Metal Processing	11
Others	9
Raw Materials	**42**
Production	42
Total	**1,128**

Source: compiled by authors based on Clarkson Research, London (2020).

Table 2 shows the current implementation status of the BRI infrastructure investments in the period 2013-2020. About 19% of all the projects have been completed, 27% are under construction, 43.8% are contracted and 8.5% have reached the stage of a signed memorandum of understanding (MOU). The remaining 21 projects (1.9%) were suspended or cancelled (S/C).

Table 2. Status of BRI project investments in the period 2013-2020.

Status	No. of project	Composition ratio (%)
Completed	212	18.8
Under Construction (U/C)	305	27.0
Contract	494	43.8
Memorandum of Understanding (MOU)	96	8.5
Suspension/Cancellation (S/C)	21	1.9
Total	**1,128**	**100%**

Note: The data period is from January 2013 to August 2020.

Source: Compiled by authors based on Clarkson Research, London (2020).

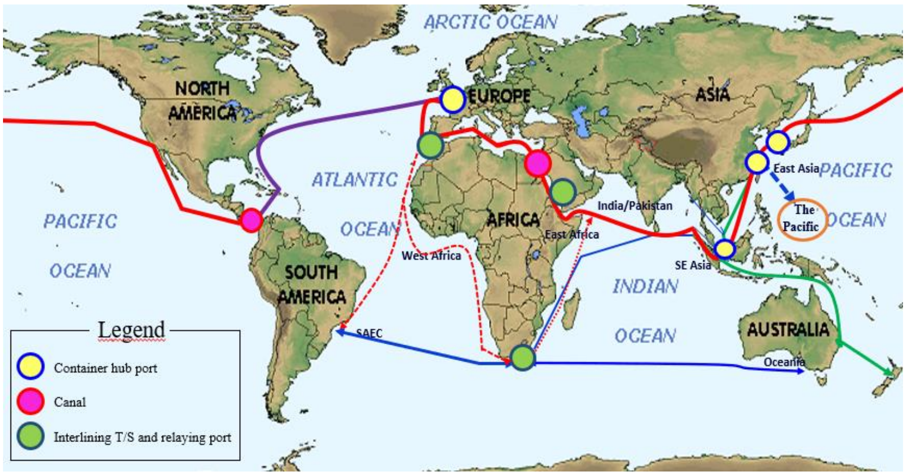
Table 3 presents a summary of China's infrastructure investments in the transportation sector in Africa. Out of the 91 projects in the African transport sector, 19 projects are related to seaports (See also Table A4.). All completed projects are located in the sub-Saharan region (SSR) (See Table A3.).

Table 3. BRI projects in the transport sector by transport mode in Africa, 2013-2020.

Transportation Sector	**Total No. of Project**	**Completed**	**U/C**	**Contract**	**MOU**	**S/C**
Seaport	19	4	8	6	0	1
Airport	9	3	2	3	1	0
Railway	18	4	6	6	2	0
Road/Highway	45	7	11	23	4	0
Total	**91**	**18**	**27**	**38**	**7**	**1**

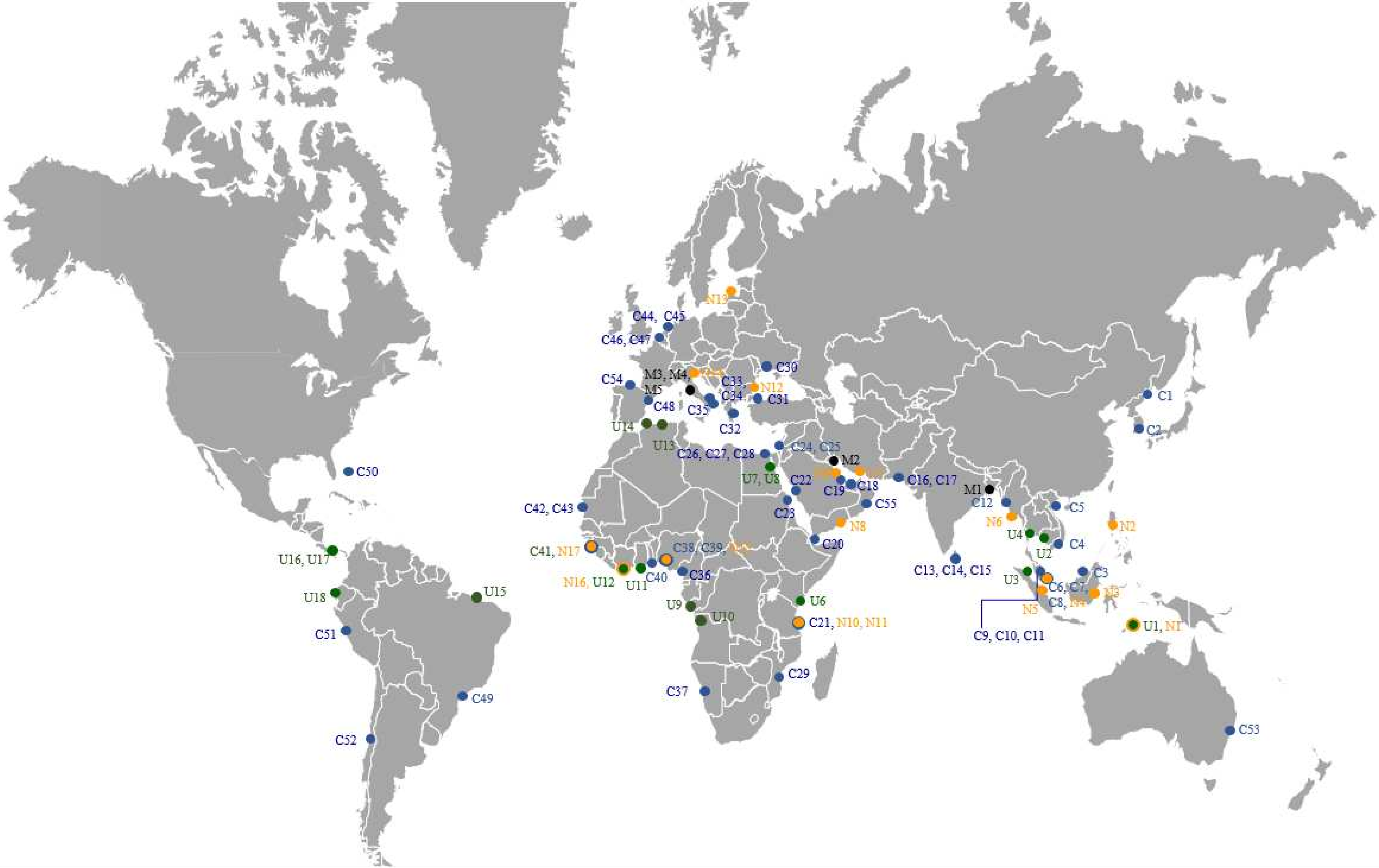
Source: Compiled by authors based on Clarkson Research, London (2020).
Note: On further detailed information, see Table A3 and Table A4 in this paper.

China's overseas port development in the context of the BRI is one of the key outcomes of China's global "going-out" strategy. These port investments are strongly aligned with the relevant container shipping routes (Figure 3) and New MSR (Chen et al., 2019; Yang et al., 2020). Figure 4 and Table A2 show the current development status of China's overseas seaport investment along the New MSR (Chen et al., 2019; Huo et al., 2019; Clarkson, 2020).



Source: Authors modified the map in UNESCAP (2020).

Figure 3. Main arteries and strategic interoceanic passages in the global container shipping network.


N13
C44, C45
C46, C47
C30
M3, M4,
C54
C33,
N12
M5
C34,
C31
C48
C35
C1
C32
U14
U13
C2
C24, C25
C26, C27, C28
M2
C50
U7, U8
C22
C19
C18
C16, C17
M1
C12
C55
C5
C42, C43
C23
N8
N6
N2
U4
C20
C4
C41, N17
C38, C39,
U2
U16, U17
C40
C36
C13, C14, C15
C3
N16, U12
U11
U3
C6, C7,
U15
U18
U9
U6
C8, N4
N3
U10
N5
C21, N10, N11
U1, N1
C51
C9, C10, C11
C29
C37
C49
C53
C52

C1	Zarubino
C2	Busan
C3	Muara
C4	Vung Tau Container Terminal
C5	Tra Vinh Province Coastal Seaport
C6	Pasir Panjang
C7	Cosco-PSA
C8	Singapore
C9	Melaka
C10	MCKIP
C11	Kuantan
C12	Maday
C13	Hambantota
C14	Colombo
C15	CICT
C16	Gwadar
C17	Qasim
C18	Abu Dhabi Khalifa
C19	Doha
C20	Djibouti
C21	Dar es salaam
C22	Jeddah Islamic
C23	Sudan Port
C24	Ashdod
C25	Haifa
C26	Suez Canal
C27	Said (East)
C28	Ain Sukhna
C29	Beira
C30	Chornomorsk
C31	Kumport
C32	Piraeus
C33	Reefer Terminal S.P.A
C34	Naples
C35	Vado Ligure
C36	Kribi
C37	Walvis Bay
C38	Lagos
C39	TICT
C40	Lome
C41	Boke
C42	Nouadhibou
C43	Friendship Port
C44	Rotterdam
C45	Euromax
C46	Antwerp
C47	Zeebrugge
C48	Noatum
C49	TCP
C50	Abaco Islands
C51	Chancay
C52	San Antonio
C53	Newcastle
C54	Bilbao
C55	Duqm Port Commercial Terminal and Operational Zone Development
U1	Tibar Bay
U2	Kampot
U3	Kuala Tanjung
U4	Laem Chabang
U18	Posorja Deepwater Port
U6	Mombasa
U7	Sokhna
U8	Damietta
U9	Pointe noire
U10	Caio
U11	Tema
U12	Abidjan
U13	El Hamdania
U14	Cherchell
U15	Sao luiz de maranhao
U16	Panama City
U17	Colon
N1	Beacu
N2	Manila North-South Port
N3	Bontang
N4	Singapore
N5	Jambi
N6	Kyaukpyu
N7	Qishm
N8	Aden
N9	Ras Al-Khair
N10	Tanga
N11	Zanzibar
N12	Varna
N13	Riga
N14	Venice
N15	Bakassi
N16	San Pedro
N17	Conakry
M1	Payala
M2	Mubarak Al-Kabeer
M3	Trieste
M4	Monfalcone
M5	Genoa

Note: The figure provides the situation in mid-2021. Some new developments have been announced. For example, COSCO Shipping Ports undertook a strategic investment in September 2021 to receive a 35% minority share in the Hamburger Hafen Und Logistik (HHLA) Container Terminal Tollerort (CTT) in Hamburg (Germany).

Sources: Huo et al. (2018); Chen et al. (2019): Clarkson (2020); AIIB (2021); and Table A2 in this paper.
http://porthebei.com/index.php?option=com_content&view=article&id=18421:2020-07-08-07-40-11-1032543897&catid=358:2017-05-22-10-28-6&Itemid=739&secmenuid=&lang=zh-cn

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https://www.aiib.org/en/projects/details/2016/approved/Oman-Duqm-Port-Commercial-Terminal-and-Operational-Zone-Development.html
https://www.cnss.com.cn/html/gkdt/20210128/339674.html (Accessed 9 June 2021).

Notes: China's overseas port/terminal investment data updated and drawn by authors. "C*i*" represents completed port/terminal investments. "U*i*" refers to ports or terminals under construction. "N*i*" refers to contracted port projects. "M*i*" means projects at an MOU initial stage of development.

Figure 4. China's Port Supply Chain Development along the New Maritime Silk Road.

This overseas port investment overview reveals that China has established a "*global port supply chain*". Five major companies have adopted major roles in overseas port investments: China Merchants Holdings (International), China State Construction (CSC), China Harbour Engineering Company (CHEC), China Road and Bridge (CRBC), and COSCO Shipping Ports (CSP). The CSP of the COSCO Group is determined to expand management control positions in overseas ports by holding majority shareholdings. The company aims to support the global shipping network of COSCO shipping company by investing in major ports in Europe and the Mediterranean Sea under China's "Going-out" strategy (Yang, He et al., 2020; Chen et al., 2019). Provincial governments and local companies in China have also invested in overseas container ports (Hue et al., 2019). China has also invested in overseas dry hub ports as will be discussed in Section 3.

The Chinese investment decisions in overseas ports are partly guided by the concepts of "centrality" and "intermediacy"[3] introduced by Fleming and Hayuth (1994) in the context of strategic commercial locations of container ports. With globalization, the function of intermediacy has become increasingly prevalent for long-distance cargo transportation and associated distribution networks (Rodrigue and Notteboom, 2010). Intermediate hub ports have emerged since the mid-1990s within many global port systems. These hubs tend to possess excellent nautical accessibilities, are located in the proximity of major liner shipping routes and provide high-quality services and high connectivity at competitive rates. The terminals are typically owned, in whole or in part, by carriers or multinational terminal operators which efficiently use these facilities. In the context of BRI, Chinese port operators have mainly targeted terminal locations which can serve as intermediate hubs in the global maritime network, but at the same time also offer an excellent centrality to reach important hinterland markets. An example is the long-term leased port of Hambantota in Sri Lanka which plays a key role in capturing transshipment cargoes in relation to coastal ports along the Indian Ocean as well as China's South-South trade route. Hambantota primarily builds on its 'intermediacy' role as a transshipment hub port for cargoes linked to the countries in the Indian Ocean (see also Chen and Yang, 2019; Ruan et al., 2019). Zhou et al. (2021) ranked multimodal transport hubs comprising of seaport, airport, and railway stations in terms of local and global centrality under the BRI, applying gravity model and complex network analysis.

In summary, the above discussion highlights some key factors to consider when assessing strategic locations of LDCs in the context of the BRI, such as China's overseas seaport and dry port development, current trade routes served by China and infrastructure investment in highways and railways in the countries along the B&R. In particular, China's regional and international collaborative mechanisms, of which most are led by China, not only are interwoven with the New MSR, SREB and Air Silk Road under the umbrella of the BRI, but also play a catalytic role in building up global LDCs. In other words, the overview of China's overseas port and dry port developments along the New MSR and SREB confirms that China has established favorable conditions to establish global LDCs along the B&R.

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[3] "Centrality generates what can be called true origin and destination container traffic from and to the local hinterland. Intermediacy generates long-distance in-transit and transhipment traffic." (Hayuth and Flemming, 1994, p. 188).

3. Candidates for the strategic location of an LDC

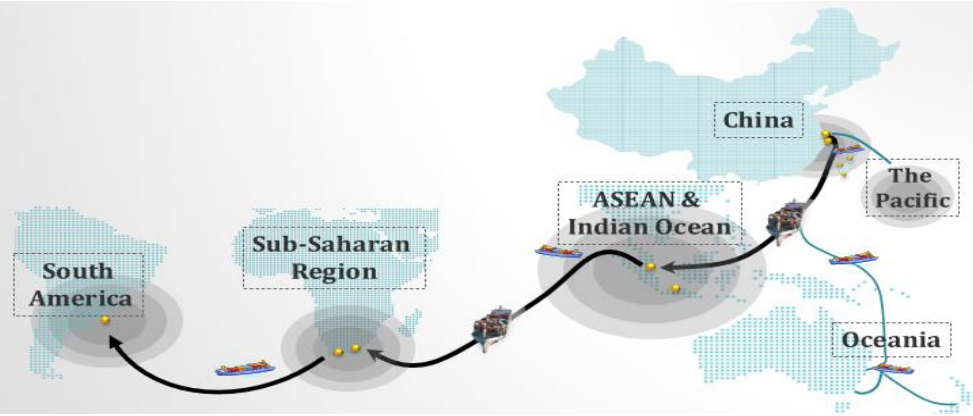
The previous section identified key factors to be considered when exploring strategic LDCs along the B&R. This section identifies potential strategic locations for LDCs. The starting point is to consider the existing maritime trunk lines in the world before the BRI in 2013. Traditionally, the two main container trunk lines are the Asia-Pacific Ocean route (Transpacific), and the Asia-Europe route. Emerging container routes include the Asia-South America route, Asia-Africa (Sub-Saharan region) route, and the Asia-Oceania route. Figure 3 presented in Section 2 depicts the main container routes in more detail (UNESCAP. 2020).

- The red line covers the Transpacific and Asia-Europe routes. These are the traditional main trunk lines for maritime container trade in North Europe-Asia-North America services, which cover the Pacific Ocean, the Indian Ocean, the Mediterranean Sea and the west coast of the Atlantic Ocean.
- The yellow circles represent container hub port regions serving the above two main trunk routes, such as the Yangtze River Delta (Shanghai, Ningbo-Zhoushan, Taicang), the Malacca Straits port system (Singapore, Tanjung Pelepas, Port Klang), the Pearl River Delta (Shenzhen, Guangzhou/Nansha, Hong Kong), the Hamburg-Le Havre range (Rotterdam, Antwerp, Hamburg, Bremerhaven, Le Havre, Zeebrugge), and the south Korean hub port Busan.
- The three red dotted lines in Figure 3 indicate relay services i) from the Strait of Gibraltar to the route of South America, ii) from the Strait of Gibraltar to the west coast of Africa, and iii) from South Africa to the Middle East. The green circles show interlining and relay ports, including logistics distribution centers to serve the above routes.
- The purple line connects Europe to the East Coast of North America and the Panama Canal. This route is connected to the Transpacific services with the ports along the west coast of North America. The pink circles indicate the Panama Canal and the Suez Canal.
- The blue lines show emerging container routes, comprising of i) Asia-ASEAN-South Africa-South America and ii) South-South trade routes connecting South America-South Africa-Oceania (Australia and New Zealand).
- The blue dotted line connects China to the Pacific islands.
- The green line shows North-South trade routes connecting North/East Asia to Oceania.

Having considered current container networks (See Figure 3) with China’s overseas port developments and BRI infrastructure investments in the countries along the B&R (See Figure 4, and Table A2), we can propose potential candidates for global LDC by region from a China’s perspective. These strategic locations enable to accessing to regional markets and augment relay and gateway services.

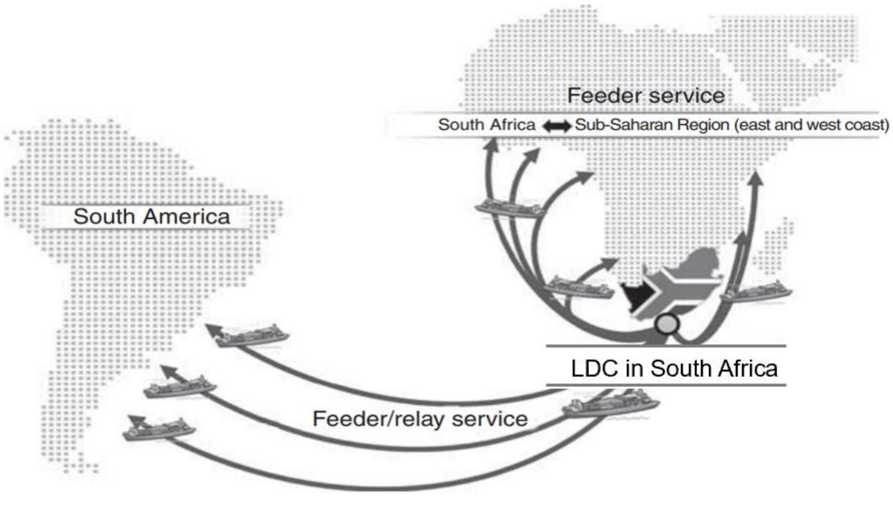
3.1. Southern Africa

South Africa is a promising region to establish an LDC along China's South-South trade routes (Figure 5(a)) as the region is in a good position to serve the east coast and west coast ports in the Sub-Saharan region (SSR), to connect to landlocked countries in the region and to relay container cargoes between Asia and South America (Notteboom, 2012), as shown in the conceptual representation in Figure 5(b). Regional seaports in a good position to combine maritime intermediacy with hinterland-based centrality include Durban, Cape Town and Ngqura in South Africa, and Maputo Port in Mozambique. Walvis Bay in Namibia has also some potential, while the ports of Toamasina (Madagascar) and Port Louis (Mauritius) lack hinterland access to the African continent and therefore can only target the relay/interlining business.



Source: Lee (2016), Vol.1, p. 60.

Figure 5(a). China's South-South Trade Routes along the New Maritime Silk Road.



Source: Lee (2016), Vol.1, p. 60.

Figure 5(b). Feeder/Relay service in Sub-Sharan region and South America through an LDC.

In particular, China's growing engagement in South-South trade with increasing maritime connectivity along the new MSR among regional economic blocks (including ASEAN, AANZFTA, IBSA, BRICS, RCEP) (See Figure A3.) is expected to promote global LDCs in SSR. Therefore, South Africa is in a good position to accommodate an LDC covering the east and west coasts of Africa with feeder services and South America with relay services (See Figure 5b).

China's active infrastructure investment in seaport, railway and road/highway have given multi-dimensional impacts on developing transport corridors, accessibility and connectivity in SSR, in particular for landlocked countries (LLCs) (See Figure 6). Table 4 shows the main ports of entry serving LLCs.

Table 4. Entry ports available for landlocked countries (LCC) in Africa.

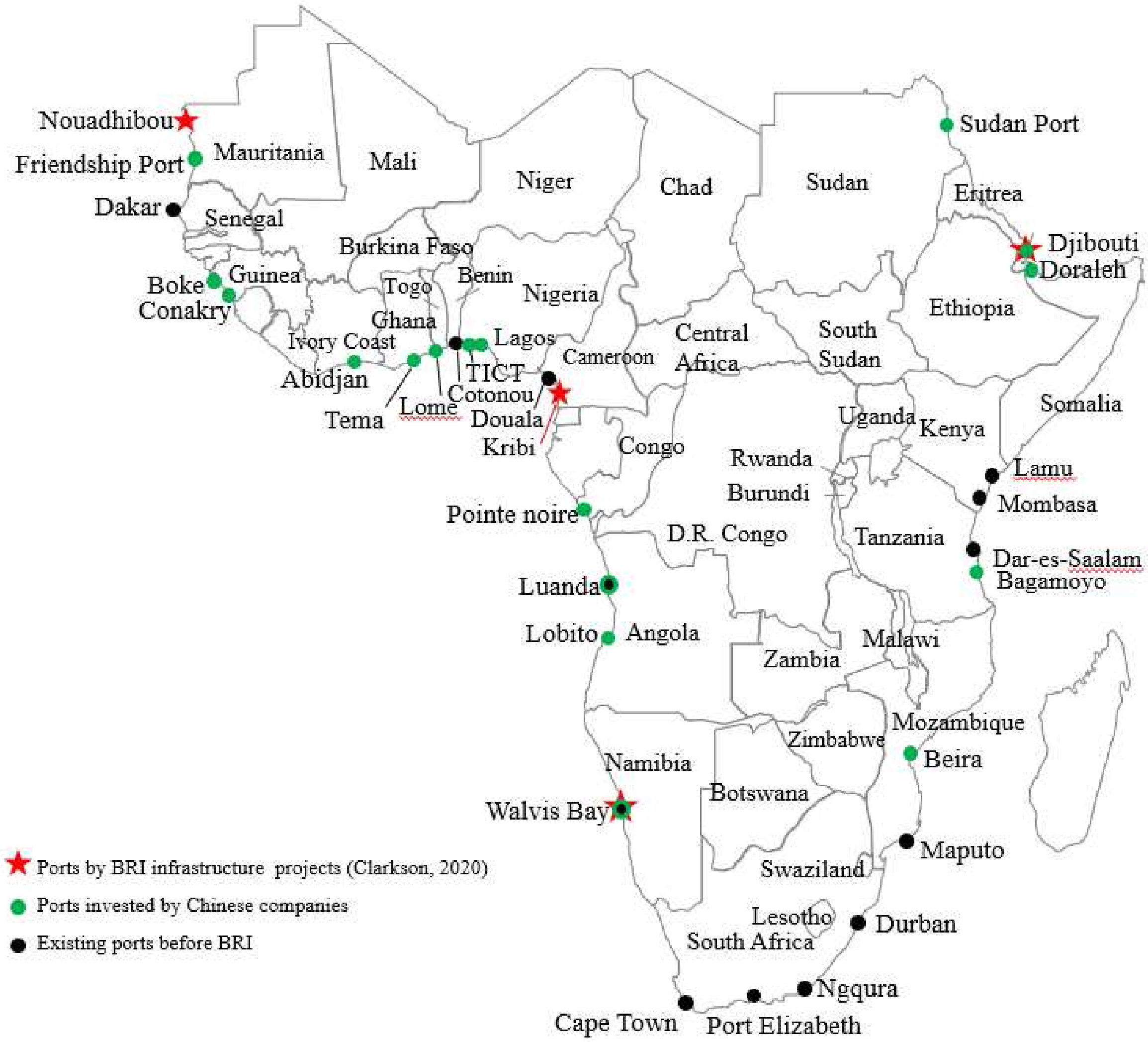
	West Africa	**Central Africa**	**East Africa**	**Southern Africa**
Main Ports of entry	Abidjan Tema Lome Cotonou Dakar Nouadhibou Conakry San Pedro Friendship Port Boke TICT	Douala Kribi Pointe noire Luanda Lobito	Mombasa Dar-es-Salaam Djibouti Lamu Doraleh Bagamoyo Sudan Port	Durban* Ngqura* Cape Town* Port Elizabeth* Maputo# Beira Dar-es-Salaam Walvis Bay
Landlocked countries (LLC) served	Mali Burkina Niger	Chad Central African Republic	Uganda Rwanda Burundi Democratic Republic of Congo (East)	Botswana Malawi Zambia Zimbabwe Democratic Republic of Congo (South)

Source: Compiled by authors based on Tables A2 and A4 in this paper.

Notes: * Ngqura, Port Elizabeth, and Cape Town ports serve Gauteng in South Africa, Lesotho and Swaziland.

Maputo has an inter-port competition with Durban for serving the Gauteng region in South Africa, Botswana and Zimbabwe. Both ports have access to extensive rail corridors to serve these hinterland regions.

Figure 6 depicts all the ports in SSR. The ports in green have received investments by major companies (e.g., COSCO and China Merchant Holdings) and provincial governments and local companies. The red stars indicate that the ports were completely constructed in the framework of the BRI projects.



Source: based on the data of Huo et al. (2018), Chen et al. (2019), and Tables 4 and A2 in this paper.

Figure 6. China’s investment in ports in Sub-Saharan Africa region (SSR).

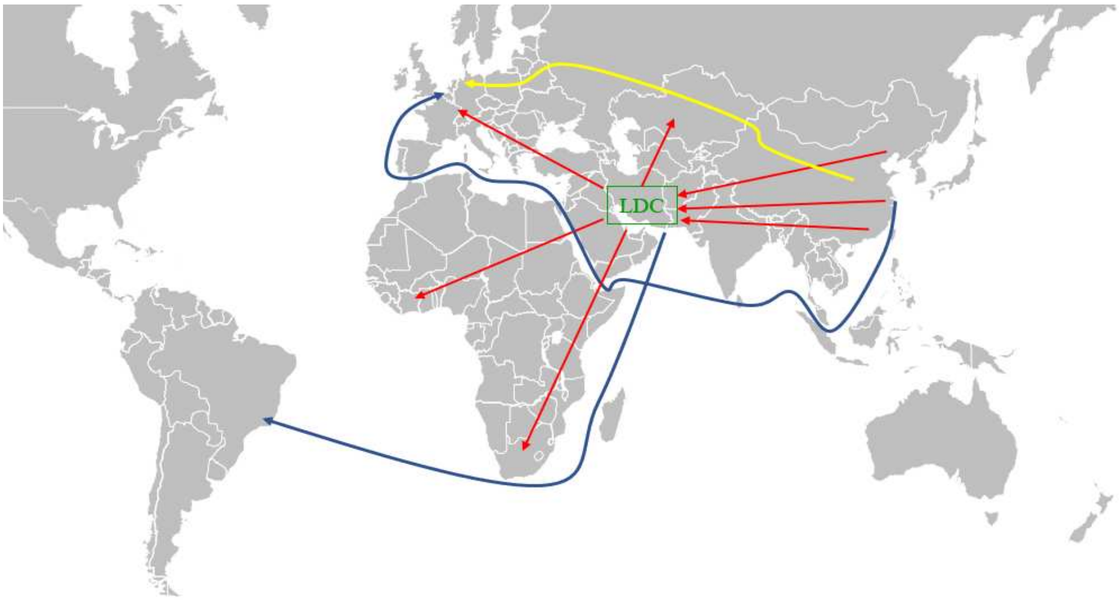
3.2. Sri Lanka as a transshipment (T/S) hub port in the Indian Ocean

Hambantota in Sri Lanka has been leased to China for 99 years. China’s engagement in developing container terminals in Colombo Port and the Port/City interface has been developing since 2012. The long-term leased port is less attractive for shippers of container cargoes because it is 256 nautical miles away from Colombo, the capital of Sri Lanka. However, from a geographical viewpoint, Sri Lanka has strategic advantages to attract T/S cargoes from the mega carriers serving Europe and East Asia and the ports in countries along the Indian

Ocean, e.g., India, Myanmar, Bangladesh, Pakistan. According to the first author's interview with mega carriers serving these ports in August 2017, they considered a frequency reduction in services calling Indian ports and a replacement with feeder services between Sri Lanka and India. In particular, it may cause the coastal ports in India to lose their competitive edge against Colombo/Hambantato ports (Chen and Yang, 2019) This inter-port competition is becoming fierce owing to short sea shipping development policy in Sri Lanka (Ruan et al., 2019), see sub-section 4.2 on the value of short-sea shipping (SSS). In addition, China-Pakistan Economic Corridors (CPEC) from Kashgar in China to Gwadar Port in Pakistan may create T/S cargoes to and from Sri Lanka. Two or three industrial economic zones are to be developed along the CPEC. Gwadar Port has the function of free trade zone, which is a favorable location in association with an international airport to attracts overseas production lines, assembly activities, warehousing, and packaging functions with foreign direct investment. This development contributes to generating container cargoes in association with the gateway role of Gwadar Port (Shibasaki et al., 2019). The two ports in Sri Lanka have good connections with African ports. Having said that, we can propose an LDC in Sri Lanka dealing with T/S cargoes for the Indian Ocean and Africa.

3.3. The Middle East

The United Arab Emirates, and Dubai in particular, are an ideal location for an LDC given the location's potential to produce and/or assemble localized products for Eastern Europe and African and Middle East markets, thereby lowering transport and warehousing costs, and mitigating risks from manpower mobility and resources caused by COVID-19 (Lau et al., 2020) and decoupling and trade conflicts between China and US, by moving resources and production lines from China. These are multi-dimensional roles of a global LDC or logistics hub for China's economy. Ports such as Dubai are located at the crossroads of the Far East-Europe trade route and shorter trade routes between India/Pakistan, East Africa and the Persian Gulf. Furthermore, Dubai has developed an intermediacy role in long-distance intermodal transport by combining airfreight services with deep-sea container services. In addition, the gradual development of southern routing alternatives for China-Europe rail services (i.e., the all-land route via Teheran in Iran to Istanbul in Turkey, and the rail corridor crossing Azerbaijan with a maritime section across the Caspian Sea) can, in the longer term, present additional opportunities for increased global rail connectivity for ports in the Persian Gulf (Iran in particular). Figure 7 shows the conceptual idea on the role of Dubai.



Source: own compilation of by authors.
Notes: Yellow line, red line, and blue lines mean CR Express, air and set network services.

Figure 7. Establishing global LDC by sea-rail-air connectivity along the B&R.

3.4. *Northern Oceania*

The global maritime network analysis method (Hu et al., 2021) shows that Australia is connected with 5,295 ports in the world and has 24,530 pairs of connections between the country and the world ports when considering all types of goods. Most container ships serving Australia call multiple ports either on the east coast downward or west coast downward in association with extended services to/from New Zealand (See Figure 8). Darwin Port has been leased to China for 99 years[4]. The port is among the top 10 ports in Australia in volume terms, but at present only plays a modest role in accommodating global container flows. An interview with the port[5] revealed that the port plans to construct container terminals with a logistics distripark adjacent to the port, which will play a role in providing feeder services along the coast lines of Australia and New Zealand. Major shipping lines such as COSCO and Maersk Line provide multiple calling services for Australia and New Zealand. As a result, it may cause not only end-users to face high logistics costs but also ship operators to bear high operating costs. SSS is a competitive and environmentally friendly transport alternative to rail transport in Australia. Darwin Port can develop into a potential transshipment hub port with an LDC so that feeder services, i.e., SSS, are linked to coastal ports. It can be attractive for the carriers to

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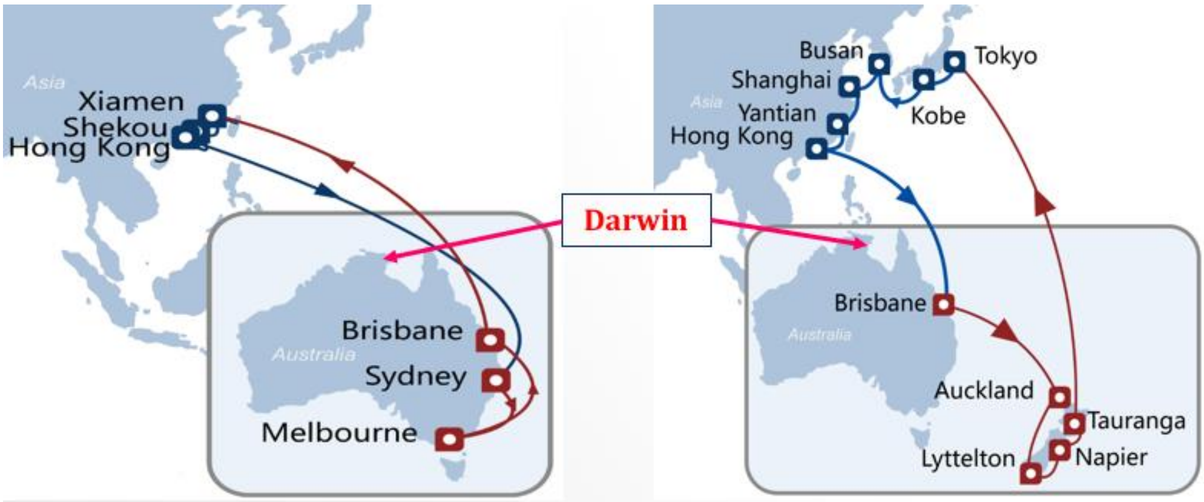
[4] Owing to recent political conflict between China and Australia, the Australian Federal Government has forced the Northern State Government to cancel the lease agreement.

[5] The first author had an interview with the port authority in Darwin in April, 2017. Recent conflicts between China and Australia have caused uncertainty about the port development which was planned with the Chinese investor.

use the port transshipment hub port to replace their existing services so that they can lower operating costs and have more flexibility in their fleet deployment strategies.



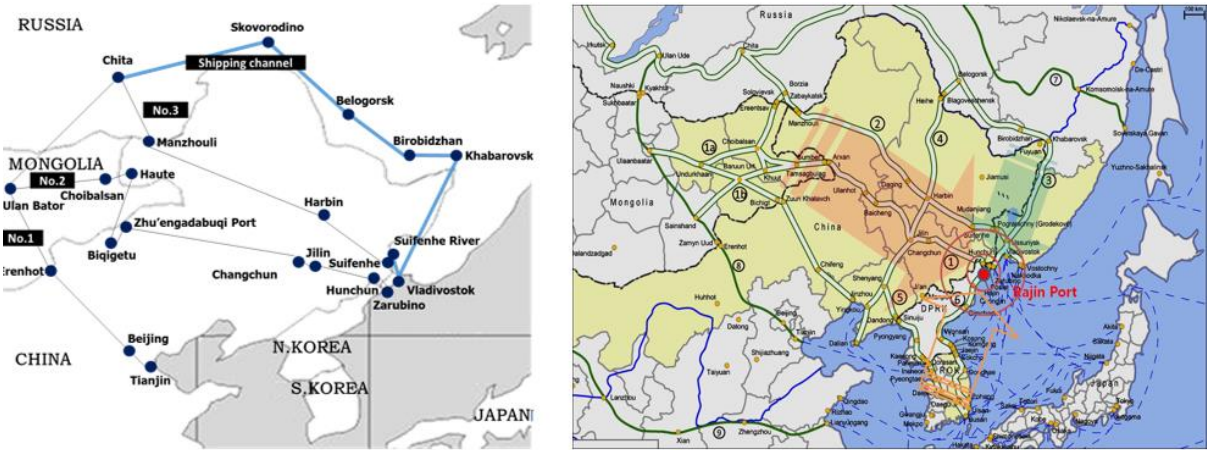
Source: COSCO (2021).

Figure 8. COSCO's multiple callings in Australia and New Zealand.

Darwin Port as T/S relaying hub port for New Zealand can also serve Indonesian trade in a competitive way because Indonesia has lengthy corridors connecting Belawan, Batam, Tanjung Priok, Surabaya, Makasar, and Sorong ports from the west and east, which causes high sea freight costs. For example, the sea freight rate per TEU from Tanjung Priok in Jakarta to Belawan and Sorong is US$ 400 and US$2000 as of 2012, respectively. Therefore, considering China's South-South trade routes (Figure 5(a)), Darwin Port has the potential to develop into a transshipment and relay hub port to cover some islands of Indonesia as well as Papua New Guinea connecting the Pacific islands. Container cargoes associated with Indonesian international trade rely on ports in Singapore and Malaysia. To lower the dependency on Singapore, the Indonesian government proposed "Pendulum Nusantara's Main and Sub-corridor Development in Indonesia" and "Indonesian international hub port plan" (Lino, 2012; Nur et al., 2018). Darwin Port in combination with a global LDC could present a competitive port value proposition to the proposed ports in Indonesia and existing reliance of Indonesia on intermediate hubs in Singapore and Malaysia. In addition, China may join the pendulum service route in Indonesia to leverage the control of Singapore in collaboration with Malaysia. This line of thought is part of the future research agenda of Chinese shipping companies in tandem with the strategic development of one or more global LDCs in the region.

3.5. Northeast Asia

Northeast Asia can be considered as a good location for LDC development because the Northeast corridor and belt (China, Mongolia and the Russia Economic Corridor/Heilongjiang Silk Road Belt) is one of the economic and transport corridors in the BRI, see Figure A2. The Greater Tumen Initiative (GTI) proposed by the United Nations Development Programme (UNDP) is similar to the routes in the NE corridor and belt as shown in Figure 9.



Source: GTI (2015), Rajin (DPRK) – Khasan (Russia) Railway and Port Study Project: Preliminary Forecast on Transport Volumes and Shipping Costs at Pacific End of Tumen Transport Corridor, Beijing: Greater Tumen Initiative, p.12.

Figure 9. Similarities between GTI (1990) and NE Corridor and Belt in BRI (2013).

The GTI aims to promote international trade in Northeast Asia, among others, by developing railways in Rajin (North Korea) and Khasan (Russia), and seaports in Rajin and Zarubino (Russia). The Eurasia Initiative (EI) proposed by the South Korean government in 2012 aims to expand the infrastructure of trust in Eurasia, in particular, extending South Korea’s freight and gas energy transportation across Eurasia and to promote logistics and Eurasian intermodal transport networks (Ministry of Foreign Affairs of Republic of Korea, 2016). Therefore, if the GTI, the BRI and the EI are efficiently integrated, the three initiatives in Northeast Asia will accelerate to achieve their common aims. The corridors in the BRI and the GTI are also closely related to the EI. Currently, container cargoes from South Korea and Japan are carried by sea to Russian ports and then are transported to Central Asia and Europe by the Trans-Siberian Railway (TSR). Some container cargoes from South Korea are transported to Chinese ports, e.g., Qingdao, Lianyungang, where they are carried by Trans-China railway (TCR). The rail connection between North and South Korea, the so-called Trans-Korean Railway (TKR), is part of the national agenda of the South Korean government but it has been halted due to international politics. The realization of TKR would open up opportunities to the three provinces in north-eastern China, i.e., Liaoning, Jilin and Heilongjiang, to serve hinterland locations in the Korean peninsula by rail. Having considered

TCR, TSR, and TKR in tandem with the three initiatives, we can propose a strategic LDC in Northeast Asia. The Sea-rail routing alternative using TCR and TSR can develop into an important route for international trade of South Korea and Japan and would increase supply chain resilience in case of disruptions along the Malacca Strait and Suez Canal route (e.g., the six days of the Suez Canal blockage in March 2021 caused by the running aground of the mega container ship *Ever Given*). The further development of a 'triple track' transportation system (i.e., new Maritime Silk Road, CR Express and Polar Silk Road) along the B&R between China and the rest of the world supports the creation of sustainable global networks in tandem with the proposed global LDC for China's economy.

3.6. Southern Europe

The gradual shift of the world's economic center of gravity from the Atlantic basin to Asia and the economic development of south, central and east European hinterland regions have created new logistics opportunities for South European seaports. North Adriatic ports (Venice, Trieste, Koper), Marseille in Southern France, Barcelona in Spain and North Italian ports (Genoa, Vado Ligure, La Spezia and Livorno) are positioning themselves as southern gateways to the European economic heartland. Their strategies are supported by massive port and hinterland infrastructure investments and the rolling out of inland corridor concepts. At the other side of the spectrum, southern Europe has witnessed the development of new transshipment hubs since the mid-1990s located at strategic maritime locations in the Med. These hubs have been inserted as an intermediate port of calls on Asia-Europe liner services. Examples include Algeciras at the Straits of Gibraltar, Gioia Tauro and Taranto in Italy, and Marsaxlokk in Malta. Valencia combines its role as a major gateway to the Spanish hinterland with substantial transshipment flows (Notteboom et al., 2019).

The 21st Century Maritime Silk Road (MSR) of the BRI has given an extra impetus to Med ports. While Venice historically played a vital role in Silk Road trade, other Med ports have so far been the main beneficiaries of the BRI. In the past decade, Chinese investors have taken shareholdings in gateway terminals at the ports of Marseilles (France), Vado Ligure (Italy) and Ambarli (Turkey) and in the mixed gateway/transshipment port of Valencia (Spain). The take-over of the majority shareholding of Piraeus port in Greece by COSCO Shipping Ports in 2016 is the most visible strategic move of Chinese interests in the Med. COSCO obtained a terminal concession in Piraeus in 2009, but was able to significantly increase its grip on Piraeus in the context of the privatisation of Greek ports. After the arrival of COSCO, container throughput at the port increased significantly from 0.83 million TEU in 2009 (no. 17 in Europe) to 5.65 million TEU in 2019 (4th largest container port in Europe; Notteboom, 2019), which demonstrates the importance of Piraeus as a major maritime node in the MSR. The strategic plan for Piraeus foresees a terminal capacity increase to reach about 10 million TEU by the end of this decade. While the transshipment incidence of Piraeus port exceeds 80%, Chinese investors are assisting in hinterland corridor development through rail infrastructure investments to connect to North Macedonia, the Balkan region, Hungary and further into Slovakia, the Czech Republic and Germany. The strong position of Piraeus in the regional maritime network in the Med combined with intensified efforts to improve the port's hinterland connectivity, makes Greece and the wider Balkan region an interesting LDC location for accessing central and eastern Europe, the Black Sea Area and coastal regions in east and central Med.

3.7. Northern Europe – the Le Havre-Hamburg range

Despite the rise of Med ports, the Le Havre-Hamburg range remains the dominant port region in Europe, handling about 47 million TEU in 2019 or 43% of total European container port traffic. The positions of the top three European container ports (i.e., Rotterdam, Antwerp and Hamburg) remain undisputed. These top 3 ports in Europe handled 35.9 million TEU in 2019 or about a third of total European container traffic. Rotterdam and Antwerp have shown strong growth (+ 45% for Antwerp between 2007 and 2019 and +37% for Rotterdam), while Hamburg's box volume is still below its record volume of 9.9 million TEU realized in 2007.

From a BRI perspective, northwest Europe remains an important market located at the end of both the China-Europe rail corridors and the east-west maritime route. China-Europe trade flows destined for this area can use the CR Express services (mainly focused on inland port Duisburg in Germany, about 200km east of Rotterdam and Antwerp) or rely on the MSR to call at the major seaports in the area. In the past 15 years, Chinese terminal operators COSCO Shipping Ports and China Merchants Holding have acquired minority shareholding positions in large container terminals in Antwerp (Antwerp Gateway terminal), Rotterdam (Euromax terminal), Le Havre (Port 2000) and more recently also in Hamburg (Tollerort terminal).

In late 2017, COSCO Shipping Ports took over the main container terminal facility in the port of Zeebrugge (Belgium), thereby for the first time acquiring full control of a container terminal in the region. This single transaction potentially has much wider ramifications than the rather modest presence of Chinese companies in other ports of this important container port market. The Zeebrugge move also marked the start of a stronger involvement of Chinese interests in the development of logistics activities in the port area and initiated an active Chinese-led corridor strategy to serve core European hinterland areas such as the Ruhr area in Germany. The development of the spearhead terminal in Zeebrugge, combined with a minority presence in other key terminals in the region and a future presence in the inland port of Duisburg (see Sub-section 3.8) constitute the foundation for a more structural LDC development from China's perspective, which complements similar initiatives in southern Europe (i.e., Piraeus and a number of gateway ports in Spain, Italy and France).

3.8. Dry hub ports along the Silk Road Economic Belt

Next to port investments, China has also invested in dry hub ports, such as the Great Stone in Minsk, Belarus to facilitate entry to the European hinterland (Figure A4). Duisport (i.e., the management company of the inland port of Duisburg), intermodal operator Hupac and COSCO Shipping Logistics are building Europe's largest inland container terminal to tap into CR Express rail volumes. In 2020, around 30% of all rail-based trade between China and Europe ran through the port of Duisburg. The 'Duisburg Gateway Terminal' will be opened in 2022 with the capability of handling 12 trains and three inland barges at the same time (www.duisport.be).

The land transport service by CR Express is also linked to China's warehouses in free trade zones in Lithuania (Lee, 2018). Lithuania is a member of EU so that once Chinese products are transported to the country, the products need no more customs clearance within the EU region. Border control services between Belarus and Lithuania take 30 minutes, i.e., the so-called "Shuttle Train Viking" service. Lithuania is well connected to the EU by well-established railway and road systems. Klaipeda Port in Lithuania where COSCO shipping services are available with a container terminal under construction by China Merchants Holdings is a gateway for cargoes coming to and from the Scandinavian Peninsula (Figure A4).

Figure 10 (a and b) summarizes the proposed global LDCs along the New MSR and Silk Road Economic Belt, i.e., Belt and Road.

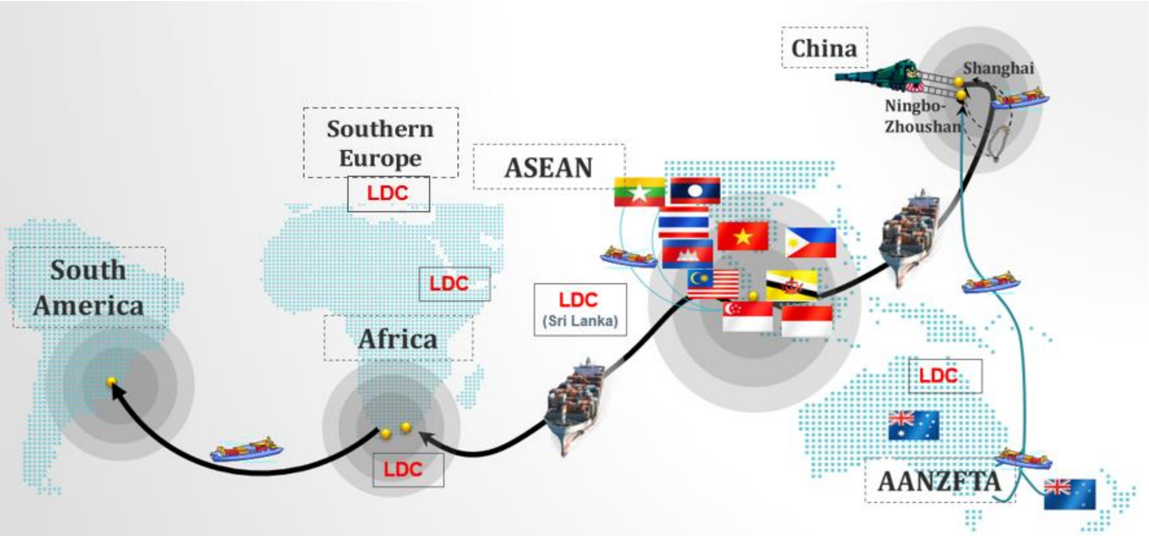


Figure 10(a). Proposed LDCs along New MSR.

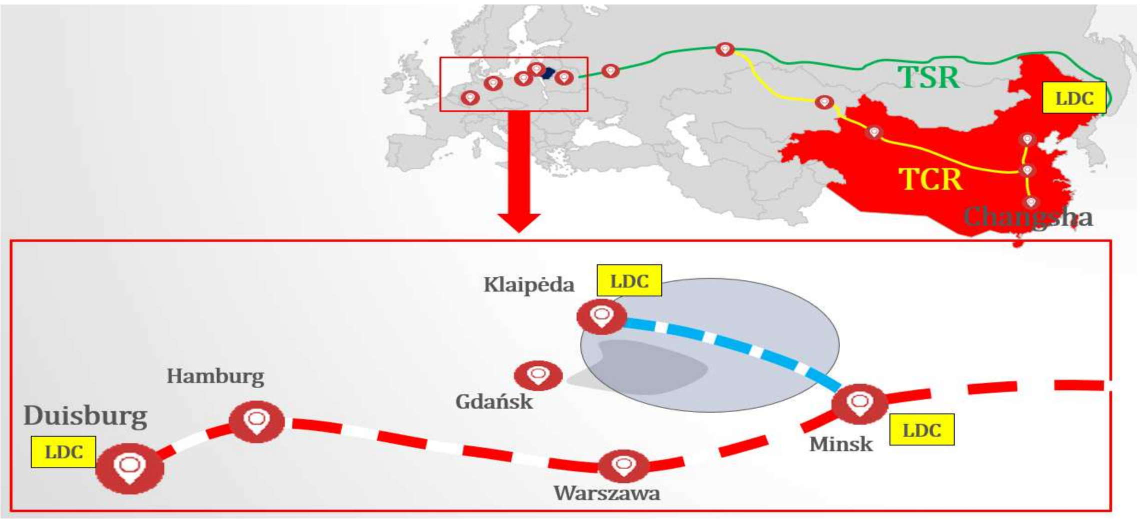
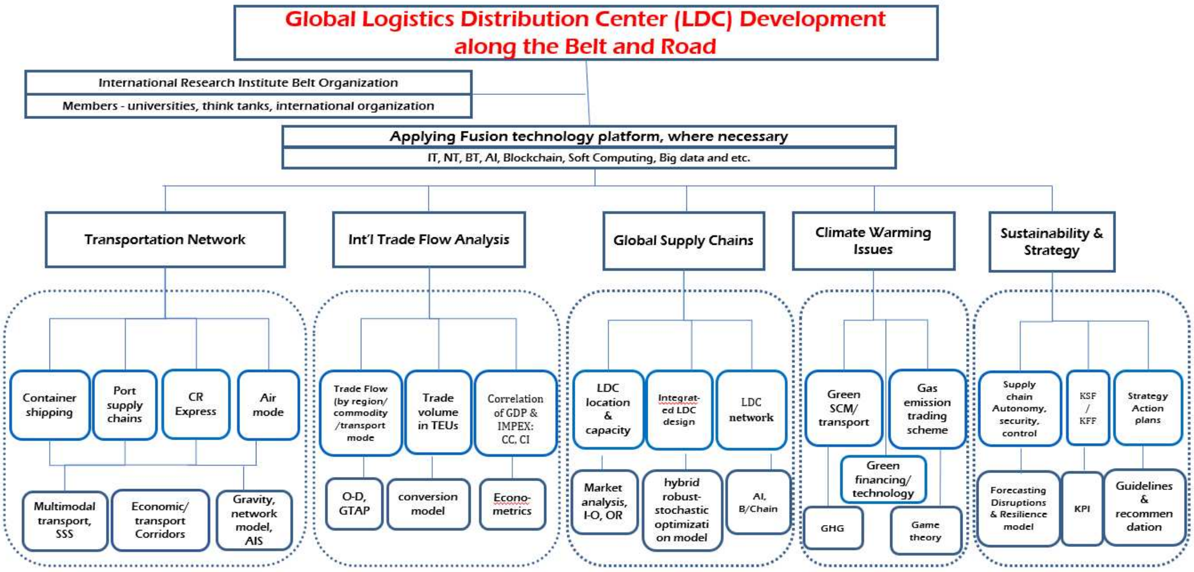


Figure 10(b). Proposed LDCs along Silk Road Economic Belt.

A complex set of decision factors guides the establishment of strategic LDCs. We have considered port supply chains with special attention for specific factors, i.e. the presence of Chinese companies with berth/terminal control power, existing container shipping line service in tandem with Chinese shipping service lines, CR Express service connections, China's regional economic blocks and regional market accessibility. Based on this explorative analysis, we have proposed three strategic LDCs along the SREB, while five more located along the new MSR, as shown in Figure 10. However, the number of locations of strategic LDCs could be flexible subject to additional factors stakeholders might consider.

4. Discussions and research agenda

This paper proposed eight strategic locations of LDCs based on maritime networks and China's overseas port development performance, China's engagement in South-South trade with FTAs and regional economic blocks (Figure 10). The proposed locations have not been validated by empirical tests. Instead, this paper proposes a research agenda with applicable methods to investigate their optimal locations in future studies. Figure 11 shows five research topics under the main theme of global LDC development: transport network, international trade flow analysis, global supply chains, the green issue, and strategy and sustainability. Global LDC development resulting from the interaction between the five research topics will need to be supported by a *fusion technology platform* comprising of big data, artificial intelligence (AI), and combinations of information technology, bio-technology, nano-technology, 5G, and other supporting technologies. Each research topic has sub-topics as shown in the sub-diagrams of Figure 11.



Source: Lee (2020).

Figure 11. Research agenda for developing global LDC along the Belt and Road.

4.1. The Need for Forecasting international trade structures and cargo volumes in weight and TEUs

Forecasting international trade, cargo type, volume in weight, and TEU between China and the regions having the LDCs is a prerequisite to design optimal capacity of global LDC in each region. The evolution of container volumes in the world is affected by a wide array of factors such as international trade patterns and structures, trade patterns in the hinterland, infrastructure development, developments in network connectivity and accessibility, port governance and central government's policy[6]. Most transport and logistics literature dealing with the BRI did not consider international trade patterns and structures. The GTAP model can be used to draw commodity types and trade values between China and a certain region (Lee, et al., 2011; Lee and Lee, 2011; Lee and Lee, 2012; Lee et al., 2013). Arguing that trade forecasts in existing literature are presented in trade value and seaborne trade forecasts are "mainly based on econometric analysis with historical time series data and business as usual assumption" (Lee and Lee, 2011, p. 172). Lee and Lee (Flynn Consulting, 2009) developed "the conversion model"[7] from trade value to container volume in TEUs, using the case of South Africa. The trade value is forecasted by global trade application project (GTAP) and is converted into container volume in TEUs, mapping HS codes between GTAP and UN COMTRADE, which has weight data. HS codes help to understand international trade cargo types. Figures 12 and 13 show the mechanism behind the conversion model.

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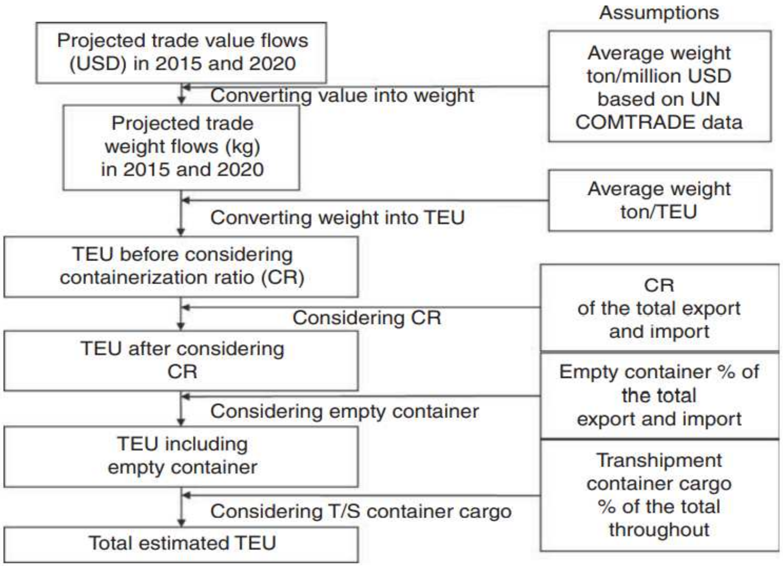
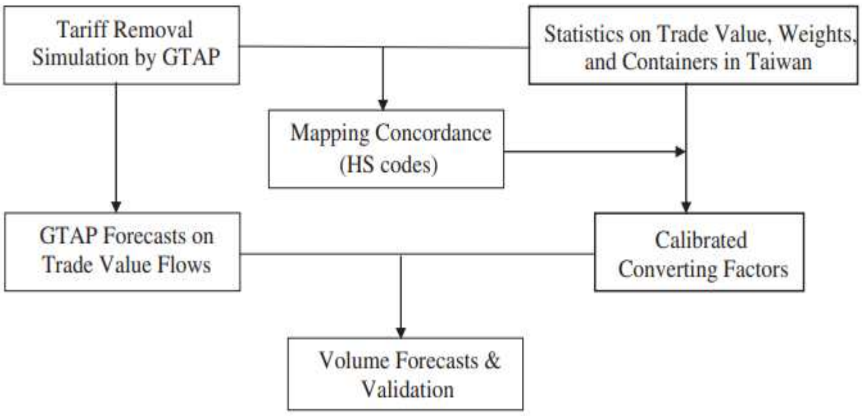
[6] Lee and Flynn (2011) investigated the structural changes in the top 25 world top container ports, the "Asian Port Doctrine" and in particular contributed to exploring the causes of remarkable growth of Asian container ports.

[7] On the details of how to convert the trade value flow into container trade volume in TEU, see Lee (2016), pp. 44-47. On the application cases of the conversion model, see Lee, Wu, Lee (2011), Lee and Lee (2011), Lee and Lee (2012), Lee, Lee and Chen (2012), Cheong and Jo (2013), Lee, Lee and Yang (2013), and Cheong and Suthiwartnarueput (2015).



Source: Lee (2016), Vol.1 p. 48.

Figure 12. Conversion model from forecasted trade value to container volume in TEU.



Source: Lee (2016), Vol.1, p. 48.

Figure 13. Conversion model reflecting shocks.

The conversion model was applied for decision-making for port investment and fleet deployment and to investigate the impacts of the FTA with tariff changes and the trade liberalization on trade volumes (Lee et al., 2011; Lee and Lee, 2011; Lee and Lee, 2012; Lee et al., 2012; Cheong and Jo, 2013; Lee et al., 2013; Cheong and Suthiwartnarueput, 2015). The conversion model can also capture the weight of the forecasted trade volume, which is helpful for the managers of platform companies to arrange block train services because block train service is regulated by the numbers of wagons and the total weight of carried cargoes. The conversion model categorizes container cargoes into containerized cargo, containerizable cargoes, and interlining cargoes.

4.2. Revisit the value of short sea shipping (SSS) for activating Global LDCs

SSS was extensively studied in Europe since the 1990s under the Common EU Maritime Transport Policy. Its economic, environmental, safety, and efficient aspects in association with intermodal transport are well recognized by literature (e.g., Pallis, 2017; Christodoulou and Woxenius, 2019). Many of the proposed locations for global LDCs provide great opportunities to develop or revitalise SSS by connecting hub ports to smaller coastal and upstream ports. Most small coastal ports in the east and west of the sub-Saharan region face some level of port congestion. For example, an LDC in South Africa that receives cargoes from carriers from Asia might need to deliver these to coastal ports in the sub-Saharan region using SSS, next to relaying part of the cargoes to South America. In addition, Considering China's infrastructure investments in ports, railways, highway/roads and the vicinity to the Suez Canal, we can consider alternative locations in Northeast Africa for an LDC to serve central African countries in SSR with partial coverage of Middle East countries, e.g., Mombasa and Djibouti (Gekara and Nguyen, 2020). Dar es Salaam can be another alternative because it is "a key hub port in the multimodal transport network in Africa in terms of global centrality" (Zhou et al, 2021, p.16). Australia and New Zealand receive multiple calls by major carriers such as COSCO and Maersk Line. If Darwin Port becomes the home for a global LDC, then SSS will be required to connect to coastal ports in Australia and New Zealand, and parts of Indonesia. As discussed above, Colombo/Hambantato ports are rising as a potential T/S hub port in the Indian Ocean. This is another demand for SSS in tandem with potential global LDC location. Moreover, some cargoes generated from South Korea and Japan which are bound for Central Asia and Europe are first carried to Chinese and Russian ports and then are connected to TCR and TSR. This is a kind of sea-rail combined transportation system in Northeast Asia (Lim et al., 2017; Lee et al., 2018c). Having considered the above, we need to revisit the value of SSS to investigate its strategic value for LDC development in the relevant regions from the perspective of economic, environmental, and risk management.

4.3. Mitigating disruptions of global supply chains through LDCs

The LDCs proposed in this paper contribute to mitigating disruptions in global supply chains. Such disruptions impose different impacts on the LDCs. For example, the Suez Canal blockage in late March 2021 significantly impacted vessel and cargo flows on the Asia-Europe maritime trade route. The resulting congestion and delays put additional pressure on existing contractual and operational arrangements between the actors in global supply chains. More resilient global supply chains can be partly accomplished by developing alternative routes such as the Arctic routes (Northern Sea Route and Northwest Passage), the China-Europe Railway Express along the SREB, and the southern maritime route via the Cape of Good Hope.

The COVID-19 pandemic disrupted the mobility of resources and humans in association with intermodal transportation, therey negatively affecting production and assembly lines, such as in the automotive and electronics industries (Kwon 2020). The irregular sequence of demand

and supply shocks caused by the pandemic disrupted production and consumption patterns across the world, with far reaching effects on the supply/demand balance in shipping and ports (Notteboom et al., 2021). Most countries faced several (local) infection waves with associated lockdown arrangements, resulting in a highly unstable and diffcult context for global supply chains and international shipping. To cope with the uncertainties in global supply chains, the resilience of the global logistics network (Chowdhury et al., 2021) should be increasingly important in the post-COVID-19 era. Risk management in global logistics should be a "new normal" (Choi, 2021) to be faced in the long run.The inventory function of the LDC can mitigate the shortage of supplies in a region. China has been facing a decoupling issue owing to trade conflicts with the US. On top of that, international manufacturing lines are leaving China. Therefore, China needs to diversify the locations of the production lines. Some can be transferred to LDC locations along the Belt and Road. For example, the industrial economic zone adjacent to Gwadar Port along the CPEC and the LDC in South Africa can not only save transportation time from China but also improve the international competitive edge of this supply chain option with favorable production costs. In particular, the LDC in South Africa can cover the west and east coast of the Sub-Saharan region (SSR) by feeder service, while land transport corridors can be used to connect to land-locked countries. Kim et al. (2018) support the role of the LDC in South Africa, investigating transshipment flows in SSR in association with main trunk routes from Europe and Asia. Moreover, the LDC can develop container relay services to South America, which helps China's shipping companies shorten ships' turnaround times and consequently save capital and operation costs. This research agenda is also related to designing integrated global LDCs along the B&R in Sub-section 4.5.

4.4. Establishing a Global Research Belt along B&R

Investigating and analyzing optimal locations of LDCs and their feasibility constitute a "global research agenda" because function, capacity, and management of LDCs are inextricably interwoven with global supply chains, intermodal transport, regional and international trade, and data collection from regional and international bodies. In particular, the scope and contents of the research and the required data are vast. In addition, regional legal and economic systems and regional data cannot be properly collected and analyzed without the participation of local scholars in the regions where LDCs are to be established. The topic of LDCs requires multidisciplinary approaches covering economic, geo-political and managerial aspects. Such a global research agenda should be conducted by a global research team. Therefore, it is suggested to establish a "Global Research Belt" along the B&R and in potential LDC locations, comprising of representative government think-tanks and research centers, and international organizations.

4.5. Designing integrated global LDCs along the B&R

When designing sustainable LDCs along the B&R, researchers and decision-makers need to consider potential disruptions in facilities and multimodal transport networks and the associated supply chain resilience, environmental effects and emissions, and the implications on total logistics costs. This sub-section deals with disruptions in LDC facilities. The studies of Snyder and Daskin (2005) and Chen et al. (2011) are based on the assumption that facilities in networks are totally out of service under disruption and give the same disruption probability to them. The risk-aversion models designed by Medal et al. (2014) and Hernandez et al. (2014) relaxed the above assumption (Liberatore et al., 2012) and focused on the recovery time of disabled facilities. As the number of disruption scenarios increases, the complexity of computation increases. To overcome this weakness, Jabbarzadeh et al. (2016) proposed a hybrid robust-stochastic optimization model while considering the uncertainty of supply and demand and shipping products from reliable facilities to unreliable facilities. However, the model did not consider the service lead time, which is critical in global supply chain networks. Having considered the above, the multiple LDCs proposed in this paper, which are located in different countries, may cause service lead time issues. In addition, as global supply chains connecting China to multiple LDCs along the B&R are vulnerable owing to disruptions caused by natural and human-made disasters, terrorism, and political turmoil, the fortification and resilience of LDCs is also a critical issue in the proposed research agenda for establishing optimal LDCs. This issue is interrelated to Sub-section 4.3 above. The risk-related parameters and probabilities of disruption in different locations are other factors to be considered when designing optimal LDCs. To achieve this, the risk evaluation in each LDC location needs to be preceded by the gathering of market and operational information from local experts through questionnaires and interviews. Furthermore, a stochastic approach for optimal LDCs along the B&R is helpful to deal with the uncertainty of supply and demand parameters. The various scenarios are also to be designed to ensure that the global LDCs network works under emergency conditions. In designing integrated global LDCs along the B&R, an analysis of diffusion trends and characteristics of firms is necessary to be associated with the multimodal transportation network formed between LDCs along the B&R (Jiang et al, 2021).

4.6. AI and Blockchain application for the LDCs network

As stakeholders in global supply chains and LDCs, such as suppliers, manufacturers, transporters, and logistics providers, are geographically dispersed, the complexity of the network increases and information sharing and stakeholder interactions become critical. This is also interrelated to the transparency, security, and efficiency of global chain networks. Blockchain networks in association with big data enable all the stakeholders and customers to deal with the above issues because they promote cybersecurity and network transparency.

Recent studies address not only advantages and benefits to supply chains when applying blockchain technology, but also elaborate on the actors' roles in its implementation (e.g., Wang, Han, Beynon-Davies, 2019; Wang and Singgih et al., 2019; Wang, Chen, Zghari-Sales, 2020; Chang et al., 2020; Pournader et al., 2020). There is room to further develop empirical evidence about the performance of blockchain solutions in global supply chains with LDCs. Existing literature still lacks empirical studies that evaluate the performance of blockchain networks and present a standardized framework on how to design blockchain networks in a supply chain setting. In designing blockchain networks for LDCs proposed in this paper, the vision of how blockchain supports the challenges in the global supply chain has to be determined. Next, the scope of its application has to be clearly defined to test and to assess its performance in the context of the proposed LDCs. Furthermore, the stakeholders in the networks need to engage in information sharing in order to guarantee transparency in relation to the operations and performance of global LDCs.

Blockchain networks will be more effective with Internet of things (IoT) and artificial intelligence (AI). These technologies can assist in detecting any disruption within LDCs and along the transport networks well in advance before it happens and in proposing appropriate solutions based on contingency plans. As LDCs along B&R are widely distributed, they are susceptible to global or regional disruptions. As the complexity of global supply chains increases, it becomes increasingly difficult for humans to detect disruptions or any patterns that might cause damage to the performance in real time. AI and blockchain could be applied to detect possible disruptions earlier and to find alternative solutions to minimize the impact.

4.7. Securing autonomy, security and control for intermodal transportation networks with LDCs

On 24 March 2021, M/V Ever Given, a 20,000-TEU container ship ran aground in the Suez Canal, resulting in a 6-day blockage of the canal. Nearly 400 ships and billions of dollars of goods trade occurred delays while a few handfuls of ships decided to sail via the longer Cape route. This maritime accident raised awareness about the significant impacts that disruptions/incidents in chokepoints[8] along the B&R can cause.

Intermodal transportation networks can be disrupted by many causes such as piracy at sea, natural disasters (e.g., earthquakes, typhoons, Tsunami), terrorist attacks, territorial disputes, and maritime accidents in canals. Having considered the strategic value of Global LDCs for China's economy and national security, China needs to identify chokepoints and bottlenecks along the B&R. Figure 14 shows 11 chokepoints in red circles along the New MSR and Polar Silk Road and four bottlenecks in yellow circles along the Belt.

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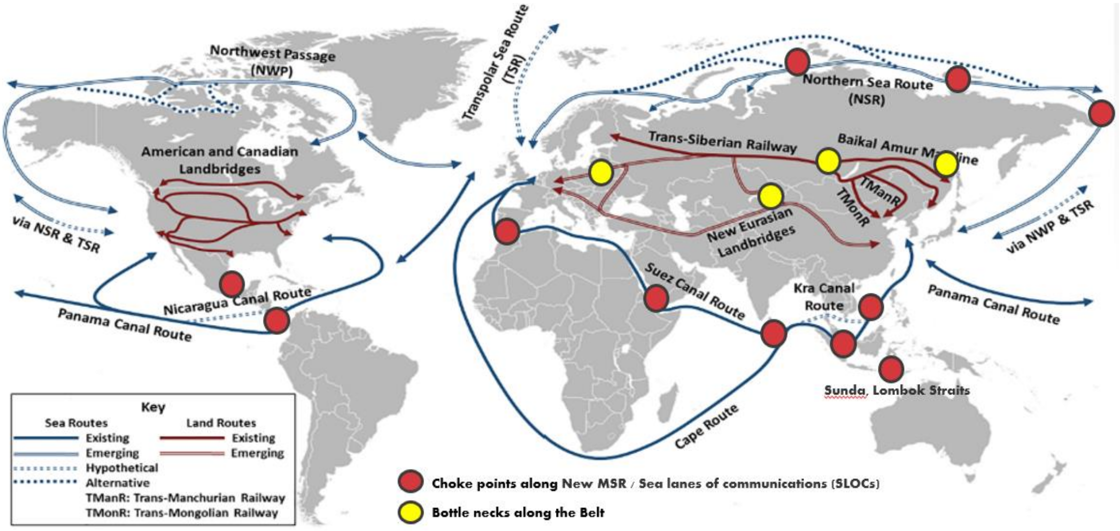
[8] Choke points have been well addressed in "sea of lanes communication" (SLOCs) in existing literature.



Source: adapted from Theocharis et al. (2018).

Figure 14. Choke points and bottlenecks along the B&R.

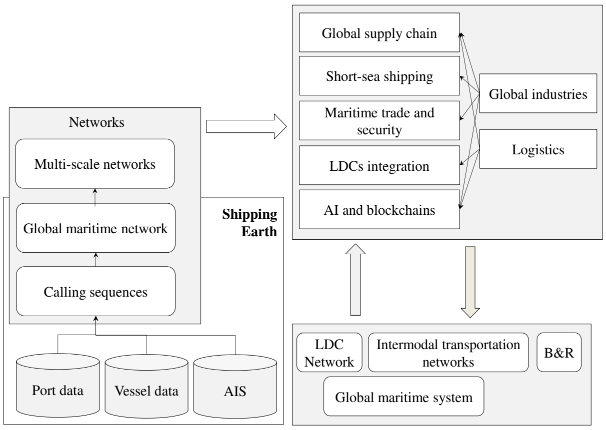
For example, the sea-rail route is an alternative trade route for international trade of South Korea. The strategic value of TCR and TSR is clear when faced with a major disruption at the Malacca Strait or the Suez Canal. The proposed 'triple track' approach of the transportation system (i.e., new Maritime Silk Road, CR Express, and Polar Silk Road) along the B&R between China (Zeng et al., 2020) and the rest of the world plays a crucial role in providing sustainable global networks in tandem with the proposed global LDC for China's economy.

Since 2013, the Chinese government has highlighted the importance of "core technology" in the manufacturing industry. The core technology is called "卡脖子" in Chinese, "*qia bo zi*". Owing to trade conflicts between China and the US, and the growing decoupling and protectionism in high-technologies, the Chinese government has further emphasized the significance of "*qia bo zi*" to Chinese manufacturing industry since 2020, recognizing that the Chinese economy could not establish supply chain autonomy, supply chain security and supply chain control (*供应链自主可控, gongyinglian-zizhu-kegong* in Chinese) in the globalized economy without overcoming "*qia bo zi*". Therefore, President Xi has been encouraging all the stakeholders in his government, research institutes, and universities to develop core technology in the manufacturing industry. The concept of such "qiabozi" can be applied to the intermodal transportation networks in association with global LDCs proposed in this paper. It can be regarded as choke points in sea lanes of communication (SLOCs), although it has been widely addressed from the viewpoints of ocean law and naval military in tandem with maritime trade (e.g., Yamazaki, 2018). China needs to identify the choke points and bottlenecks along the B&R, i.e., China's port supply chains, locations of LDCs, CR Express routes and secure autonomy, security and control in the context of intermodal transportation, international logistics, global supply chains. In addition, China needs to establish contingency plans subject to potential disruptions, which are to be caused by terrorist attacks, natural disasters, accidents in all transport routes available for China. In addition, China needs to keep up national merchant fleets and facilities of CR Express services and cultivate and train human power in transportation and logistics. In building up a Global Research Belt, China should make an effort to deepen software knowledge of pricing including cross-subsidization, port governance and port development policy (Lee and Flynn, 2011; Lee and Lam, 2017), political-driven perspective in association with overseas investment (Chen et al., 2021), and cross-cultural aspects related to LDCs beyond infrastructure investment along the B&R.

4.8. Systematic framework development for LDCs using Automated Information System (AIS)

Following forecasting of trade volume in TEUs as discussed in Sub-section 4.1, global maritime network (GMN) analysis is a core issue not only because it is closely related to multimodal transportation network, but also because the share of containerized and containerizable cargo in global trade cargoes is more than 90%. In addition, as shown in Figure 11, the GMN analysis is also intertwined with international flow analysis, locations and capacity of LDCs, and emission issues linked to ship movements among maritime ports in association with LDCs.

As part of the research agenda, this paper proposes a systematic framework using AIS data as a base for LDC studies as shown in Figure 15.

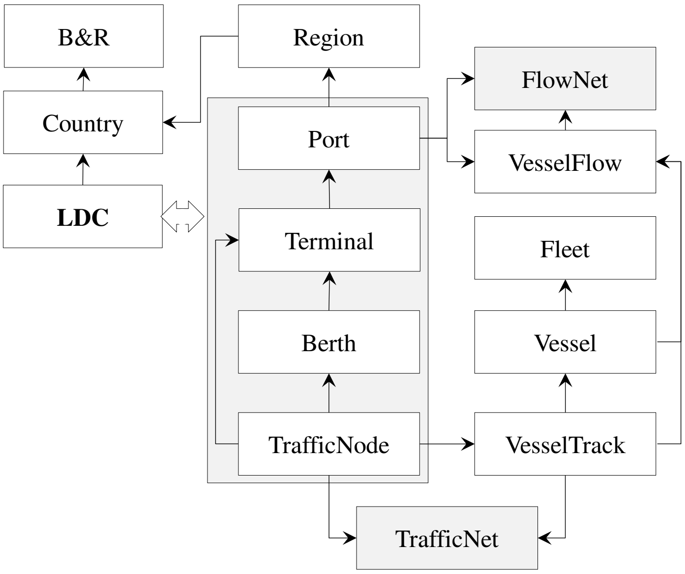


Note: authors modified the framework in Figure 5 in Hu et al. (2020) and in Figure 2 in Hu et al. (2021, p. 470).

Figure 15. A systematic framework for LDCs studies along the B&R using AIS data.

Lee et al. (2018a) and Hu et al. (2020a) developed three modules as a two-level framework. First, the *Shipping Earth* data system collects the data on ports, vessels, and vessel tracking data. Second, GMN is constructed as a base for slicing various sub-networks with different scales (e.g., terminal and port levels and regional and national levels). Third, in the GMN analysis module, typical scenarios are investigated by constructing analysing methods for specific maritime networks by incorporating additional data. In the context of LDCs, this paper considers the B&R, and intermodal transportation networks that interact with the maritime networks. As indicated in the framework, using these data-driven networks, we can investigate global supply chains (Hu et al., 2020a; Hu, 2020), short-sea shipping, maritime trade, and security, and even discuss the impacts of advanced technologies (e.g., AI and blockchain) on logistics and global industries. In the systematic framework proposed in Figure 15, the relations among the entities are essential for analysing their impacts on LDC design and development. These entities include maritime traffic nodes, berths, terminals, ports, regions, LDCs, and the countries along the B&R.

In Figure 16, an arrow between two different entities represents the belonging relation between them.



	Dataset = (LDC, Country, Region, Port, Terminal, Berth, TrafficNode, Fleet, Vessel, VesselTrack, VesselFlow, FlowNet, TrafficNet)
(1)	Country=(ID,Name)
(2)	Region=(ID, Name,CountryID)
(3)	Port=(ID, Name, RegionID, Latitude, Longitude)
(4)	LDC=(ID,RegionID,PortID,Name)
(5)	Terminal=(ID, PortID, Latitude, Longitude)
(6)	Berth=(ID, PortID,TerminalID, Latitude, Longitude)
(7)	TrafficNode=(ID, Latitude, Longitude)
(8)	Fleet=(ID, Name)
(9)	Vessel=(ID, Name, FleetID, Tonnage)
(10)	VesselTrack=(VesselID, FromNodeID, ToNodeID)
(11)	VesselFlow=(VesselID, DeparturePortID, ArrivalPortID)
(12)	FlowNet=(OrignPortID, DestinationPortID, Tonnage)
(13)	TrafficNet=(FromTrafficNodeID, ToTrafficNodeID, Distance)

Note: authors modified Figure 3 in Hu et al. (2021, p. 471).

Figure 16. Relations among various entities coupling maritime data and LDCs.

For example, a terminal generally belongs to a port. These hierarchical relations give a way of feature reduction and extensive modelling in data-driven analysis (Hu, 2019; Hu et al., 2020b). In this study, an LDC is generally combined with a logistics facility, e.g., a container terminal or port. So, the logistics function of an LDC can be delegated by such facilities. The complicated and large-scale maritime network, therefore, can be reduced to an LDC network because an LDC belongs to a region or country. By the same reduction method, the impacts of relations between nations on LDC design and development can be investigated by specific maritime networks by incorporating additional data on LDCs, countries, and B&R.

In the devised frameworks above, we use the data of more than 300,000 vessels' AIS tracks and 6,000 maritime ports to construct a global maritime network. A vessel's track of its positions recorded in AIS can be processed as a calling sequence of maritime ports. By this process, we can obtain the port calling sequences of all vessels. Within these vessels, only about two out of three can have port calling sequences. Here, *N* is a set of maritime ports in the global maritime network; E is a set of connections among ports. We can generate E by analyzing the calling sequences. As described above, various data sources are considered in the proposed framework. We tailored a dataset with 13 parts for the demonstrations, as denoted in the right part of Figure 16. The structures of the 13 parts are further represented by their key properties. Besides the *ID*s, some properties of the entities are given, e.g., Name, Latitude, and Longitude. A typical analysis on LDCs can be conducted by using these data and relations (Hu et al., 2021).

The data system described above can cover the relations between LDCs and various entities, including cargo vessel flows, berths, terminals, ports, regions, countries, and the B&R. These data-driven relations benefit the locations and designs of the LDC networks. Furthermore, the impacts of these entities on LDCs can be investigated through mutual data-driven interactions.

5. Conclusion

Since the inception of the Belt and Road Initiative in 2013, China has been investing in transport infrastructures along the Belt and Road. This development contributes to promoting connectivity and accessibility of intermodal transport for the regional and global economy. This paper has proposed eight strategic location sets for global logistics distribution centers (LDCs) along the B&R from China's perspective, focusing on container cargoes. Their locations have been proposed by considering the global maritime network, China's port supply chain created through overseas port investment, China's led regional economic blocks in association with international economic associations, international trade patterns and cargo flows. One set of LDC locations are linked to dry hub ports served by China Rail Express, i.e., Duisburg, Minsk, Lithuania, and Northeast China. The seven remaining locations for global LDCs are identified in the Sub-Saharan region (South Africa in particular), the Middle East (Dubai), Northern Oceania (Darwin port), Northeast Asia, Southern Europe (Piraeus and a number of gateway ports), Northern Europe (the Le Havre-Hamburg Range with specific focus on Zeebrugge) and Sri Lanka (Colombo and Hambantota ports). The function of each LDC is subject to the regional market and economic situation and international trade pattern. The main role of LDCs is similar to logistics distriparks and free trade/industrial zones in tandem with the global or regional distribution of freight. The latter may contribute to regional economic development in association with the transfer of production lines from China and other economies. The former contributes to the sustainability of global supply chains passing through the global freight network and the accessibility to regional and international markets. The strategic value of global LDCs along the B&R is high given mounting disruptions in global supply chains, the restricted mobility of manpower caused by health, economic and natural crises, and the decoupling caused by trade conflicts between China and the US. Global LDCs may play a key role as places where intermediacy and centrality are combined to serve the globalized economy via international logistics and intermodal transportation along the B&R.

Although this paper discussed key factors affecting the locations of LDCs, it has not employed sound quantitative methodologies to determine the 'optimal' locations. Instead, the LDCs proposed in this paper are the outcome of an explorative analysis following a Chinese strategic perspective. Therefore, this paper has presented a major research agenda and a set of methodological approaches aimed at further quantifying and substantiating the strategic value added and locations of global LDCs in the context of B&R. First, forecasting trade volume in TEU among trading partners with the proposed locations is necessary to estimate, among others, the required capacity of LDCs, fleet capacity and infrastructure investment. The conversion model is helpful to achieve this as it allows to convert trade values to trade volumes expressed in container boxes, in association with GTAP and input-output model. Second, further research is needed to analyze the value and operational imperatives of short sea shipping as a transport mode that guarantees maritime links between global LDCs and maritime access points in local and regional markets. For example, LDCs in South Africa, Darwin, and Sri Lanka can connect to seaports along nearby coastlines through the development of regional hub-feeder networks, in view of lowering logistics costs, operating time and freight costs for the mega carriers, and reduce emissions. Third, LDCs can mitigate disruptions in global supply chains through smart use of their warehousing, inventory, packaging, and assembly functions. CR Express services in association with LDCs located inland provide another option to mitigate any potential disruptions in maritime chokepoints such as the Suez Canal and the Malacca Straits. Fourth, as the number and complexity of possible disruptions increase, a hybrid robust-stochastic optimization model is to be considered to deal with the uncertainty of supply and demand and freight transport from reliable facilities to unreliable facilities or among LDCs, which are located in different countries. Fifth, having considered several stakeholders of global supply chains and transparency and security of data among them, AI and blockchain technology is to be applied for LDCs. Potential disruptions and barriers to data sharing may be obstacles in securing autonomy, security and control of intermodal transportation networks with LDCs. Referring to the chokepoints and bottlenecks in the global freight transport system (Figure 14), contingency plans and proactive measures are to be studied by applying AI and by information sharing among the LDCs and stakeholders in global supply chains.

Further studies on the optimal locations of LDCs along the B&R thus require a solid global research agenda supported by sound academic approaches and methodologies (Section 4 and Figure 11). The emerging challenges linked to the establishment of global LDCs cannot be efficiently addressed by a single research unit or a single country. A global multidisciplinary research team should be formed to jointly embark on the global research agenda journey. Therefore, it is recommended to establish a so-called ”Global Research Belt” comprising of universities and think tanks along the B&R.

This paper dealt with container cargoes for locating strategic LDCs and, therefore, has not considered the opportunities for dealing with crude oil, LNG, breakbulk cargo and dry bulk commodities at the LDCs. The global energy transition makes energy supply chains an important issue in the context of the BRI from the perspective of the Chinese economy. Considering the dependence of China on energy, the significance of energy for the Chinese economy, and security risks in the Malacca Strait (Rimmer and Lee, 2007), a future study is to look into energy supply chains comprising of LNG and crude oil along B&R from the viewpoint of China. Future studies on global LDCs can explore key success factors as well as pitfalls in their establishment and operation and introduce key performance indicators of global LDCs using insights from operations research and management science. Such studies would provide decision-makers with a solid decision-support system for the strategic planning of LDCs in terms of capacity and facilities.

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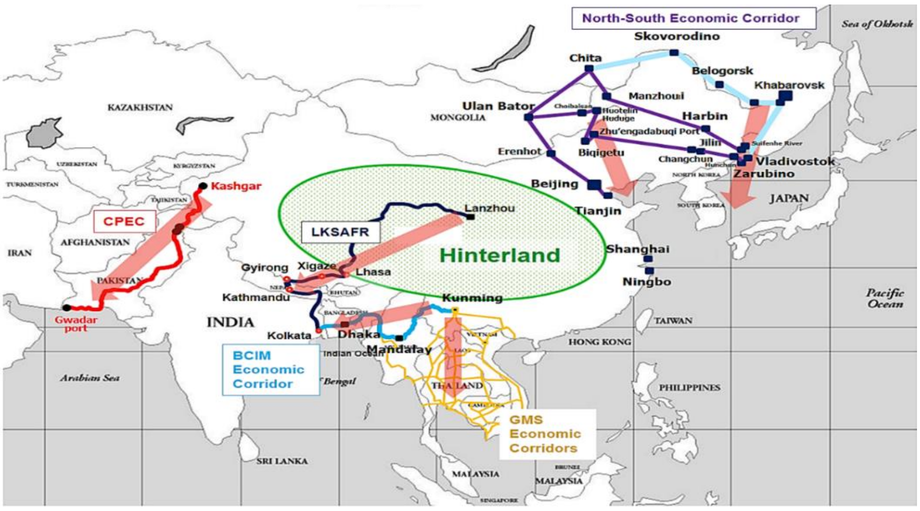
Appendix: Figures and Tables

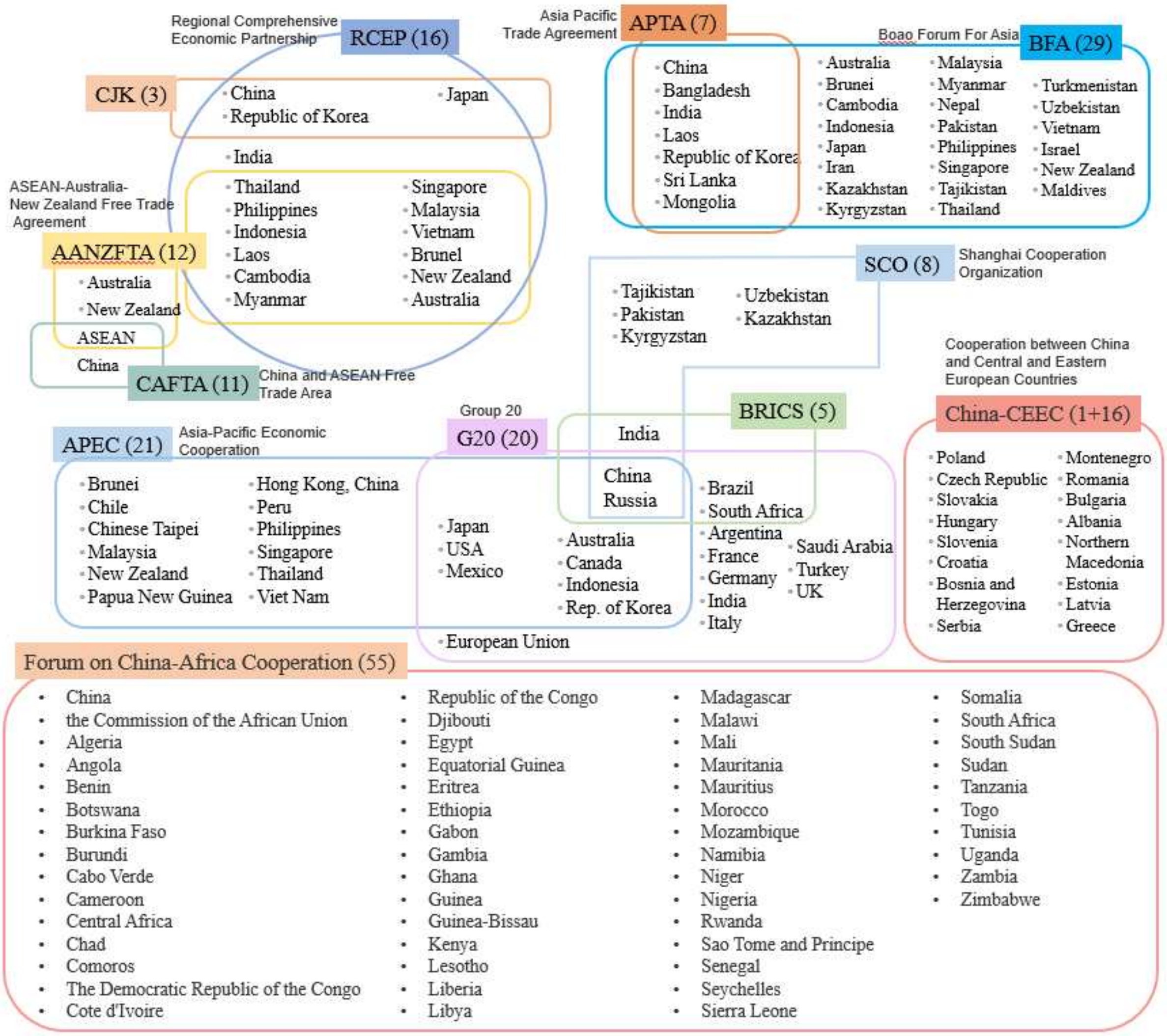
Source: Lee (2016). This map was reproduced in Lee et al. (2018), p. 191.
Notes: Blue dot line indicates 21st Century Maritime Silk Road (MSR). Red and Yellow dot lines are an expansion of the MSR, a so-called the New MSR.

Figure A1. New Maritime Silk Road.



Source: Lee (2016). This map was reproduced in Lee et al. (2018), p. 293.

Figure A2. Summary of economic and transport corridors in the BRI.



Source: compiled by authors.

Note: Lithuania withdrew her membership from CEEC in May 2021.

Figure A3. China's regional economic blocks and associated international organizations.

Source: Klaipeda Port, Lithuania (2018).

Figure A4. Great Stone Industrial Park in Minsk.

Table A1. China's current Free Trade Agreements (FTAs) and FTAs under negotiation.

China's Free Trade Agreements	Free Trade Agreements under Negotiation
• Regional Comprehensive Economic Partnership (RCEP) • China-Cambodia FTA • China-Mauritius FTA • China-Maldives FTA • China-Georgia FTA • China-Australia FTA • China-Korea FTA • China-Switzerland FTA • China-Iceland FTA • China-Costa Rica FTA • China-Peru FTA • China-Singapore FTA • China-New Zealand FTA (including upgrade) • China-Chile FTA • China-Pakistan FTA • China-ASEAN FTA • Mainland and Hong Kong Closer Economic and Partnership Arrangement • Mainland and Macao Closer Economic and Partnership Arrangement • China-ASEAN FTA Upgrade • China-Chile FTA Upgrade • China-Singapore FTA Upgrade • China-Pakistan FTA second phase	• China-GCC (Gulf Cooperation Council) FTA • China-Japan-Korea FTA • China-Sri Lanka FTA • China-Israel FTA • China-Norway FTA • China-Moldova FTA • China-Panama FTA • China-Korea FTA second phase • China-Palestine FTA • China-Peru FTA Upgrade

Source: compiled by authors.

Table A2. Chinese overseas port investment around the world.

Region	Huo et al. (2019)	Chen et al. (2019)	Clarksons (2020)	Authors (2021)
Asia				
ASEAN		Brunei: Muara	Brunei: Muara	Brunei: Muara
		Indonesia: Jambi		
		Malaysia: MCKIP, Kuantan, Melaka Gateway	Malaysia: Kuantan	Malaysia: Kuantan
	Myanmar: Kyaukpyu	Myanmar: Kyaukpyu, Maday,		
	Singapore: Cosco-PSA	Singapore: Cosco-PSA, Pasir Panjang	Singapore: Singapore	Singapore: Cosco-PSA, Pasir Panjang
	Vietnam: VICP	Vietnam: VICP, Vung Tau Container Terminal	Vietnam: Tra Vinh Province Coastal Seaport	
				Philippines：Davao
Rest of Asia		Israel: Southern Port of Ashdod, Haifa		
		Pakistan: Gwadar, Qasim	Pakistan: Gwadar	Pakistan: Gwadar
				Saudi Arabia: Jeddah Islamic
	Saudi Arabia: Jeddah Islamic	Saudi Arabia: Jeddah Islamic		
	South Korea: Busan	South Korea: Busan		South Korea: Busan
	Sri Lanka: Colombo, Hambantota, CICT	Sri Lanka: Hambantota, CICT, Colombo	Sri Lanka: Hambantota, Colombo	Sri Lanka: Hambantota, Colombo
	Turkey: Kumport	Turkey: Kumport	Turkey: Kumport	Turkey: Kumport
	U.A.E.: Abu Dhabi Khalifa	U.A.E.: Abu Dhabi Khalifa	U.A.E.: Abu Dhabi Khalifa	U.A.E.: Abu Dhabi Khalifa
				Bangladesh: Payra
				Qatar: Doha

Europe	Belgium: Antwerp, Zeebrugge	Belgium: Antwerp, Zeebrugge		Belgium: Zeebrugge
	Greece: Piraeus	Greece: Piraeus	Greece: Piraeus	Greece: Piraeus
	Italy: Reefer Terminal S.P.A, Vado Ligure	Italy: Naples, Reefer Terminal S.P.A, Vado Ligure	Italy: Vado Ligure	
	Netherlands: Rotterdam, Euromax	Netherlands: Rotterdam, Euromax		Netherlands: Rotterdam
	Russia: Zarubino	Russia: Zarubino		
	Spain: Noatum	Spain: Noatum		Spain: Noatum
			Ukraine: Chornomorsk	Ukraine: Nikolayev, Odessa, Ilyichevsk
				France: Marseille
				Latvia: Riga
Africa				
SSR	Nigeria: Lagos, TICT	Nigeria: TICT		
				Angola: Lobito, Luanda
		Guinea: Boke		
	Djibouti: Djibouti	Djibouti: Djibouti	Djibouti: Djibouti	Djibouti: Doraleh, Djibouti
			Cameroon: Kribi	
		Namibia: Walvis Bay	Namibia: Walvis Bay	Namibia: WalvisBay
		Mauritania: Friendship Port	Mauritania: Nouadhibou	
				Ivory Coast: Abidjan
		Sudan: Sudan Port		Sudan: Sudan
	Tanzania: Bagamoyo	Tanzania: Bagamoyo		Tanzania: Bagamoyo, Dar es salaam
				Congo: Pointe noire

				Mozambique: Beira
	Togo: Lome Container Terminal	Togo: Lome Container Terminal		
				Ghana: Tema
				Guinea：Conakry
Non-SSR	Egypt: Suez Canal	Egypt: Said (East), Ain Sukhna, Suez Canal		
				Algeria: Cherchell
				Madagascar: Tamatave
Oceania	Australia: Newcastle	Australia: Newcastle		Australia: Melbourne, Darwin, Newcastle
South America	Brazil: TCP	Brazil: TCP		Brazil: Sao luiz de maranhao
				Ecuador: Posorja
				Venezuela: Moron
	Peru: Chancay	Peru: Chancay		Peru: Chancay
				Chile: San Antonio
Others				Panama: Margaret Island
				Panama: Colon
				Mexico: Tuxpan
				Bahamas: Abaco Islands

Sources: Huo et al.(2018); Chen et al. (2019); Clarkson (2020); and Asian Investment Infrastructure Bank (2021).
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Table A3. Current status in BRI project progress in Transportation sector in Africa, 2013-2020.

Region	Transportation Sector	No. of Project (Total 91)	Completed	U/C	Contract	MOU	S/C
Non-SSR	**Seaport**	3	0	3	0	0	0
	Airport	0	0	0	0	0	0
	Railway	1	0	0	1	0	0
	Road/Highway	0	0	0	0	0	0
SSR	**Seaport**	16	5	5	6	0	1
	Airport	9	3	2	3	1	0
	Railway	17	4	6	5	2	0
	Road/Highway	45	7	11	23	4	0

Source: compiled by authors based on Clarkson Research, London (2020).
Note: SSR means sub-Saharan region.

Table A4. Seaport projects in completion and under construction by country in Africa, 2013-2020.

Country	Seaport Project Name	Completed project	Project U/C
Algeria	El Hamdania Port Development		1
Egypt	Sokhna Port - Basin 2 Container Terminal Development		2
	Sokhna Port & Damietta Port Expansion		
Angola	Caio Deepwater Port Development		1
Cameroon	Kribi Deep Sea Port Ph.2		1
Djibouti	Djibouti Damerjog Industries Development - Livestock Terminal	3	
	Djibouti Multipurpose Terminal Ph.1		
	Djibouti Port Equity Acquisition		
Ghana	Tema Terminal 3 (Phases 1-2) Development		1
Ivory Coast	Abidjan Port Expansion		1
Kenya	Mombasa Kipevu Oil Terminal (KOT) Development		1
Namibia	Walvis Bay Port Container Terminal Expansion	1	
Total (9)		**4**	**8**

Source: Clarkson (2020) and Table A2.