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# Systematic optimization of port clusters along the Maritime Silk Road in the context of industry transfer and production capacity constraints

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ABSTRACT

This paper addresses a port cluster problem that considers industry transfer and the capacity constraints along the Maritime Silk Road (MSR). A method is proposed based on hub and spoke network model and spatial competition model to determine the equilibrium port supply and manufacturing scale along the MSR. The model is simplified into a nonlinear one by converting objective functions into constraints. The numerical analyses indicate that Jawahalal Nehru Port and Singapore Port will be still hubs as their current situation with Belt and Road Initiative (BRI), and port cluster growth will benefit both manufacturing industry and social welfare.

## 1. Introduction

The 21st century Maritime Silk Road (MSR) is one of the two most important components of the BRI, which aims to strengthen the cooperation priorities, including policy coordination among the countries in the region, facilities connectivity, unimpeded trade, financial integration and people-to-people bonds (State Information Center, 2017a) in the region. In the context of the BRI, financial support will be offered to promote investment and trade in the region through financing platforms (PRC State Council, 2016). For example, as of June of 2017, the total investment amount of the Silk Road Fund alone has reached 6 billion US dollars and covers many countries along the BRI region (State Information Center, 2017b). The financial support of these financing platforms also improves the transport infrastructure (PRC State Council, 2016). For example, on December 12th of 2016, Asian Infrastructure Investment Bank (AIIB) claimed the loan for Oman, a country along the MSR, to construct the port infrastructure of Dukum (AIIB, 2016). Additionally, in the context of the MSR, other policies and various political and international trade agreement decisions could also induce changes in the logistics and transport-related activity over time (Sheu and Kundu, 2017). Resulting from these pushing factors under the BRI, numerous large-scale port projects have emerged along the MSR (Table 1).

These newly invested ports may increase regional accessibility and further the economic and transport advantages of the isolated regions along the MSR, enhancing the development of manufacturing in these regions and enabling international industry transfer (Chen and Yang, 2017). For example, China and Germany jointly invested 400-million USD to construct the Dera Gazi Khan cement plant, which will be the largest cement plant in Pakistan. In Sylhet in the southeast of Bangladesh, a salad fertilizer plant, the largest fertilizer plant in Bangladesh, was constructed by China. Moreover, industrial parks along the MSR (such as the Vietnam Longjiang Industrial Park and the Thailand Industrial Park of Thai-China Rayong Industrial Park) have also been showing rapid development.

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**Table 1**
Port projects along the MSR with Chinese investors.
Source: Based on online sources.

| Country | Port Project | Company | Shareholding | Year |
|---|---|---|---|---|
| Netherlands | Rotterdam | COSCO | 47.50% | 2016 |
| Sri Lanka | Colombo | CMHI | 85% | 2011 |
| | Hambantota | CMHI | 64.98% | 2014 |
| Djibouti | Djibouti | China Merchants | 23.50% | 2012 |
| Israel | Haifa | Shanghai Port | Franchise | 2015 |
| Panama | Panama | Land bridge Group | Franchise | 2016 |
| Pakistan | Gwadar | COSCO | Land use rights | 2015 |
| Italy | Puerto Vallo | COSCO | 40% | 2015 |
| | Naples | COSCO | 50%% | – |
| United Arab Emirates | Caliph | COSCO | Joint operation | 2016 |
| Singapore | Singapore | COSCO | 49% | 2016 |
| Malaysia | Guantan | Beibu Gulf Port Group | 40% | – |
| Myanmar | Madeleine Island | Petro China Co Ltd. | 50.90% | – |
| Egypt | Said | COSCO | 20% | – |
| | Egypt | ChEC | – | 2015 |
| | Damietta | ChEC | – | 2015 |
| Belgium | Antwerp Port | COSCO | 25% | 2004 |
| | Zeebrugge | Shanghai Port | 25% | 2014 |
| France | Terminal Link | China CMHI | 49% | 2013 |
| Turkey | Istanbul | CMHI COSCO | 65% | 2015 |
| Greece | Equity transfer | COSCO | 69% | 2016 |

Hence, ports cluster along the MSR shall further expand their capacities to meet the increased demands induced by the relocated manufacturing along the MSR. The interaction between the manufacturing growth and the expansion of port clusters along the MSR will reach a temporary equilibrium after a period of time. Under equilibrium, port and manufacturing industries are unwilling to further increase their scales (Chen and Yang, 2017) as they are unable to gain more profit through regrowth and further marginal port and industry investments. Therefore, the investment and construction of port cluster should be studied considering the manufacturing relocation and the interaction between the manufacturing and port clusters.

Additionally, the manufacturing scale in a site is limited by the supply of a few key production factors: land and labour. When the labour demand from manufacturing exceeds the upper bound of the supply under a certain salary, based on the Lewis turning point (Watanabe, 1994; Ranis, 2004), wages rise quickly at the point where the labour supply cannot match the demand; hence, excessive expansion of the manufacturing industry can induce increases in the labour costs. In this situation, with the increment in the manufacturing scale, the average cost for producing a unit of product will increase correspondingly; this phenomenon is described as diseconomies of scale (Jin et al., 2006; Lu et al., 2014; Wikipedia, 2017). As a result, when undertaking industrial transfer by improving transport accessibilities (such as building ports), it is essential to consider the upper bound of the production capacity.

In the context of the BRI, there are two potential modes for developing port clusters along the MSR. On one hand, the port enterprise (or private investors) and local governments consider the net profit and local welfare separately (Cheng and Yang, 2017; Wu et al., 2016; Zheng and Negenborn, 2014); these ports will compete with each other with minimal cooperation (De Borger et al., 2008). These characteristics represent the actual situation without the BRI. On the other hand, entities can form a union based on certain organizations (such as the AIIB). In the field, ports invest and develop along the MSR, and the union behaves quite similar to the central government. In this case, the investors want to maximize not only the efficiency of the port cluster by avoiding cut-throat competition (Zheng and Negenborn, 2014) but also the total social welfare (Zheng and Negenborn, 2014, 2017), which may be determined by the export-oriented economy in the involved countries along the MSR. The latter mode can achieve a systematic optimum of port cluster investment, achieve the real purpose of the BRI and realize a win-win case among the isolated countries. In this paper, the optimization of port cluster problem (OPCP) along the MSR from the perspective of systematic optimization is studied in terms of the latter mode from the view of a virtual decision maker, which may be a union or an alliance.

In this paper, our first contribution is to determine the impacts of the BRI on port clusters along the MSR. The second contribution is to develop a model to systematically optimize the growth of port clusters in the context of manufacturing relocation and the production capacity (e.g., land or labour) constraints. The third contribution is to propose a mathematical description to predict the process of manufacturing relocation, and the fourth contribution is to determine the upper bound of the scale of the manufacturing relocation subject to the site production capacity constraint.

The rest of the paper is organized as follows: The second section outlines the relevant literature. The third section develops a systematic optimization of the port cluster model (SOPCM). The fourth section introduces the mathematical deduction and designs an algorithm for the model solution. The fifth section presents an application of the SOPCM and discusses the results based on the ports and zones along the MSR. The final section presents a few concluding remarks.