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Urban intermodal terminals: The entropy maximising facility location problem

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ABSTRACT

An important problem confronting port cities is where and how to accommodate port growth. Larger ships combined with increased container throughput require more yard space and generate more traffic, straining the urban fabric in the vicinity of the port. A promising solution to this problem is the development of urban intermodal container terminals (IMTs) that interface with both road and rail (or possibly inland waterway) networks. This raises two linked choices; where to locate the intermodal terminals and what will be their likely usage by multiple shippers, each having a choice of whether or not to use the IMT as part of an intermodal transport chain. The use of an IMT by a shipper indicates the shipper's choice of intermodal transport, which comprises a combined use of a high capacity mode (rail or barge between the port and the IMT) and trucks (between the IMT and the cargo origin or destination). The overall problem therefore comprises a mode choice problem embedded within a facility location problem. This paper employs the method of entropy maximisation to combine a logit mode choice model with a facility location model, leading to a non-linear mixed integer programming model. The principal features of the entropy maximising facility location model are illustrated by small and large numerical examples.

1. Introduction

The growth in containerised trade in most economies has not been matched with proportionate investment in transport infrastructure between the port and the hinterland. Moreover, the increase in ship size has increased the need for more yard space for the storage, sorting and movement of containers. This has often resulted in congestion and associated safety and environmental problems in and around ports. These problems are compounded for port cities like Sydney close to city centres with limited or no space for expansion. Inefficient port operation increases the cost, travel times and unreliability of delivery times when transporting the cargo from the port to the hinterland and vice versa. Additionally, it can negatively affect a nation's foreign trade and its ability to compete in global markets, since the port is the transit point for the greater part of this trade, at least in terms of volume.

An attractive solution to the above problems is the development of intermodal terminals (IMTs) that interface with both road and rail/barge networks such that containers arriving at the port can be transported by a high capacity mode, such as rail or barge (benefit from economies of scale), to the IMT and then be transferred to trucks for onward movement to the destinations. Also, export containers can first be consolidated at the IMT before being transported to the port by rail or barge for export. This intermodal system is referred to as the import/export intermodal transport system or urban inter-

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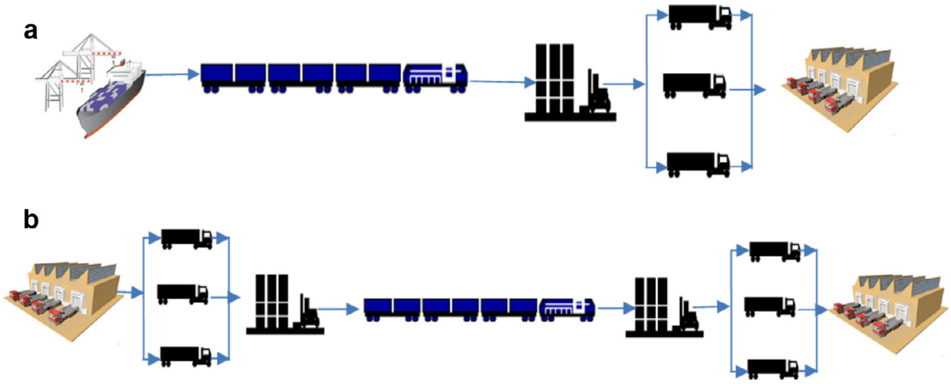

Fig. 1. (a) Urban intermodal transport: import market (export market is the reverse). (b) Regional intermodal transport (not considered in this paper).

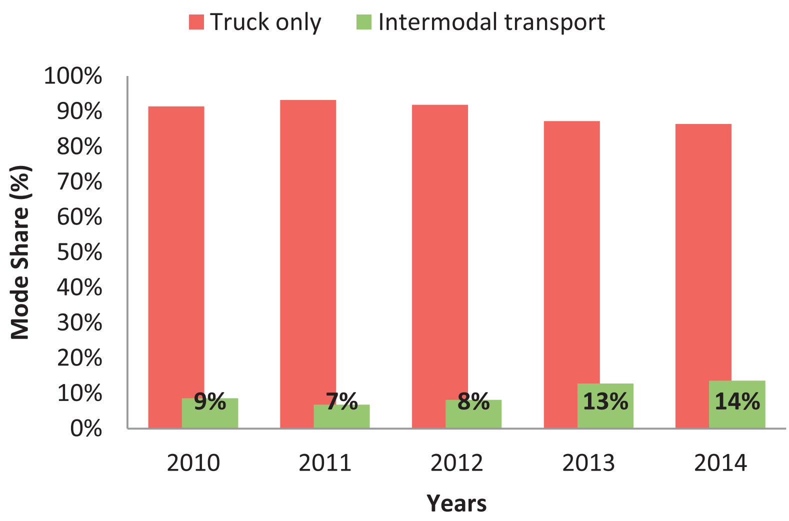

Fig. 2. Mode share in Australia's IMEX markets (Source: data compiled by the authors from http://bitre.gov.au/publications).

modal transport system (UITS) as shown in Fig. 1a (Teye et al., 2015; Meyrick, 2007). Another intermodal transport system identified in the literature (Meyrick, 2007; Arnold et al., 2001) is the regional intermodal transport system (RITS). The RITS involves the use of two IMTs as transfer nodes along the intermodal transport chain (Arnold et al., 2001). In this system, the cargo are first consolidated at an IMT close to the cargo origin using trucks and then transported by a high capacity mode to another terminal close to the cargo destinations where the cargo are finally distributed by trucks to their final destinations, as shown in Fig. 1b. This type of system is the traditional concept of intermodalism where both economies of scale and distance are key drivers for the location and use of the IMTs (Park et al., 1995; NCHPR, 2007; Lin et al., 2014).

The focus of the paper is on developing the UITS and is largely motivated by continuous growth in container throughputs, increased 'lumpiness' of throughputs produced by larger ships, limited physical space for expansion, and lack of inland transport infrastructure connecting the ports and the cargo origins/destinations in the urban region, which often leads to congestion, safety and environmental problems in the vicinity of the port, increased cost, and unreliability of cargo delivery times. The use of one IMT along the intermodal transport chain can go some way to alleviating these problems. Fig. 2 illustrates the market share of intermodal transport mode in Australia's IMEX market over a five year period. It shows that the intermodal mode share rose from about 9% in 2010 to about 14% in 2014.

The key element in the UITS is the locations of the IMTs, which determines its likely usage and in turn its financial viability. This is because an IMT usually has high setup costs and so needs to attract a minimum amount of cargo to make it viable (AHRCR, 2007). An IMT adds another mode of transport (intermodal transport) and hence increases the modal options for shippers. The shippers are expected to choose the mode (intermodal or road alone) that offers them the highest utility given their preferences and the constraints (time availability, reliability, etc.) placed on their decision making. The two main modes under consideration are the road alone transport mode leading to the use of only trucks and intermodal transport mode leading to a combined use of a high capacity mode (e.g., rail or barge) and trucks for delivering