Direct over Indirect Container Transport for ‘Remote’ Areas: A Case for North Queensland?

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Abstract: This paper investigates trade-offs between direct and indirect shipping of overseas containers from East Asia to North Queensland, Australia. Direct shipping is where fully consolidated containers are directly transported to a destination port near which end customers are located; indirect shipping uses hub ports where de-consolidation/consolidation of goods occurs, and then land bridging to end customers in more distant locations. Indirect shipping is common in Australia for coastal locations with less volume. However, recent demographic changes in Queensland make the option of direct shipping, especially for goods from East Asia, more viable. This paper compares the cost, lead time, inventory level and social benefits for these two options. A quantitative case is then presented to illustrate these differences for a typical home appliance commodity. The results indicate that once sufficient freight volume is accumulated direct shipping is beneficial. These changes have significant consequences for Australia’s logistics landscape.

Keywords: Supply chain management, direct shipping, Australia-East Asian freight.

1. INTRODUCTION

Containerization, as an important means to facilitate global trade, has been playing an increasingly important role in Australia. Major ports across Australia have evidenced steady increase of container volume over the years. Figure 1 displays the volume change of containers handled from 1993/94 to 2009/10 for the major Australian ports in terms of millions of TEUs (twenty foot equivalent units). It can be observed that the volumes more than tripled over the 16 years period for all the ports listed except for Melbourne, whose volume increased nearly three times, maintaining its status as the largest container port in Australia.

The increase of the container volume across Australia is closely related to the increasing volume of the nation’s international trade, particularly with three of Australia’s leading trading partners in China, Japan and South Korea. For example, the 5-year trend growth rates of Australian import and export from 2008 to 2013 were reported to be 6.1% and 6.3%, respectively (DFAT, 2014, pp. 7-8). The import growth was driven by the demand for consumer goods from overseas, population and income growth across Australia, which subsequently boosted overall demand, and by declines in Australian manufacturing. Figure 2 depicts the population change from 2001 to 2010 across Australia (SoEC, 2011) showing that certain areas in Australia have experienced rapid population growth over the first decade of the 21st Century. For instance, Perth witnessed a population increase of 30-40%, while Queensland population centres such as Brisbane, Cairns, Townsville and Mackay achieved a
20-30% population growth.

In order to effectively meet demand from various regions, companies deploy supply chain strategies to help plan and manage their supply chains, to meet their customers’ demand in a timely fashion and reduce costs. This can sometimes prove to be difficult for certain regions as a result of low demand (where it is difficult to justify timely distribution or use of high volume transport equipment) or where there is a lack of proper infrastructure. We use the term ‘remote’ to describe such regions although they might not be geographically-remote, per se. With the shift in demographics in remote regions and the concentration of much global manufacturing into key regions in East Asia the possibilities for direct shipping into markets such as North Queensland are becoming stronger, with direct shipping from East Asia already being trialled for small volumes of containers into the Port of Townsville in 2013 and 2014. The key questions these changes pose include how can companies most effectively serve these ‘remote’ areas? What type of shipping mix should be employed as demand patterns change? And what might be the implications for East Asia-Australia freight flows, and the Australian logistics landscape?

Figure 1: Container volume for major Australian ports in 1993/94 and 2009/10 (BITRE, 2011, p102).

Figure 2: Australian population percentage change from 2001 to 2010 (SoEC, 2011)

Due to its geographical features, most consumer goods, as non-bulk commodities, are
transported into Australia by sea via containers. Once they reach the traditional hub ports, they are generally handled by two strategies described in Jula and Leachman (2011). Containers may be shipped inland, by road or rail, straight through to regional distribution centers (RDCs), or they may be unloaded at inventory mixing facilities (logistics centres) and the contents sorted and re-shipped in domestic vehicles to multiple RDCs using a consolidation/de-consolidation strategy (Jula and Leachman, 2011). Of course, both approaches have their respective advantages and disadvantages in terms of cost, lead time, reliability and volume requirement, etc. Variants of these two strategies include alternative ports of entry, alternative landside modes, and alternative groupings of RDCs (Leachman, 2008).

In this paper, we focus on the full container movement from overseas suppliers to end clients. We assume all the freight movements are in containers and we are not considering the last mile distribution problem. Instead our focus is the issue of the choice of port of entry, as illustrated by Figure 3. For example, in North Queensland, the distribution of full containers can be via a hub port such as Port of Brisbane. By this indirect shipping strategy containers are delivered to the Port of Brisbane and then land transported (via rail or via road) north to the final destination as depicted by the red (solid line) arrow in Figure 3. Alternatively, the same containers can be directly shipped to a port that is close to its destination, as indicated by the green (dotted line) arrow in Figure 3, and then forwarded by land transport to its final destination. We refer to transportation via a hub port as ‘indirect shipping’ and the transportation direct to a port near the final destination as ‘direct shipping’ in the rest of the paper.

Figure 3: Indirect versus direct shipping to North Queensland

As an island, Australia’s place in the international economy and its productivity, living standards and quality-of-life largely depend on its trade performance (Infrastructure Australia, 2010a, 2010b). In 2012, the annual growth of total trade through ports in Australia reached 9.8% (Port Australia, 2012). With the rapid growth of trade volume, ports and related landside logistic chains face major challenges managing future volumes. And the decisions of East Asian freight forwarders for supply chain management are likely to have major consequences for the shape and structure of Australia’s logistics landscape, including the fortunes of the existing key hub ports. At the same time, the increasing encroachment of residential and commercial developments near port infrastructure, in part due to gentrification in the major cities, presents a major challenge to the development of port capacity (Infrastructure Australia
From an urban planning perspective, the indirect shipping approach will aggravate the freight burden around the hub ports, particularly in Melbourne, Sydney and Brisbane. Moving away from the indirect shipping to direct shipping would on one side reduce the freight task around the hub ports, and on the other side create new issues as remote ports, including for port infrastructure, freight corridors and the urban community/port interface. Understanding the likely future of direct shipping is important to allow for proper and proactive urban planning to take place. The importance of freight corridor protection has been realized and incorporated into planning guidelines, such as the *Freight Futures* framework in Victoria, Australia, which has emphasized the importance of reserving freight corridors for meeting future freight volume increases (*Freight Futures*, 2008, p. 30) though direct shipping may dramatically curtail those predicted volumes.

To respond to these dilemmas, this paper attempts to investigate the trade-offs between direct and indirect shipping of overseas containers for North Queensland, Australia. Qualitative analysis is first conducted for both shipping strategies in general terms, such as lead time, inventory level, social benefits, and reliability. This is followed by a quantitative investigation for Townsville as a special case, where a particular commodity is modeled across the supply chain. The paper is guided by the following research questions:

1) What are the influencing/driving factors that may produce a shift from indirect to direct shipping?
2) What are the specific urban and inter-urban impacts that may be experienced?
3) What does this mean for the planning and organization of freight and related land uses, particularly within metropolitan regions.

The rest of the paper is organized as follows: Section 2 reviews the relevant literature; Section 3 presents the research methodology that guides the paper; Section 4 qualitatively compares the indirect and direct shipping options, followed by the quantitative measurement of the cost and lead time differences for the special case (Townsville). Section 5 discusses the research findings and concludes the paper.

### 2. LITERATURE REVIEW

Efficient movement of goods is essential for economic growth and development. For freight service users, the determination of freight route and mode selection will imply different logistics and supply chain system costs and service levels. A carefully investigated logistics solution can potentially save companies and organizations on logistics costs and improve the service level. While moving freight is largely a private sector activity, governments can play a vitally important role in planning and developing the freight network. Efficient freight networks can lead to improved logistics performance and efficient traffic management, mitigate road congestion, improve road safety, and boost local, regional, and national attractiveness and competitiveness.

Among the five modes of transport (road, rail, air, sea and pipeline) each has its own advantages and when compared with others, incurs some trade-offs, such as lead time and inventory level, transport cost and service reliability, etc. Which particular mode and more importantly, which particular route would be best for a particular freight task is therefore a complex question. Further, the demand for freight services is changing over time, which consequently requires companies and organizations to periodically review and assess their supply chains. Cullinane and Toy (2000) applied content analysis to the route/mode choice literature and suggested that the five most-often-considered factor categories in the freight route/mode selection literature are cost/price/rate, speed, transit-time reliability, characteristics
of the goods, and service.

In order to make an informed decision on whether to use direct shipping, researchers have developed tools to aid the decision-making process. Caputo et al. (2005) presented a decision-support system that enables the analysis of the cost-effectiveness of direct-shipping long-haul road transport policies, including full truck loads and less-than-full truck loads, and the selection of the optimal carrier. In a similar fashion, albeit for a different mode, Leachman (2008) described an economic optimization model of containerized imports from East Asia to the USA via sea transport. The imports were allocated to various ports and logistics channels in order to minimize the total logistics cost, which includes the transport and inventory costs. The logistics channels investigated included direct shipping of containers via truck or rail, and transloading in the hinterlands of the ports of entry from marine containers into domestic trailers or containers. Jula and Leachman (2011) further employed a mixed-integer non-linear programming model to optimize the supply chains of importers of sea containerized goods from Asia to the USA. The least-cost strategy for an importer was determined in terms of sea and land-based transport and included costs for transport and handling, pipeline inventory, and safety-stock. These authors’ diverse research approaches demonstrate not only methods for comparison between alternative shipping policies, but also how they enable what-if analyses and exploration of the outcomes of alternative decisions.

One particular aspect of transport mode selection is the lead time variability as it directly affects a company’s inventory level. Harrison and Fichtinger (2013) explored the relationship between time-related variables in global ocean transportation networks and the shipper’s inventory management performance. They found that the highest inventory reduction potential comes from a combination of high lead time reliability and improved service frequency.

Addressing the issue of port of entry has significant practical importance. Wan et al. (2013) empirically investigated the impacts of urban road congestion and road capacity expansion on the competition between major container ports in the United States. One finding was the shift to competing rival ports due to more delays on urban roads. The emergence of the dry port concept would be able to at least partially address the road congestion issue, albeit it is not related to this research. [The dry port concept ‘extends’ a seaport to an inland intermodal terminal via the provision of direct rail connection. Roso et al. (2009) suggested that the dry port concept can help identify ways of shifting freight volumes from road to more energy efficient traffic modes that are less harmful to the environment, relieve seaport cities from some congestion and facilitate improved logistics solutions for shippers in the port’s hinterland].

3. METHODOLOGY

In this section, we describe the methodological approach that is used to investigate the proposed research questions. Srivastava (2007) suggested that a combination of various tools and techniques may be useful for the purpose of formulation, approximation, analysis and solution of complex logistics and supply chain problems. Logistics and supply chain problems are complex and can involve many trade-offs. For example, the trade-off between lead time and transport cost, and the trade-off between the reliability of transport service and the safety stock inventory level. Therefore, we accept Srivastava’s (2007) suggestion and adopt a multi-methodological approach, which combines different research methodologies to explore research problems (Singhal and Singhal, 2012a, 2012b).

Figure 4 depicts the general steps involved in the multi-methodological approach that
can be applied to this research. It starts with the process analysis, which is the foundation for qualitative analysis and for determination of data to be collected. Once process maps are finalized and data (parameters) to be collected are determined, logistics and supply chain performance indicators such as the cost, lead time, service level, etc. can be collected (and/or calculated) for both the direct and indirect shipping models. In order to hedge the inaccuracy/unavailability of data, variables can be embedded into the system to allow sensitivity analysis so that better informed decision can be made. Lee and Wu (2014) exemplified that such a multi-methodological approach works well for investigating the sustainability issue in supply networks, where different transport options are available for deployment.

![Diagram](image)

**Figure 4: The general framework for analysis**

### 3.1 Process Mapping

Process mapping is “a valuable communication device to understand how processes operate and where responsibility lies” (Collier and Evans, 2007, p. 273). Accurate process mapping facilitates the identification and recording of related activities and thus ensures that proper qualitative analysis and data collection take place. In supply networks and logistics systems, some changes such as modal switching and network re-design, have long-term system impacts on economic and environmental performance. These cases require careful and thorough analyses of the associated costs, benefits and other key performance indicators. Appropriate process maps are cornerstones in conducting meaningful analyses of such networks and systems.

### 3.2 Variable Determination and Data Collection

Once proper process maps are constructed, it is possible to determine the types of data to be collected, including key variables/parameters. Common data sets to be collected for transport systems include fuel or power consumption (and associated cost), time spent for each step in the process map, etc. While determining the variables, the process map also provides an
opportunity to identify the relationships among variables, and makes it possible to examine the interactions among them.

3.3 Sensitivity Analysis

Sensitivity analysis compensates for the inaccuracies of available data and accommodates the assumptions on unavailable data. It eventually allows decision makers to see the interactions between different variables so that system dynamics can be observed and better understood. In certain circumstances, a slight change in one variable might significantly change the overall system performance, and therefore sensitivity analysis will allow the identification of such variables and ensure that proper action is taken to address such scenarios.

The ultimate objective of sensitivity analysis is to have a comprehensive understanding of the logistics system and supply chain under investigation. A static point of view of logistics systems certainly is not enough and can be misleading for decision makers as the business operating environment is constantly changing over the time.

4. THE QUALITATIVE AND QUANTITATIVE ANALYSIS

This section first conducts a qualitative analysis on the similarities and differences of indirect and direct shipping. Factors such as cost, lead time, transport reliability and inventory level are used to facilitate the comparison and discussion. A quantitative case is then presented using one particular commodity as an example to compare the cost and lead time differences between the two shipping options.

4.1 The Process Maps for Indirect and Direct Shipping

The major steps in the process maps for both indirect and direct shipping are displayed in Figure 5. Generally speaking, for the indirect shipping, containers are transported from overseas ports to the hub port, where the containers are processed by the port, customs and other related government agencies for importation. Once the containers clear these requirements and finish port handling, they are ready to be transported to the final destination. As the hub port is relatively far away from the ultimate clients, both rail and road transport may be considered to fulfill the land-based transport leg. Necessary transload handling, in full containers, is therefore required. In the case of road-based transport, one transload activity is sufficient as trucks can deliver full containers to the ultimate clients. However, in the case of rail-based transport, additional transload activities are needed as it is less common that the ultimate clients are co-located with rail terminals. Road transport will be engaged to manage the transport of containers from the rail terminal to the ultimate clients.
For the direct shipping option, the importation process is the same as the indirect shipping up to the point of port handling. Once the containers are ready to be delivered, they can be directly transported to the ultimate clients using road transport. It should be noted that although ‘road transport’ appears in all three approaches (two for indirect shipping and one for direct shipping) in Figure 5, the distances travelled by these approaches are different. The indirect shipping approach using road-based (not rail) transport will incur the longest road transport, while the other two approaches would result in significantly short road distances as in Australia it is generally safe to assume that both the rail terminal (indirect shipping) and the destination port (direct shipping) are closer to the ultimate clients.

4.2 The Qualitative Analysis

For the ultimate freight service users, the choice between indirect and direct shipping may narrow down to the questions of freight route determination and mode selection. There are various criteria that can be applied to route determination and mode selection, such as cost, speed, frequency, flexibility and many others as listed in Cullinane and Toy (2000). Commonly used selection criteria may include cost, speed (transit time or lead time, also depends on service frequency), quality and reliability. We will discuss both shipping options in regards these aspects.

**Volume:** ‘Volume’ refers to the overall freight service demand at the destination area in this paper’s context. In order to make direct shipping viable, sufficient volume must exist so that shipping companies are willing to provide direct service. This may explain why there are often no direct services for certain ‘remote’ areas in Australia, even though they have ports and related infrastructure capable of handling containers. Of course, as mentioned before, less population and thus less demand may have limited the provision of such direct services as it was difficult to justify the visit of a container ship.

**Cost:** Total logistics cost might be the most direct factor that freight service users will consider when selecting service providers. The most direct cost component out of total logistics cost for both indirect and direct shipping is the transport cost. However, transport cost should never dominate the selection process and logistics and supply chains are complex systems and low transport cost does not necessarily lead to low total logistics cost. For example, if lower transport cost is associated with longer transport time, then the service users must weigh the cost differences between the reduction of transport cost and the increase of pipeline inventory holding cost. For high-value items, additional pipeline inventory holding cost might outweigh the potential savings from a lower cost transport option.
**Frequency:** Service frequency is closely linked to the overall freight volume. One potential advantage of indirect shipping is that it relies on the hub port, which can guarantee frequent services from overseas ports. For direct shipping, it may take a longer time to accumulate enough volume for a direct ship to sail, which reduces service frequency.

**Lead time and its variability:** Technically speaking, direct shipping will have shorter lead times compared with indirect shipping as containers do not need to be shipped down to the hub port and then transported via land bridges. In the case where rail-based transport is used for indirect shipping, there will be more transloading operations, which will increase the lead time. Furthermore, in logistics systems and supply chains, it is common to observe that the more activities in the processes, the more likely that there will be higher variability of the lead time. A direct consequence of higher lead time variability is higher safety stock, which will provide additional inventory holding cost for companies.

**Inventory level:** Inventory is commonly used to fulfill customer demand while waiting for order deliveries and hedge against demand uncertainty. Inventory level will depend on factors such as overall customer demand, order frequency, targeted service level (which will directly impact the safety stock level) and lead time (which will affect the pipeline inventory level). In the context of this research, the inventory level can be directly affected by the service frequency, the lead time and its variability.

**Urban and inter-urban impacts:** Adopting direct shipping will eliminate the need to go through the urban areas around the hub port and hence help address the issues faced by the city-freight-gateway nexus. It will also free up demand for intrastate freight service and therefore allow more productive freight systems.

**Planning and organization of freight and related land uses:** The planning and organization of freight movement in the case of direct shipping will be easier for the ultimate clients. This is enabled by the fact that they will be able to access the containers once they leave the port. Alternative arrangements, such as expediting the container movement, can be managed. In terms of land use planning, it is essential for the governments at state and local level to identify and preserve freight corridors to manage the urban/freight network interface.

Table 1: Summary of the advantages and disadvantages of indirect and direct shipping

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Indirect shipping | • No need to worry about the freight volume  
• More frequent service to hub port |
| | • More handling  
• Longer overall lead time due to extra handling and transport  
• Higher transport time variability  
• Higher inventory level required due to longer lead time and higher variability  
• Exerts more freight pressure at the hub port |
| Direct shipping | • Less handling  
• Shorter overall lead time  
• Lower inventory level  
• Reduces the freight task at the hub port  
• Reduces intrastate freight service demand  
• Easier planning and organization of freight  
• Potentially cheaper transport cost |
| | • Requires sufficient volume to enable the direct service  
• Less frequent service to destination port |

Table 1 summarizes the advantages and disadvantages of indirect versus direct shipping. As noted earlier, key priorities for customers are often cost, frequency, speed (lead time) and the capacity to lower their inventory levels. Overall, direct shipping, if provided, can offer potentially cheaper transport, shorter lead time and hence lower inventory level for ultimate customers. And it will help address the pressure of freight tasks around the hub ports, which is a major concern in Australia’s major cities.
4.3 The Quantitative Case

We present a quantitative case based on a typical commodity in this section to demonstrate the potential cost and lead time differences between indirect and direct shipping. We use household refrigerators as the commodity and assume the destination is Townsville in North Queensland. The following assumptions are made to facilitate the quantitative analysis:

1) Total of 8,000 refrigerators are demanded annually, where each refrigerator is purchased at the price of $600 and shipped from Shanghai, China. This demand is estimated based on the local population, the average household size, and the refrigerator lifetime of eight years.

2) The weekly demand for the refrigerators is 150, based on the annual demand of 8,000 units, with a standard deviation of 30. Note there might be demand seasonality which consequently increases the demand variability. However, higher variability, as demonstrated later, will only favor the direct shipping option.

3) The inventory holding charge rate is $0.20$/year. This inventory holding charge rate varies across different industries, but it is commonly believed to be in the range of 25–55% (Richardson, 1995), i.e, $0.25–0.55$/year.

4) The ultimate clients use 40’ containers and 80 refrigerators can be fitted into each.

5) Direct service is established (this is expected in the near future; there are already services between Townsville and Singapore).

6) There is full container movement (i.e., the containers are delivered through to the ultimate clients’ facilities).

7) Port handling efficiencies, and charges, such as terminal handling charge, port service charge and container lift on/lift off charge, are all the same for the hub and destination ports (all major ports in Australia charge similar rates for overall port charges, ‘cancelling’ each other out somewhat in cost difference terms).

Note in the above assumptions, parameters are estimated in a rather conservative way. We focus on the Total Logistics Cost (TLC, sometimes also referred to as Total Landed Cost, see e.g., Bowersox et al. (2010), pp. 384–385) as the cost indicator:

\[
TLC(Q) = cD + c_t \left( \frac{Q}{Q} \right) + c_e \left( \frac{Q}{2} + k \sigma_{DL} + LD \right)
\]

(1)

where,

- \(Q\) : the order quantity,
- \(D\) : the annual demand,
- \(c\) : unit cost including transport cost,
- \(c_t\) : ordering cost per order,
- \(c_e\) : inventory holding cost per unit,
- \(k\) : safety factor, typically depends on targeted service level,
- \(\sigma_{DL}\) : standard deviation of demand over lead time, and
- \(L\) : lead time

The TLC includes the purchasing cost, the ordering cost, and the inventory holding cost, which corresponds to the three terms in Equation (1). Once the commodity is selected and the company determines an ordering policy, the first term will be similar as the unit cost will only differ in terms of unit transport cost. Such a difference is usually dwarfed by the unit cost of the product itself. The second term would be the same as the ordering cost and the number of
orders will be same no matter which shipping options are used. Therefore, we are more interested in the third term, i.e., the inventory holding cost. The inventory holding cost can be further divided into cycle stock holding cost, safety stock holding cost and pipeline (lead time) stock holding cost.

Using all the parameters available and assuming the ordering cost is $5,000 per order, we can calculate the economic order quantity $Q$ as about 800 refrigerators per order. That is ten 40’ containers per shipment. As the economic order quantity is a rather robust parameter (Ziplin, 2000, p. 38), we will accept this value for all calculations.

Table 2 lists the cost (in $), average lead time (in days) and lead time variability (in days) for the three approaches. Two of them belong to indirect shipping where either rail or road is used upon leaving the hub port. The direct shipment uses road transport from the destination port to the ultimate clients. The data sources are provided at the bottom of the table, along with key assumptions and justifications. The lead time is estimated based on distance traveled, quoted transit times from transport operators, and adjusted according to the suggestions of Harrison and Fichtinger (2013).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost ($)</th>
<th>$\mu_L$</th>
<th>$\sigma_L$ (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea trunk transport</td>
<td>Transport to hub port</td>
<td>$1,200^a$</td>
<td>21$^a$</td>
</tr>
<tr>
<td></td>
<td>Port handling</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>Indirect: via a hub port</td>
<td>Transload to train</td>
<td>$30^b$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Rail transport to destination rail terminal</td>
<td>$1,920^c$</td>
<td>2</td>
</tr>
<tr>
<td>Rail-based transport to client</td>
<td>Transload to truck</td>
<td>$30^b$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Road transport to destination/client</td>
<td>$100^d$</td>
<td>0.5</td>
</tr>
<tr>
<td>Road-based transport to client</td>
<td>Transload to truck</td>
<td>$30^b$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Road transport to destination/client</td>
<td>$2,400^e$</td>
<td>1.5</td>
</tr>
<tr>
<td>Direct</td>
<td>Transport to destination port</td>
<td>$2,000^e$</td>
<td>19$^e$</td>
</tr>
<tr>
<td></td>
<td>Port handling</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Transload to truck</td>
<td>$30^b$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Road transport to destination/client</td>
<td>$100^e$</td>
<td>0.5</td>
</tr>
</tbody>
</table>


$^b$ Based on cost per full container lift in Shipping Australia Limited (2011, p. 10).

$^c$ Assuming 80% of road transport cost from Brisbane to Townsville as rail transport has the advantage of economy of scale.

$^d$ Assuming one hour delivery, based on truck hourly cost in Shipping Australia Limited (2011, p. 11).

$^e$ Assume direct service or transshipment from Singapore. No current quote was available, however the transport cost is (probably over) estimated at $2,000, based on the fact that it costs about $450 from Shanghai to Singapore, and the comparable rate of $1,200 from Shanghai to Brisbane.

From Table 2, we can derive the total lead time and the lead time variability for the three approaches. This, coupled with the demand uncertainty, can create some significant differences for the demand over lead time and its variance. Table 3 lists the mean and standard deviation for the overall lead time and the demand over lead time for the three approaches, assuming a weekly demand of $\sim N(150, 30)$. It can be observed that the indirect with rail-based approach incurs the longest lead time and highest lead time variance, which subsequently leads to highest demand and highest variance over lead time. The direct shipping approach achieves the shortest lead time and lowest lead time variance and consequently has the lowest demand and demand variance over lead time.
Table 3: Statistics for overall lead time and demand over lead time

<table>
<thead>
<tr>
<th></th>
<th>( \mu_L )</th>
<th>( \sigma_L )</th>
<th>Weekly demand</th>
<th>( \mu_{DL} )</th>
<th>( \sigma_{DL} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect rail-based</td>
<td>27.5</td>
<td>2.87</td>
<td>( N(150,30) )</td>
<td>589</td>
<td>86</td>
</tr>
<tr>
<td>Indirect road-based</td>
<td>25.5</td>
<td>2.50</td>
<td>( N(150,30) )</td>
<td>546</td>
<td>78</td>
</tr>
<tr>
<td>Direct</td>
<td>22.5</td>
<td>2.12</td>
<td>( N(150,30) )</td>
<td>482</td>
<td>70</td>
</tr>
</tbody>
</table>

Applying all the information available, and assuming a targeted service level of 95%, the TLC for all three approaches can be calculated. The results are displayed in Table 4. The unit displayed is in thousand dollars and the cost differences are calculated using the direct shipping option as the baseline. It can be observed that the purchase costs for the three approaches are quite different as they include the transport costs. Direct shipping has a conspicuous cost advantage over the other two approaches and this directly translates to a cost saving opportunity. The differences in lead time and lead time variability also contributes to the total cost and direct shipping incur the lowest cost due to these differences. Overall, direct shipping will cost $5,189K, which is the lowest among all three approaches, while rail-based indirect shipping will cost an additional $135K and road-based indirect shipping will cost an additional $164K. While road-based indirect shipping has a lower lead time and lower lead time variability, the additional transport cost per container makes it the highest cost approach.

Table 4: Cost decomposition and cost difference for the three approaches (in $1,000)

<table>
<thead>
<tr>
<th></th>
<th>Purchase</th>
<th>Ordering</th>
<th>Cycle stock</th>
<th>Safety stock</th>
<th>Pipeline inventory</th>
<th>Total</th>
<th>Cost difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect rail-based</td>
<td>5,128.0</td>
<td>50.0</td>
<td>51.3</td>
<td>18.0</td>
<td>77.3</td>
<td>5,324.5</td>
<td>+135.1</td>
</tr>
<tr>
<td>Indirect road-based</td>
<td>5,163.0</td>
<td>50.0</td>
<td>51.6</td>
<td>16.6</td>
<td>72.1</td>
<td>5,353.4</td>
<td>+164.0</td>
</tr>
<tr>
<td>Direct</td>
<td>5,013.0</td>
<td>50.0</td>
<td>50.3</td>
<td>14.5</td>
<td>61.8</td>
<td>5,189.4</td>
<td>Baseline</td>
</tr>
</tbody>
</table>

Figure 6: Sensitivity analysis of cost differences between indirect and direct shipping

As we mentioned earlier, the estimation and assumption of parameters can only provide a snapshot of the system and sometimes sensitivity analysis is required. We illustrate the effect of sensitivity analysis in Figure 6 by examining the impacts of inventory holding rate and safety factor \( k \). Figure 6(a) shows the additional cost required by indirect rail-based transport, while Figure 6(b) displays the additional cost required by indirect road-based transport. We achieve these two figures by varying the inventory holding rate from 10% to 30%, and the safety factor from 1.64 to 2.58, which corresponds to targeted service levels of 95% and 99%, respectively. The results indicate that, within the parameter ranges provided, there will always be an additional cost required to use indirect shipping. In other words, direct
shipping is always preferred. Sensitivity analysis for other parameters can be conducted in a similar way.

Through this quantitative case, we have demonstrated the advantages of direct shipping for one typical home appliance commodity to reach Townsville. It should be pointed out that the cost saving opportunities are not only from transport, but also from other related logistics and supply chain activities, such as inventory holding cost. The key is to adopt a systems view. Furthermore, this quantitative case only considers the delivery of full containers to the ultimate client. It does not include the return journey of containers and it only focuses on one commodity. The potential cost savings could be significant for the region once other commodities are included into consideration.

5. CONCLUSION

This analysis demonstrates methods to ascertain the likely benefit of indirect vs. direct shipping options for remote coastal cities and regions. The factors identified as being influential by this analysis are likely to have significant effects on future shipping strategies to Australia’s remote coastal cities from East Asia. As our results demonstrate, it is likely that direct shipping may play a greater role over time to regions such as North Queensland, as their populations and demand for import goods increases. The implications for policy and practice of the viability of direct shipping are also considerable. East Asian firms and freight forwarders and Australian customer’s decisions regarding shipping strategies may see more demand for container shipping into regional ports, such as Townsville, with commensurately less demand at hub ports, especially locations such as Melbourne, which has a disproportionate share of container freight at present, but also Sydney and Brisbane. Current proposals for new infrastructure around the hub ports, such as port road links and inter-modal terminals in Brisbane, including on the northern rail line that services North Queensland, should not be planned presuming continuous growth in existing hub traffic out of Brisbane, but should consider the likelihood of a shift in shipping strategies to service remote regions to the north over time. Our methods have numerous limitations, including the focus on one commodity to one region. Further analyses to explore the impacts of other factors are possible, to further isolate those of greatest influence. Discrete choice models across a range of commodities and port contexts could be developed to help practitioners determine from available indirect and direct shipping options. The methods provided in this paper also open opportunities to explore a range of broader issues, such as the potential for alternative stopping patterns for container ships visiting Australian shores from East Asia, and the possible effects on shipping strategies that key road and rail improvements proposed in Australia may have, especially a long proposed Brisbane-Melbourne in-land freight rail corridor.

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