Potential for a Logistics Island to Circumvent Container Port Congestion in a Constrained Environment

Motivation

From a Shipper’s perspective

• Port Congestion is a Major Supply Chain Problem
  • Increases average in-transit times
  • Adds unreliability to supply chains

• Current Mitigations for congestion at LA and Long Beach ports
  • Shipping to East Coast Ports
  • Switching to Air Freight
  • Increased parts and product inventory
Existing Intercontinental Freight Modes

How does freight move from origin to destination across the ocean?

Air Freight

- Expensive
- Fast
- Reliable

Ocean Vessel Freight

- Extremely cost-efficient
- Slow
- Unreliable
  - Stems from land connection

Where are the hybrid modes?

Is there a mode or combination of modes that can provide the cost-efficiency of an ocean vessel without the unreliability of ports?
The Need for Hybrid Modes

Examining Important Transportation Characteristics

<table>
<thead>
<tr>
<th>Mode</th>
<th>Cost</th>
<th>Speed</th>
<th>Reliability</th>
</tr>
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<tbody>
<tr>
<td>Air Freight</td>
<td>Expensive</td>
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</tr>
<tr>
<td>New Hybrid Mode(s)</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Conventional Ocean Freight</td>
<td>Inexpensive</td>
<td>Slow</td>
<td>Unreliable</td>
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![Diagram showing the need for hybrid modes](image)

- **Expensive**: Air Freight
- **Cheap**: Ocean Vessel/Port
- **Slow**: Ocean Vessel/Port
- **Fast**: Air Freight
- **?**: New Hybrid Mode(s)
Logistics Island Concept

Supported by Vertical Take-Off and Landing (VTOL) Aircraft

• Physical Characteristics
  • Essentially an off-shore port that would allow both ships to dock and VTOL aircraft to land

• Operational Characteristics
  • High-Value and/or time-sensitive containers removed from ship by VTOL or a crane
  • VTOL transports container:
    • Direct to destination – 150 mile range
    • To surface transportation mode:
      • Truck
      • Rail
Logistics Island Concept
Supported by Vertical Take-Off and Landing (VTOL) Aircraft

Port of Shanghai

Origins

Logistics Island

Port of LA

Destinations

Surface Transportation Network

Value Proposition for the Logistics Island

• Shipper’s Perspective (the focus of this analysis)
  • Take advantage of the cost savings of ocean vessel transportation
  • Overcome the congestion issues occurring at ports
    • Reduce average transit time
    • More importantly, increase reliability within supply chains

• Social Welfare Perspective
  • Reduced environmental impact
    • Specifically reduced air pollution in heavily populated regions
  • Shorter turnaround times
  • No dredging required
    • Now and in the future
  • Potential ocean transshipment location
  • Reduced risk of terrorist attacks
    • The Portunus Project
Background

Existing Offshore and Deep-Water Ports

• Deep-Water Liquid Natural Gas Ports
  • Neptune and Northeast Gateway
    • Massachusetts

• Deep-Water Oil Ports
  • Louisiana Offshore Oil Port (LOOP)

• Offshore Container Ports
  • Shanghai
    • Completed
  • Venice
    • Phase Unknown
Research Questions

- How does the Logistics Island/VTOL concept compare with other methods of circumventing congestion at ports?
- What value of time and reliability does a shipment need to have in order for use of the Logistics Island/VTOL concept to make economic sense?
  
  - From the shipper’s perspective
Qualitative Analysis

Focus Groups and Industry Interviews

• Why use a focus group?
  • Powerful method to test reactions to a new idea

• Participants
  • Maritime Transport Consultant
  • Ocean Carrier Representative
  • Drayage Industry Representative
  • Helicopter Company President

• Relevant Takeaways
  • Optimism regarding the ability of VTOL to circumvent port congestion issues
  • Freight transport, wherein VTOL is used to bypass port congestion, could be competitive with air freight
  • **VTOL provides a ‘midway’ solution that fills the large gap between ocean vessel transport and air freight**
  • Economics is obviously the most important thing for shippers
  • Reliability of travel time is an extremely important component of freight supply chains
    • Even more important than transit times
Quantitative Analysis

Methodology

• Identify relevant and quantifiable transportation attributes to compare freight transport modes
  • Cost
  • Mean Travel Time
  • Travel Time Reliability (Standard Deviation)

• Identify current methods used to circumvent port congestion for freight shipments travelling from East Asia

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Destination</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestion</td>
<td>Containers enter Congested Ports</td>
<td>West Coast</td>
<td>Ocean Vessel</td>
</tr>
<tr>
<td>Rerouting</td>
<td>Ocean Vessel travels to EC ports</td>
<td>East Coast</td>
<td>Ocean Vessel</td>
</tr>
<tr>
<td>Switch to Air</td>
<td>Air Freight instead of Ocean Vessel</td>
<td>West Coast</td>
<td>Airplane</td>
</tr>
<tr>
<td>Logistics Island/VTOL</td>
<td>As Described Earlier</td>
<td>West Coast</td>
<td>Ocean Vessel and VTOL</td>
</tr>
</tbody>
</table>

• Compare different transportation methods
  • Use Utility Maximization Framework in conjunction with freight transport attributes
  • Conduct Sensitivity Analysis on the ‘Competitive’ VOT/Willingness to Pay with respect to:
    • VTOL’s unit cost
    • Value of travel time reliability
Utility Maximization Framework

\[ U_{\text{Mode-i}} = \beta_{\text{cost}} \ast (\text{cost rate}_{\text{mode-i}} \ast \text{payload} \ast \text{distance}) + \]
\[ \beta_{TT} \ast \left( \frac{\text{distance}}{\text{speed}_{\text{mode-i}}} + \frac{\text{distance}}{\text{speed}_{\text{mode-i}}} \ast CV_{\text{mode-i}} \ast SD_{\text{multi}} \right) \]

Disutility Function. Looking to find when \( U_{\text{mode-i}} > U_{\text{VTOL}} \)

\[ \beta_{\text{cost}} \ast (\text{cost rate}_{\text{mode-i}} \ast \text{payload} \ast \text{distance}) + \]
\[ \beta_{TT} \ast \left( \frac{\text{distance}}{\text{speed}_{\text{mode-i}}} + \frac{\text{distance}}{\text{speed}_{\text{mode-i}}} \ast CV_{\text{mode-i}} \ast SD_{\text{multi}} \right) > \]
\[ \beta_{\text{cost}} \ast (\text{cost rate}_{\text{VTOL}} \ast \text{payload} \ast \text{distance}) + \]
\[ \beta_{TT} \ast \left( \frac{\text{distance}}{\text{speed}_{\text{VTOL}}} + \frac{\text{distance}}{\text{speed}_{\text{VTOL}}} \ast CV_{\text{VTOL}} \ast SD_{\text{multi}} \right) \]

Introducing \( VOT = \frac{\beta_{TT}}{\beta_{\text{cost}}} \)

\[ VOT > \frac{(\text{payload}) \ast (\text{distance}) \ast (\text{cost rate}_{\text{VTOL}} - \text{cost rate}_{\text{mode-i}})}{\text{Speed}_{\text{mode-i}} \ast \{1 + CV_{\text{mode-i}} \ast SD_{\text{multi}}\} - \frac{(\text{distance})}{\text{Speed}_{\text{VTOL}}} \{1 + CV_{\text{VTOL}} \ast SD_{\text{multi}}\} } \]

\[ \frac{VOT}{\text{payload}} > \frac{(\text{distance}) \ast (\text{cost rate}_{\text{VTOL}} - \text{cost rate}_{\text{mode-i}})}{\text{Speed}_{\text{mode-i}} \ast \{1 + CV_{\text{mode-i}} \ast SD_{\text{multi}}\} - \frac{(\text{distance})}{\text{Speed}_{\text{VTOL}}} \{1 + CV_{\text{VTOL}} \ast SD_{\text{multi}}\} } \]
Quantitative Analysis

Parameter Values

\[
\frac{VOT}{\text{payload}} > \frac{(\text{distance}) \times (\text{cost rate}_{VTOL} - \text{cost rate}_{mode-i})}{\text{Speed}_{mode-i} \times \{1 + CV_{mode-i} \times SD_{\text{multip}}\} - \frac{(\text{distance})}{\text{Speed}_{VTOL}} \{1 + CV_{VTOL} \times SD_{\text{multip}}\}}
\]

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<tr>
<th>Mode</th>
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<th>Time Reliability</th>
</tr>
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<tbody>
<tr>
<td>Units</td>
<td>Miles per Hour</td>
<td>$/ton-mile</td>
<td>Coefficient of Variation</td>
</tr>
<tr>
<td>Airplane</td>
<td>540</td>
<td>0.62</td>
<td>0.1</td>
</tr>
<tr>
<td>VTOL</td>
<td>150</td>
<td>3.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Truck</td>
<td>28</td>
<td>0.142</td>
<td>0.1</td>
</tr>
<tr>
<td>Ocean Vessel 1 (Congestion)</td>
<td>16</td>
<td>0.018</td>
<td>0.2</td>
</tr>
<tr>
<td>Ocean Vessel 2</td>
<td>16</td>
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- Weight of Reliability \([SD_{\text{multip}}]\) \(\rightarrow\) 2x
- Need to consider the distance each mode travels
Quantitative Analysis

Base Value Results

• VTOL and Logistics Island vs. Congested Port
  • $2.2/ton-hour and higher

• VTOL and Logistics Island vs. Re-routing Ocean Vessels
  • $0.3/ton-hour and higher

• VTOL and Logistics Island vs. Switching to Air Freight
  • $7.8/ton-hour and lower

• VTOL is the best mode of travel for shippers with a willingness to pay ranging from $2.2/ton-hour to $7.8/ton-hour
  • A large range
Quantitative Analysis

Sensitivity Analysis w.r.t. VTOL’s Cost Rate

- VTOL’s cost rate in the literature varies between $3/ton-mile and $9/ton-mile
  - Necessary to perform sensitivity analysis

![Sensitivity w.r.t. VTOL Cost Rate](chart.png)
Quantitative Analysis

Sensitivity Analysis w.r.t. Weight of Reliability

- Different shippers value reliability differently
### Attributes of Logistics Island and VTOL Shipments Compared to Air Freight and Conventional Ocean Freight

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- **Cheap**: Ocean Vessel/Port
- **Fast**: Airfreight
- **Slow**: Ocean Vessel/Port
- **Reliable**: Logistics Island and VTOL
Summary

• Large gap between Ocean Freight and Air Freight transport
• Port congestion issues have made ocean vessel transport even slower and more unreliable
• Introduction of Logistics Island/VTOL to fill gap
• The Logistics Island/VTOL concept is compared with:
  • Using congested ports
  • Re-routing shipments to East Coast ports
  • Switching shipment mode to airfreight
• The analysis determines the value of time per payload required of a shipment to warrant use of the Logistics Island/VTOL concept
  • For shipments with a VOT/payload of $4-$7/ton-hour, Logistics Island/VTOL is the best mode of freight transport
• Sensitivity analyses of the ‘competitive’ VOT with respect to modal attributes
Questions