Beyond the Seaport: Assessing the Inland Container Transport Chain Using System Dynamics

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Topic Area(s): Transportation, Simulation, Strategy

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Summary: The increase in containerized global trade, with limited seaport yard capacity and increase increased competition, container terminals are seeking alternatives to improve container turnaround time. The paper develops a System Dynamics framework that assess the impact of different strategies on the intermodal transport chain. Jordan's Aqaba Container Terminal is taken as an example to showcase how the framework can be developed and used in practice.

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KEY INSIGHTS

1. Increasing efficiency in the container terminal on its own does not reduce the dwell time and container delivery time. Collaboration with related stakeholders is needed to improve the intermodal transport chain.
2. A holistic view needs to be applied when assessing different strategies to reduce container delivery time.
3. System Dynamics is a powerful tool for assessing strategies in the container transport chain under different scenarios, while factoring in the existing complexities.

Introduction

Seaports play an instrumental role in enabling global trade and can significantly impact global supply chains. According to the International Maritime Organization (IMO), Maritime transport accounts for 90% of global trade activities (UN, 2018), of which containerized trade value is believed to account for approximately 60% (Statista, 2017). The movement of containers from and to seaport requires interactions between multiple subsystems which involve different stakeholders and processes. Delivering a container from the terminal requires interactions with the following parties: container terminal, customs, inspection authorities, ship agents, freight forwarders and carriers. These interactions add complexities to the container transport chain, making the assessment of different strategies a challenge. Moreover, the impact of an improvement in one process may be limited because of a constraint in another. For example, reducing the number of days to complete import documentations may not result in improving the container delivery time to destination if trucking capacity is limited.

The objective of the study is to develop a framework that assess the impact of policy and investment changes related to cargo movement on the container transport chain. The paper takes Jordan's container transport chain as case study, and answers the following questions:

1. What are the main subsystems affecting the container delivery time?
2. How do the identified subsystems relate to one another and affect the container delivery time and the container transport chain, as a whole?
3. How can System Dynamics be used to assess the impact of changes in any of the identified subsystems on the container transport chain?

This study develops a System Dynamics (SD) framework that assesses the impact of policy and investment changes on Jordan's container transport chain. The benefits of having such a framework provides decision makers with a tool to assess the effectiveness on a policy and investment change on the container transport chain. In addition, the framework can also be used to evaluate the container transport chain's level of resilience and ability to accommodate shocks in the system. The study's made possible by the support of Aqaba Container Terminal, operated by APM Terminals, providing data and information to support the research.

Jordan's container terminal, Aqaba Container Terminal (ACT), is a joint venture between Aqaba Development Corporation, a government entity, and APM Terminals, part of the AP Moller Maersk Group. ACTs' Annual throughput stood at 793 thousand TEUs in 2016, almost doubling in a period of a decade. The container dwell time, the time to pick up a container, averaged at nine days in 2016. The government plans to reduce the dwell time to the global average of three days in the next years.

Methodology

System Dynamics is a methodology for studying and managing complex feedback system. Literature shows that SD has been used to study complex maritime transportation system. However, literature did not create a System Dynamics framework for the inland container transport chain, which assesses the impact of different policies on the transport chain, as a whole. In addition, no literature reviewed the Jordanian container transport system.

Four general steps were taken to address the research question:
A. Process Mapping. The process was mapped by conducting interviews with local stakeholders and leveraging both authors experience in the industry.
B. Conceptual Model. After understanding the process, a Casual Loop Diagram (CLD) was constructed to illustrate the conceptual relationship that exists between the stakeholders and processes. The CLD focused on how changes in the variables will ultimately affect time delays, and the terminal's competitiveness in the long run.

C. Simulated Model. A stock and flow diagram was then developed, to assess the impact of alternative strategies on the inland container transport chain. Data relating to container flows were collected through secondary sources, which included Aqaba Container Terminal for container volumes and Jordan's Land Transport Regulatory Commission for data relating to trailers.

D. Model Testing & Review. Based on industry trends and initiative decisions expected to be taken in Jordan over the coming years, three alternative strategies were identified. Investment in a dry port, technology implementation, and a mix of both dry port and technology implementation, are the three alternatives compared. The three alternatives have been simulated over four scenarios. In addition to the base scenario, the different scenarios included constraints in the following: container terminal yard capacity, trucking capacity and documentation capacity. The alternatives were compared against

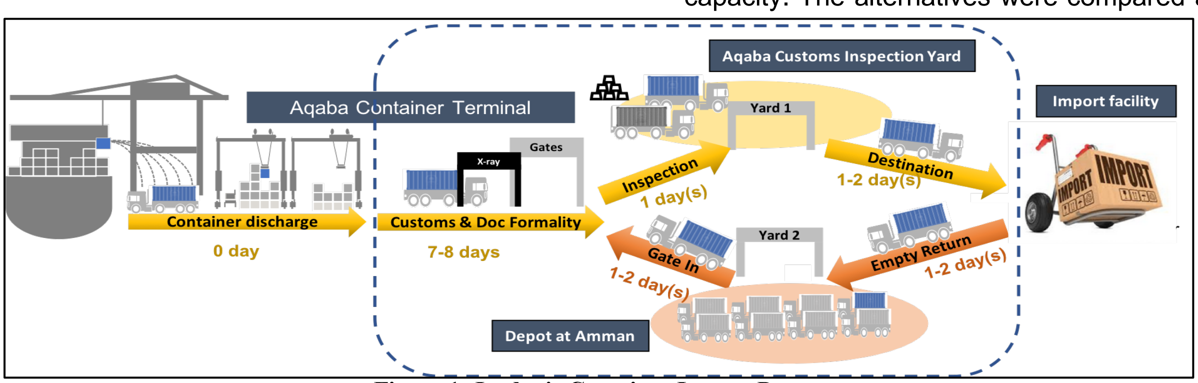

Figure 1. Jordan's Container Import Process

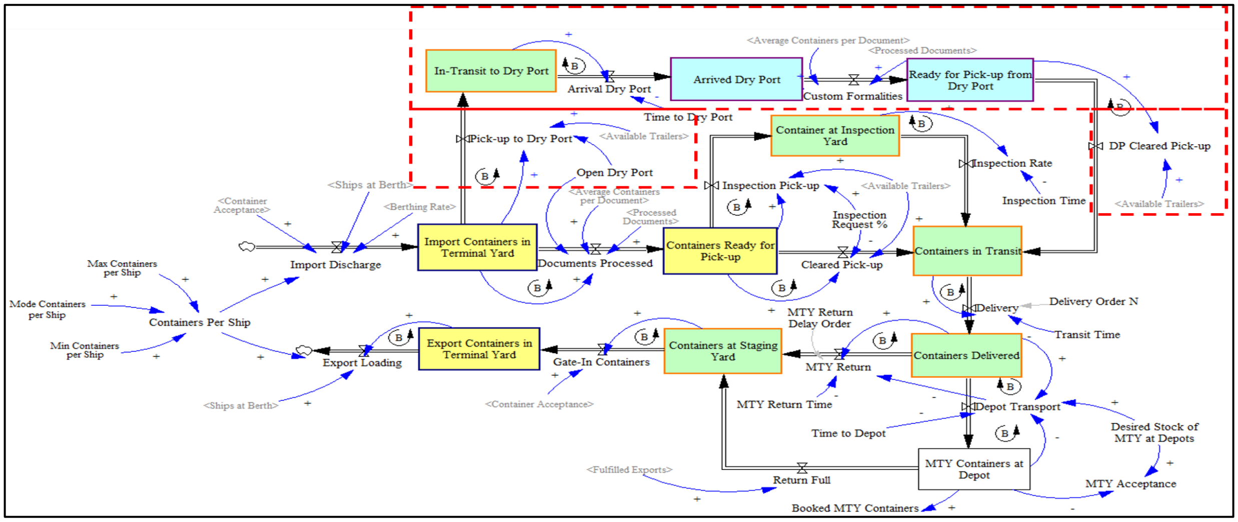

Figure 2. Inland Container Transport Chain

three defined KPIs. The best output performance is given a rank of 4, and the lowest is given a rank of 1. The alternatives are compared against three KPIs: Containers turnaround, trailers occupancy, and delivery time.

The Import Process

Jordan is an import-dependent country, with Aqaba being its only access to the sea. The dwell time, or the average time to have an import gate out of ACT was nine days in 2016. Figure 1 illustrates the current inland transport chain process in Jordan. The only mode of inland container transport is by truck. Custom inspection takes place at a custom yard outside the port, and no inland terminal currently exists.

Simulation Model

Figure 2 presents the stock and flow model of the import container movement sub-system, which is the trunk of the container chain. The following sub-systems have been identified and were connected to the import container chain: quayside, documentation, trucking, container terminal yard, and container movement (both imports and exports).

The stock and flow model was used to assess the three identified alternative strategies aimed at reducing container delivery time. The alternatives were first compared against the base case over a thirty-day period and one ship arrival during the period over four different scenarios.

Simulating the alternatives over a short period of time with one ship provides greater insights into the containers turnaround, trailers turnaround and delivery times. The first alternative, opening an inland terminal, reduces container dwell time to an average of two days but does not reduce the container delivery time. The second alternative reduces the delivery time but does not provide the ability to accommodate greater volumes of containers at the terminal, as deduced from scenario one. The third alternative achieved a lower delivery time and added resilience to the terminal, from the added capacity.

Figure 3 presents the container turnaround output for the three alternatives under the base scenario.

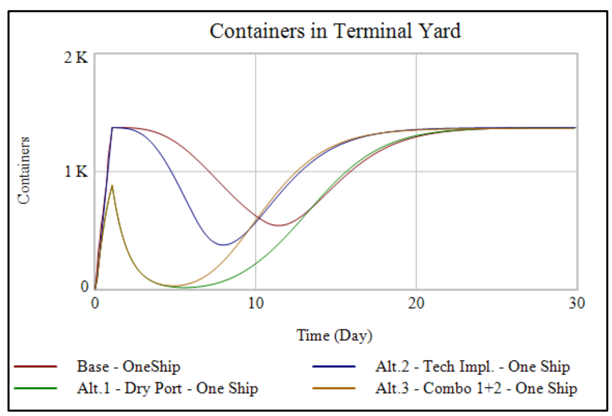

Figure 3. Containers Turnarounds Under Base Scenario

The third alternative is simulated against the current alternative over a one-year period, with daily ship arrivals. Interestingly, the third alternative only outperforms the current alternative for a short period of time. At day 275, the terminal gets fully congested. The third alternative adds significant pressure on the trailers, thereby increasing fleet utilization. As trailers will now be needed to transport containers from port to inland terminal and again from inland terminal to destination and back to the port.

The alternative comparisons under different scenarios and time frames showcase the complexities that exist in the container transport chain. In addition, the output results further emphasize the need to take a holistic approach when assessing the impact of different alternatives on the container transport chain.

When the terminal yard capacity is an issue, having faster documentation processing time alone does not solve the capacity issue at the terminal. Leveraging both the hinterlands and technology provides the container terminal with a greater capacity and achieves lower delivery time but will require more trucking trips. As trucking trips increase, if fleet size isn't adjusted, fleet utilization increases, and will eventually result in backlog of containers at the terminal.

Conclusions

The paper developed a SD framework to assess the impact of alternative decisions on Jordan's container transport chain. The complexities that exist in the container transport chain require the need to take a holistic view, and look beyond the seaport, when assessing the impact of a decision on the system. As the simulation model showed, focusing on improving the efficiency would not always result in improving the overall system.

The results further emphasized the importance of having such a framework employed and used by container terminals, policy makers and other stakeholders in the container transport chain. Policy makers and other stakeholders using the framework will be able not only to assess the impact of changes but know how to react. Employing the developed framework will assist policy makers to better plan for the future to avoid.

The SD models presented were only a framework, further steps need to be taken to bring the framework closer to reality. The framework must be first tested against real previous data, to reduce the number of assumptions. The model will be run across a wider timeframe and a goodness of fit would then be determined. Running different scenarios would also illustrate the importance of taking a holistic view when assessing strategies and encourage collaboration.