

IMPACTS OF A TRACKING AND TRACING SYSTEM FOR CONTAINERS IN A PORT-BASED SUPPLY CHAIN

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ABSTRACT

Purpose - Intermodal transport chains often appear as “black boxes” to the cargo owners and their clients, who lose track of the container until it arrives at the final end of the chain. The paper discusses why a tracking and tracing system should represent an important added value for them.

Design/methodology/approach - We describe here the configuration and features of a novel low-cost system to track and trace containers in an intermodal supply chain, provide information to shippers regarding delays and other unexpected events, and assist terminal operations accordingly. We then analyze the positive impacts of such a system over the entire supply chain, identifying the requirements of the main chain actors regarding the availability of information and how the proposed system contributes to the fulfillment of those requirements.

Findings - The visibility of containers throughout the entire supply chain provides multiple benefits for shippers, terminals and transport providers.

Research limitations/implications - The operational and economic benefits of the system are clear, but the lack of historical data does not allow for a quantitative estimation of those foreseen benefits.

Practical implications - Intermodal terminals might see this type of information systems as an opportunity to generate added value for their customers, including shippers and carriers. In a scenario with high competition levels between terminals, this added value could represent the competitive advantage necessary to guarantee the growth of a terminal without requiring expensive investments and costs.

Originality/value - The paper describes the benefits provided by the system to the main stakeholders of the intermodal supply chain and provides some conclusions with respect to those benefits and to future developments.

Keywords: Containers; tracking and tracing; supply chain; logistics; port

1. INTRODUCTION: SUPPLY CHAIN VISIBILITY

The evolution of supply chain management (SCM) over the last half century can be described through an increase in integration and information sharing (Muzumdar *et al.*, 2001). The first phase, encompassing from World War II until the late 1980s, witnessed the development of the departmentalised or functional SCM, with areas or departments operating in an isolated environment and decisions being made by managers within each area. The second phase covered from the late 1980s to the late 1990s and gave birth to the concept of integrated SCM, incorporating tools like advanced planning and scheduling systems (APS), enterprise resource planning (ERP) and business process reengineering (BPR). Finally, the third phase corresponds to the transformation of supply chains into value networks, with integrated and centralised planning, focusing on increased availability and sharing of information and thus aiming for higher customer service levels and lower supply chain costs.

Vernon (2008) examines the most important attributes of supply chain visibility and proposes a more precise definition, i.e., "Supply chain visibility is the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events". According to a study which was conducted among 524 companies in North America and Europe (Aberdeen Group, 2006), nearly 80% of the respondents pointed to a lack of critical supply chain process visibility and had started or were planning to take actions to enhance their visibility-related technology both for domestic shipments and global supply chains. Furthermore, Muzumdar *et al.* (2001) identified four key elements as essential for achieving operational success when supply chains migrate from push to pull models:

- Visibility across the entire supply chain
- Flexibility of supply and sourcing options
- Responsiveness to changes in customer demand and product lead times
- Rapid new product introductions based on market trends and new designs.

If companies are strongly focusing on these elements, all the different links participating in the supply chain should be equally prepared to facilitate them, and this is one of the reasons why tracking and tracing systems for containers have evolved so notably over the last few years (Ahn, 2005; Schmidt *et al.*, 2008), so that companies can track their shipments throughout the long-haul operations. The same can be said of terminals, where tracking and tracing facilitates the monitoring of loading, unloading and moving cargo (Shi *et al.*, 2011), but also enables the terminal to share all that

valuable information with shippers and logistics operators. Seo *et al.* (2014) describe information sharing as one of the main components of supply chain collaboration, which in turn helps to create reciprocal benefits by also satisfying shippers' requirements.

We present here a novel low-cost tracking and tracing system which, in combination with a series of planning tools and automatic devices, provides visibility throughout the entire containerised transport link of the supply chain. Our aim is to demonstrate how this type of system covers all the visibility-related requirements of the supply chain.

2. SUPPLY CHAIN REQUIREMENTS

The main drivers that force companies to implement visibility solutions in order to remain competitive in today's business environment or even better distinguish themselves among competitors by offering premium services to customers include the following (Aberdeen Group, 2006):

- Improve on-time delivery performance
- Proactively alert customers of late shipments
- Reduce lead times and lead time variability
- Just-in-time and lean programs causing shorter delivery windows
- Ability to make midcourse corrections

The achievement of these customer-related goals can be translated into a series of requirements addressing critical parameters that technology solutions should provide in all the links of the supply chain for a successful overall performance. These visibility requirements can be grouped into six categories (Boile *et al.*, 2014):

1. *Transparency*: this implies the availability of accurate information regarding the location of the shipment, which is expected to enable exception management while improving container utilisation and availability. Improved visibility of containers will also assist in the better organization of receipt and last mile delivery leading to more efficient management of local fleets.

2. *Security*: improved visibility across the extended supply chain is expected to reduce the number of pilferages and damages while alert notifications regarding unexpected events (e.g., unauthorised opening of the containers' door) can ensure secure container transport leading to significant benefits for several involved actors (e.g., reduced waiting time for customs clearance due to enhanced container profile in terms of security issues).

3. *Reliability*: visibility enables logistics operators to enhance customer satisfaction and strengthen their company profile by providing highly reliable services.

4. *Timeliness*: accurate information regarding the containers' estimated time of arrival may have a positive impact on supply chain processes (e.g., better arrangement of terminal operations, faster customs clearance, etc.) thus reducing lead time, achieving faster delivery of products and ultimately reducing the door-to-door lead time.

5. *Costs*: since reducing container transport costs is within the goals of all supply chain actors, supply chain visibility can lead to:

- Reduced administration costs due to less customs physical inspections and requirements
- Reduced communication costs due to improved access of all involved actors to supply chain data
- Savings in customs' business organisations and processes

6. *Effort/efficiency*: Better management/arrangement of the whole supply chain is expected to be realised by improving supply chain visibility leading also to better organisation of intermodal connections (e.g., better management of truck and rail operations) as well as better arrangement of terminal procedures (e.g., yard planning).

In the following section we will describe a new integrated system that provides all these six requirements to a sea-rail intermodal container chain. Following this requirement fulfillment, we will then describe the benefits provided by the system to the main stakeholders involved in the chain.

3. SYSTEM DESCRIPTION

Our proposed system (see Figure 1) covers the transport link of a road-train-vessel port-based container supply chain. The system is based on an intermodal terminal with rail and road access, and connected to the sea via an inland waterway. The system's main elements are the following:

A. The tracking/tracing of containers on trains is achieved with specifically designed sensors that communicate with a concentrating unit located in the locomotive, instead of using individual GPS connections for each container, which enormously reduces cost and energy consumption. Besides, additional sensors detect any unexpected event in the container, like its opening or an anomalous temperature raise.

B. The availability of real-time information can provide valuable input for the planning of drayage fleets used for the collection and delivery of containers.

C. The access of the train to the port terminal is facilitated with automatic signal boxes, and planned with a specifically built planning unit.

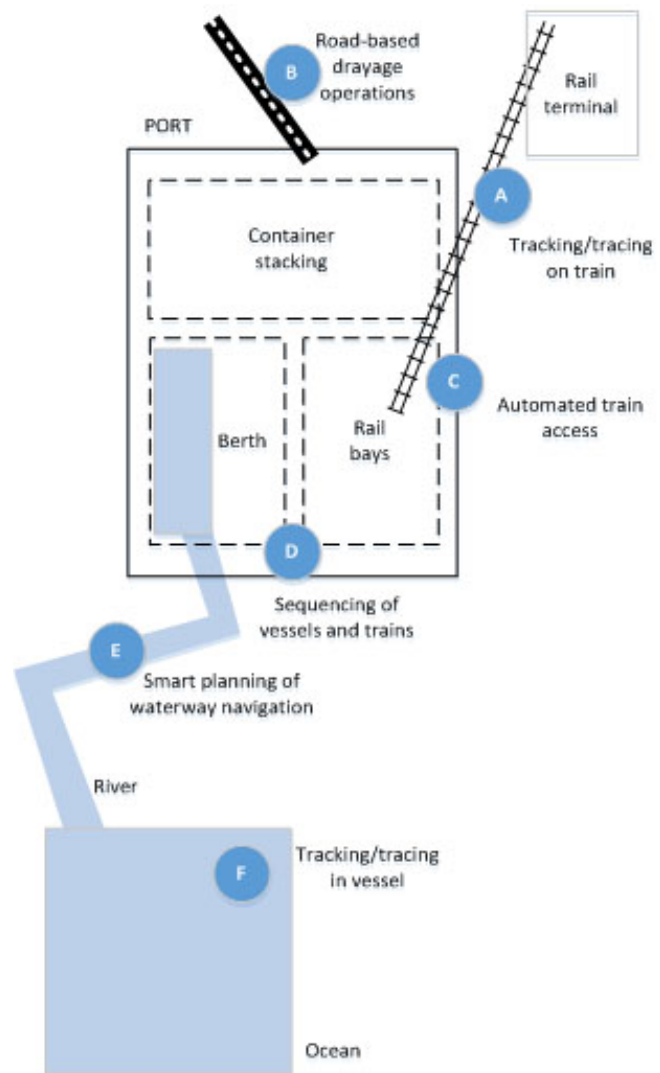


Figure 1. Schematic representation of the proposed system
Source: the authors own.

D. The sequence of vessels and trains entering the port is planned in order to minimize lead times.

E. The inland waterway that gives access to the port is also equipped with a smart navigation system, to guide vessels, plan crossings and any other events, regulate light buoys and detect timing deviations.

F. Finally, the container loaded onto the vessel is also tracked by means of a concentrator similar to the ones installed on trains.

Another advantage of this system is that it functions on a common database which brings shippers and carriers together by providing a single interface. For shippers, they do not need to log into the different carriers' system in order to know a specific consignment's status. They can gain uniform visibility of all the shipments regardless of which carrier physically delivers them. For carriers, they do not need to log into different shippers' system in order to keep

them updated of the shipment status. This removes the replication and saves them time and efforts (Wang *et Potter*, 2008).

4. EXPECTED IMPACTS

Our objective here is to determine the expected supply chain impacts of the system described above. Table 1 contains a list of requirements linked to the six categories described in Section 2, together with the stakeholder groups (L for logistics operators and carriers, T for the terminal and S for the shipper) that would be positively affected by the fulfillment of each requirement. Then, for each requirement, the last column of the table contains the expected outcome of our system as described in Section 3: “**” indicates that the system, as it is currently defined, will have an impact on the fulfillment of this requirement, whereas “*” indicates that the system does not directly provide the fulfillment of the requirement, but provides the basis for the development of tools which may fulfill it in the medium term.

It is interesting to note that logistics operators and carriers (including here rail operators, naval operators, and – in case of a further extension of the system – drayage haulers) would be positively affected by the fulfillment of almost any of the requirements in Table 1. On the other hand, the terminal would be mostly interested in those functionalities affecting its internal operations, in order to improve the smoothness and efficiency of container flows through the facility. Finally, the shipper is mainly concerned with supply chain issues, including the management of delays or anomalies, container security, transport reliability and cost.

With respect to the proposed system, it does not fulfill completely any of the six categories of requirements, but does have an effect on all of them, except for cost. Nevertheless, the system constitutes a first step towards the fulfillment of the unaddressed requirements, allowing for the development of additional tools and services focused on them. Even in the case of cost reduction, the availability of real-time data on the location and status of containers provides invaluable input to inventory, routing and planning systems, which in turn help reduce supply chain costs and inefficiencies.

5. POTENTIAL SUPPLY CHAIN BENEFITS FOR SHIPPERS

We have shown that the proposed system impacts the supply chain from multiple points of view and with respect to multiple actors. We concentrate now on the potential benefits provided for shippers whose supply chain incorporates the described system in its intermodal link. These benefits constitute a significant increase of the service level offered by the terminal to the industrial actors, with the corresponding impact on their business processes. The potential benefits include the following:

Table 1. Supply chain requirements related to the container tracking and tracing service.

Category	Requirement Description	Stakeholder	System
Visibility	Transparency and visibility on terminal shipping processes	L, T	**
	Earlier information on hinterland transport	T	**
	Visibility during recovery processes from anomalies (reactive)	L, T, S	**
	Traceability of empty containers for better repositioning strategies	L	*
	Enablers of exception management	L, T, S	**
	Accuracy of position of container in terminal area	T	*
Security	Opening of container only once/as less as possible	L, T, S	*
	Fight counterfeiting	L, T, S	*
	Reduce theft	L, T, S	**
	Avoid cargo damage (liability issue) by knowing the sensitivity of the commodity	L, T	**
Reliability	Decrease lead time variability and capture deviations within margins	L, S	**
Timeliness	Reducing total door-to-door time, minimize idle time	L, S	**
	Reduce dwell time at terminals by improved availability of information to different actors thus contributing to better process planning	L, T	**
	For some users, waiting time can be functional	L, T, S	*
	Enabling companies to go intermodal by reducing complexity and solving interoperability issues	L	*
	Contribution to e-freight and internet of things vision becoming a reality	L, T, S	*
Cost	Reducing total door-to-door cost	L, T, S	*
Efficiency	Reducing administrative burden/single window offering one stop-shop-service	L, T, S	*
	Pre-announcement of hinterland operators to improve terminal efficiency	L, T, S	**
	Value added services from platform: automatic document generation from users	L, T, S	*

Source: adapted from Boile *et Sdoukopoulos* (2014)

- Better supply chain visibility through real-time information regarding the containers' location and integrity status
- Potential lead time reduction
- Enhanced supply chain cooperation through information sharing between partners along the supply chain
- Better arrangement of pickup and delivery procedures in terminals due to information on the exact time of vessels' arrival
- Competitive advantage resulting from the ability to create premium services through the real-time tracking of containers, making companies unique in the market.
- Reduction of communication costs
- Container fleet capacity reduction and better decision making as a result of the real-time management of containers and accurate data on container movements
- Easier communication with customs authorities - early notification of container ETA and integrity
- Better organization of intermodal connections. Alerts regarding the availability of the cargo (when and where it is available) can assist in better managing truck and rail or other mode operations
- Improved container safety and security through alarms and alerts regarding any unexpected events (exception management)
- Savings in customs' business organization and processes
- Delayed deadlines for decision making with respect to the final destination of the cargo
- Better management/arrangement of the whole supply chain

As an example, Table 2 shows some disruptive situations that may arise in the intermodal chain and how the proposed system could help to alleviate or overcome them.

Table 2. Possible benefits provided by the proposed system to the supply chain in case of different disruptive situations

Scope	Disruptive situation	Benefit provided by the system
Punctuality	Container misses ship at port of departure	Alerts and information exchange avoid a cascade of disruptions in the supply chain
Transshipment	Unscheduled transshipment	Communication regarding new vessel and time and place of departure avoids disruptions

ETA/ATA	Labor capacity peaks	Reporting of ETA during sea/rail voyages result in opportunities to adjust inbound logistics planning
Cargo quality/reliability monitoring	Cargo damaged upon reception	Monitoring of cargo quality may help to determine liability
Lead time analysis	Shipment exceeds time windows	Alerts and information exchange avoid a cascade of disruptions in the supply chain

Source: adapted from Arendt *et al.* (2011)

6. POTENTIAL OPERATIONAL BENEFITS FOR THE TERMINAL

The intermodal terminal operator is responsible for managing the navigation of vessels through the inland waterway and the access of trains, as well as for all the movements carried out inside the terminal's premises. These movements include the loading and unloading of containers from/to vessels, trains and trucks, the internal shifting of containers between the different areas of the terminal, and their storage in the stacking area when necessary, which requires all the necessary equipment, including different types of cranes and internal trucks (Günther *et al.* Kim, 2006). Taking all this into account, the positive effects generated on the terminal by the described developments may come from three different axes:

- In the first place, these positive effects may come from a straightforward increment of the business figures. With the appropriate commercial policy, the tracking and tracing system can be presented as a competitive advantage to the terminal's current and potential customers, which in turn represents a competitive advantage for the terminal against its competitors. Additional traffic could therefore be gained by the terminal from other terminals or from other transport chains. This would result in a positive impact on movement-related indicators, like the number of vessels, trains and trucks passing through the terminal, the number of TEUs and tons per year, the occupation of storage capacity, etc.
- Second, additional positive effects are likely to appear from the reduction of direct costs enabled by the new technologies. Train management and guidance, navigation planning, crane and workforce scheduling or customer management are essential tasks that will see a reduction in the amount of resources that need to be devoted to them.
- Finally, the third source of positive effects for the terminal is the increase in efficiency resulting from the implementation and appropriate use of

the system, particularly in all the aspects related to the sequencing of vessels (due to an improved navigation system) and trains (due to better train scheduling, internal guidance and incidence management). The indicators pointing at vessel, train and truck residence times, and at crane operation times and productivity, are likely to improve accordingly. Less idle times in the operation of internal resources, and higher dispatching capacity, should be additional observable effects.

Table 3 shows a compilation of the different indicators that should show a positive effect due to the implementation of the new technology. The indicators are classified according to the different aspects they are related to, and to the intensity of the expected income (high, medium or low). Movement, intermodality and management indicators are likely to show comparatively large effects, as are the indicators related to operational and residence times and to operational costs. The effects on infrastructure use and equipment productivity should be comparatively smaller, as these are second-degree effects, which would only show as a follow-up of the previous category. Finally, a number of indicators related to the amount of warehousing space required, the occupation of that space and the operation time of the terminal's equipment appear as third-degree effects, and would have relatively small effects.

7. POTENTIAL WORKLOAD BENEFITS FOR TRANSPORT OPERATORS

Transport operators working with an intermodal terminal include vessel companies, railroad operators and truck companies. In their case, the benefits that can be expected from the implementation of the tracking and tracing system also have two sides, the direct and the indirect one. Direct benefits result from the foreseeable gain in efficiency provided by the system, which allows for cost reduction due to the reduction of idle times. More specifically, the following effects can be expected:

- For vessels: the automatic scheduling of operations, together with the improved navigation system, should allow vessels to reduce their stay at the port terminal as much as possible.
- For trains: again, the scheduling of operations is combined with the automatic train guidance system which increases the capacity of the network and reduces waiting times for available trains entering or leaving the terminal.
- For trucks: the system allows drayage truck drivers to know in advance when their container needs to be delivered or when it can be collected, thus reducing unnecessary waiting times at the terminal.

Table 3. Expected impacts on the indicators related to the terminal

Aspect	Indicator	High impact	Medium impact	Low impact
Movement	No of vessels-trains-trucks/year	x		
	Tons/year	x		
	Movement growth rate	x		
Intermodality	% of rail cargo	x		
Infrastructure	Warehousing space			x
	Warehouse occupation		x	
Management	Average stay of vessels	x		
	Average stay of trains	x		
Berth	Containers/m/year		x	
	% berth occupation		x	
Loading and unloading	TEUs/crane		x	
	Crane utilization		x	
Stockage	Space occupation			x
	Container residence time	x		
Internal traffic	Idle times		x	
Reception and dispatching	Dispatching time	x		
	Daily vehicle capacity	x		
	Reception capacity		x	
	Dispatching capacity		x	
Productivity	Terminal productivity		x	
	Warehousing productivity		x	
	Berth productivity		x	
Profit	Operational cost per TEU Cargo income	x		
			x	
Time	Residence time	x		
	Crane operation time			x

Source: the authors own.

On the other hand, these stakeholders could also expect indirect benefits from the system, resulting from the increase of activity in the terminal. The competitive advantage provided by the new technology might bring new customers willing to ship their containers through the terminal, and the subsequent increase in traffic also should represent an increase in their business figures for the vessel, rail and trucking industries.

These direct and indirect impacts would also be reflected in the corresponding indicators. In this case, the affected indicators would be the ones related to traffic figures and to cycle times, which indirectly report efficiency levels:

- No of vessels-trains-trucks/year
- Tons/year and TEUs/year
- Movement growth rate
- Average stay of vessels and trains

8. CONCLUSIONS

The activity of an intermodal container terminal is related to the transshipment of containers between the different transport modes. Therefore, the appropriate synchronization of those modes, combined with full knowledge of the real-time location of the cargo, seem essential to guarantee the efficiency and robustness of the operations. However, intermodal terminals often lack those integrated information systems to coordinate, standardize and support the exchanges of information between the different stakeholders operating in the intermodal chain, including the terminal itself, shippers and vessel, train and truck operators. This is why the conceptual advance of the proposed system is mainly focused on the centralization of information, which can then be made accessible to the relevant stakeholders, and on the scalability of the system.

The geo-positioning system for containers provides a tracking application which also incorporates the monitoring of information collected from different sensors, including light, movement, acceleration, etc. The integration of this technology with other systems operating at the terminal allows the platform to know where a given container is at all times, and what is the record of events that have happened to that container. The automatic guidance system for trains includes planning, signaling, sensor and monitoring elements in order to manage automatically the traffic of trains in the terminal's grounds. Finally, the monitoring, signaling and navigation planning on the inland waterway will provide the same functionality for vessels, increasing capacity and helping the terminal's planner and the vessel's captain to respond to unforeseen events that may arise.

The integration of all this information on container positioning and state with the planning capabilities of the new system provides a series of added-value services to the capabilities of the terminal, which can then be transferred to its customers and stakeholders:

- Real-time viewing of the container's location by all the enabled stakeholders: each container has a unique identifier in the system, and any stakeholder with the corresponding permission can have remote access to all the related information on location, sensor information and historical data.
- Statistical analysis of all the information collected, which provides the terminal with valuable data to assist strategic decision-making.
- Integrated planning of logistics operations: the terminal can use all that real-time information on containers (origin, destination and real-time location) and transport units (expected times of arrival) to sequence the operation of vessels, trains and cranes in order to minimize the time spent by containers and transport units in the terminal.

- Pre-notice of container arrival: using the real-time information, the terminal can inform shippers in advance of the arrival of a given container, which allows for better planning of drayage operations. This service is also extremely useful for customs agencies and inspection services, helping them to plan their activities in advance and to reduce the waiting and overall residence times of containers.

With respect to future developments, some additional services that could be provided using the new technology as a starting point are the following:

- Real-time destination management: the available information would allow the shipper to use the intermodal chain as a moving warehouse, delaying as much as possible decisions related to the final destination of the cargo. These decisions can also be related to the sensors identifying the possibility of cargo damage, opening of the container or temperature loss.
- Optimization of container returns: the transport operators could integrate the information provided by the system with their container planning processes, thus reducing the displacements of empty containers and reducing costs accordingly.

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