A Collaborative Supply Chain Management System for a Maritime Port Logistics Chain

L.M. Ascencio[1], R.G. González-Ramírez*[2], L.A. Bearzotti[3], N.R. Smith[4] and J.F. Camacho-Vallejo[5]

[1]Escuela Universitaria de Ingeniería Industrial Informática y de Sistemas
Universidad de Tarapacá, Avda. 18 de Septiembre 2222, Arica, Chile
[2]Escuela de Ingeniería Industrial, Pontificia Universidad Católica de Valparaíso,
Av. Brasil 2241, Valparaíso, Chile.
*rosa.gonzalez@ucv.cl
[3]Escuela de Ingeniería de Transporte, Pontificia Universidad Católica de Valparaíso,
Av. Brasil 2241, Valparaíso, Chile.
[4]Centro de Calidad y Manufactura, ITESM, Campus Monterrey.
Eugenio Garza Sada Sur 2501, Monterrey, Nuevo León, México. CP. 64849.
[5] Facultad de Ciencias Físico-Matemáticas, Universidad Autónoma de Nuevo León,
Av. Universidad s/n., Ciudad Universitaria, San Nicolás de Los Garza, Nuevo León, México

ABSTRACT
In this article we propose a collaborative logistics framework for a Port Logistics Chain (PLC) based on the principles of Supply Chain Management (SCM) that rely on stakeholders integration and collaboration, providing a reference model for the inland coordination of the PLC. A comprehensive literature review was conducted, analyzing several cases in which SCM practices have been implemented as well as studies related to port development, governance, coordination and best practices associated. This background information was used to identify current gaps in logistics management practices and potential scopes of intervention within the PLC to suggest a redesign process and configure new structures under a collaborative scheme, following the guidelines of SCM.

Keywords: Port Logistics Chain, Supply Chain Management, Demand Management, Orders Management, Vehicle Management.

RESUMEN
Entender las disrupciones y su propagación a lo largo de las cadenas de suministro se ha vuelto crítico para el diseño de cadenas de suministro globales operando en economías emergentes. Esto no solo implican pérdidas económicas a cualquier organización involucrada en una cadena de suministro, sino que además disminuye la competitividad logística nacional. Este trabajo provee elementos numéricos de la importancia de la seguridad en América Latina y al mismo tiempo, propone un modelo de evaluación desde la metodología de dinámica de sistemas con base en información real, capaz de establecer escenarios para medir los impactos relacionados de la propagación de interrupciones en la cadena de suministro causados por actos criminales. Finalmente, se presentan conclusiones para el diseño de cadenas de suministro más resilientes, así como propuestas de investigación futura.

1. Introduction

A port logistics chain (PLC) embraces all the global logistics chains that operate through a seaport, including different stakeholders involved in the international trade processes, such as the importers and exporters, the Port Authority, the terminal operators, customs, customs agents, transport companies (ground and maritime), freight forwarders, empty container parks, etc. The PLC faces important challenges for the integration of those supply chains processes and the huge number of public and private stakeholders. Another challenge faced by the PLC is the existence of several sources of variability that affect the import and export flows.

This could be either from the maritime perspective with variability in the arrival time of ships to the port, or from the inland perspective with uncertainty regarding the exact arrival time of external trucks to the port terminal, as well as service times at each echelon of the logistic chain. These factors strongly impact the resource and capacity utilization of the different stakeholders. Hence, the PLC should focus on the reduction of variability through a better coordination among the physical and documental flows, based on the well-known inter-enterprise concepts of Supply Chain Management (SCM).

Chilean foreign trade has experienced a sustained growth in the last decades, as it can be observed in the reports of international commerce provided by the Chilean Customs and related gremial associations. Due to free trade agreements with several countries and the trade globalization process, this trend is expected to continue in the future. As a consequence, port infrastructure has been improved and increased.

However, after performing in site visits to Chilean Ports and interviews with key stakeholders such as transport operators and stevedore’s managers, those investments in port infrastructure lack of modifications and improvements in logistics processes. Previous issue is also supported by the current position of Chile (or any Latin American country) at international benchmark measures such as the Logistic Performance Index (LPI), in which Chile occupied the first place in LATAM in 2012 report, but the position number 39 with respect to developed economies. Hence, it is clear that there is room for logistics improvements that may enhance the competitiveness of international trade of the nation.

Previous issues and the fact that international trade has significantly increased, has led to high logistics costs, congestion at port facilities, and document based processes prone to mistakes and duplications, among other problems. As a solution to the above problem, we present a proposal for the design and implementation of a collaborative logistics framework as a reference model for the coordination of the inland operations of the PLC. The proposed framework includes three main components:

(1) Management of Port Logistics Governance. This is based on the existence of a Port Community with a well-defined organizational structure that facilitates dialogue and communication among the public and private stakeholders involved in the port logistics chain, fostering the analysis and continuous improvement of the international trade procedures.

(2) Port Logistics Operations Model. This considers the relationship between the main infrastructure of the port and the logistics processes associated, which could be centralized, descentralized or hybrid, according to the existence or not of a pre-terminal or a facility that is used as an extension of the port where total or partial flows should be directed;

(3) Logistics Management Platform System. This includes a conceptualization of the planning, scheduling, and control activities cycles of physical and information flows and the technological systems that support them through the entire port logistics chain.

The remainder of the paper is organized as follows. A literature review on SCM and other studies related to Port Operations and Development is addressed in Section 2. Section 3 presents the proposed framework and its main components and Section 4 provides details related to the Logistics Management Platform System and the subsystems Demand Management System (4.1), Vehicles Management System (4.2) and Order Management System (4.3). Section 5 presents a brief description of the case of a Chilean PLC. Conclusions, managerial insights and further research are provided in section 6.

2. Literature Review

Due to the globalization, e-commerce, and mass customization trends, global logistics management in business operations has become more important than ever. In this regard, transportation is becoming a more strategic business function because transport costs are accounting for a larger percentage of the cost of goods sold [1]. In addition, delays in transit time can undermine enterprise performance, affecting the organization’s competitiveness [2]. Consequently, ports are now seriously exploring the potential of the supply chain management (SCM) concept. Effective SCM is an essential strategy for enterprise success in global and e-markets to get products to market faster and at a minimal total cost [3-5].

Globalization has introduced additional concerns to companies participating in international supply chains. These include interest rates, exchange rates, taxes, duties, and customs regulations. This environment is continuously changing, and so is the volatility of the freight market [6]. All these issues have contributed to increasing the pressure on port operations, as well as the introduction of structural changes in logistics and new patterns of distribution.

In a broad sense, a supply chain consists of two or more legally separated organizations linked by material, information, and financial flows. These organizations may be firms producing parts, components and end products, logistic service providers, and the customer. SCM recognizes the strategic nature of coordination between trading partners. The higher the degree of integration across the supply chain the better a firm performs [7,8]. There are dangers if suppliers and customers are not fully integrated in terms of their business processes [9].

Currently the competition in the global market does not occur between companies but between supply chains and flexibility is becoming one of the most important requirements of production systems in which the product/service is often produced with contribution of several companies [10]. Going beyond organizational barriers, aligning strategies, and speeding up flows along the supply chain are typical issues in SCM [11]. So the next step is to achieve supply chain collaboration [12]. Simatupang and Sridharan [13] offer as a definition: “A collaborative supply chain simply means that two or more independent companies work jointly to plan and execute supply chain operations with greater success than when acting in isolation”.

When a common action plan is executed by the legally separated firms in a supply chain, they collaborate to improve the competitiveness of the supply chain as a whole [11].

It is generally accepted that a relationship exists between competitiveness and supply chain structure [14-16] and the ability to adapt the structure of the supply chain quickly according to market needs has been recognized as one of the major advantages of this type of organization [11]. This is a very useful ability for a volatile environment like the one associated with seaport clusters [6]. Supply chain performance assessment has been proved to be a key element on the current global environment, and systematic approaches are essential to understand the interactions of the different echelons of the logistics chain [17].

The existence of a huge number of public and private stakeholders that interact in transport operations and the logistics of international trade cargo generates significant coordination problems among the port terminals and their main users, in addition requiring a huge number of transactions and documentation processes, most of them based on paper documents. These characteristics strongly impact the logistics efficiency of the transport industry, the exporter, and the importer, generating congestion at the access point to the terminal as well as long waiting times at the different nodes of the international trade logistics chain.

Traditionally, ports act as an interface between ships and shore by providing shelter and a berthing space, temporary storage, and infrastructure for cargo operations and movement within the port [18,19]. However, the evolution of supply chains urges market players such as maritime shipping lines, stevedoring companies, inland transport operators (freight forwarders and rail and trucking companies), and shipping and customs officers to re-think their role in the logistics process and poses great challenges to the role of ports as functional nodes in logistics networks [20] and to achieving a more active role in supply chains with additional integration levels, which goes beyond their traditional transshipment role [21].

The tendency towards supply chain orientation and logistics integration in the port and maritime industry is well documented in recent literature [22-27]. In a new trend among port system shippers, third party logistics providers and port authorities need to reconfigure a more competitive port network structure.

Thus, ports need to be oriented towards supply chains to meet the changing needs of their users and customers [28]. It is very common for maritime shipping lines and inland transport firms to consist of different companies who may attempt to establish long-term business relationships. Some strategies such as joint ventures and network integration through coordination among players have been deployed in order to share logistics information, techniques, and resources to gain bargaining power over suppliers [20]. Based on these principles, this research provides a framework for logistics management and improvement of the inter-enterprise processes that include common areas and resources that should be administrated by several actors.

Tongzon et al. [28] analyzed how much the port sector is supply chain oriented by means of an empirical study, considering the port of Incheon (South Korea) as a case study and measuring the degree of its supply chain orientation. The study considered the perspectives of both the port terminal operator and the shipping line calling at the port. An analysis of the main discrepancies between both perspectives is presented as well as an analysis of the impacts on the performance of the port terminal.

One main finding of their study is the difficulty of achieving integration in the supply chain because of data sharing and the lack of cohesion and trust among the different public and private stakeholders. Another conclusion of the study is that more emphasis should be placed on generating additional value-added services as well as improving the port´s access to the hinterland in order to improve the attractiveness of the port to its users.

Ascencio et al., [29] performed a study to measure the degree of cohesion among the stakeholders of the port supply chain of the Port of San Antonio, as well as the levels of satisfaction with respect to the service level received. It was observed that those stakeholders with a high frequency of interaction with each other perceived better service levels and manifested greater satisfaction compared to those that maintained lower frequencies of interaction. Low degrees of trust and confidence with respect to the services provided by the port terminal, the empty container depots, and warehouses were observed, as well as low satisfaction levels with respect to the price-quality ratio.

Furthermore, via a number of group sessions with representative stakeholders of the PLC, the main limitations, opportunity areas, and possible threats to the port system were identified. The main concerns were related to the need for a global entity that enhances the integration and collaboration among the different stakeholders (governance).

Almoratair and Lumsde [30] presented a comprehensive theoretical analysis and conceptual foundation of the port logistics platform as it relates to SCM concepts using a systems theory approach. A port logistics platform is a group of enterprises that work in an environment of close collaboration to strategically position and increase the operational efficiency of each enterprise involved, and in this way achieve competitive advantages in the whole supply chain. Three main systems that constitute the port logistics platform are identified: the port logistics system, the multimodal transport system, and the information and communications system, which are closely interrelated.

The Port Authority has a strategic role, interacting with the stakeholders involved in international trade logistics, such as exporters, importers, logistics operators, customs agents, inland carriers, and shipping lines in order to identify the main factors that impact the logistics performance of the port system [31].

In the research proposed herein, a collaborative framework to improve inter-enterprise processes for a port logistics chain is presented, with the aim to optimize the collaborative operations in the context of international trade and transport interactions, based on the principles of SCM. SCM is “a set of approaches that efficiently integrate suppliers, manufacturers, warehouses and stores for planning, implementing and controlling of the materials and information flows from origin to the point of destination, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements” [32].

Analogously, SCM for a PLC can be defined as follows: “The Management of a Port Logistics Chain promotes the efficient integration and coordination of public and private stakeholders for planning, implementing and controlling the flow of maritime and ground transport, cargo and information flow (service orders and documentation of international trade) from origin to the point of destination (hinterland, foreland) in an efficient and effective way, in order to minimize system wide costs while satisfying service level requirements of importers and exporters (agility and predictability)".

3. Collaborative Logistics Framework Description

To design and implement the proposed collaborative framework, we focused on the study and analysis of the current degree of integration of the inter-enterprise processes of a PLC, focused on the inland side. We analyzed the current practices of the main Chilean ports and their daily operations and contrasted them with respect to best practices in the literature and case studies in which SCM practices have been implemented successfully, such as in the textile retail, automotive, and supermarket industries. This background information was used to identify current gaps in logistics management practices and potential scopes of intervention within a PLC. Once the current business practices of a port and the challenges to logistics management practices were understood, a redesign process was applied to configure new structures under a collaborative scheme, following the guidelines of SCM.

Figure 1 presents a diagram of the proposed framework, which is composed of three elements: (a) Management of Port Logistic Governance, (b) Logistics Management Platform System, and (c) Port Logistics Operations Model.

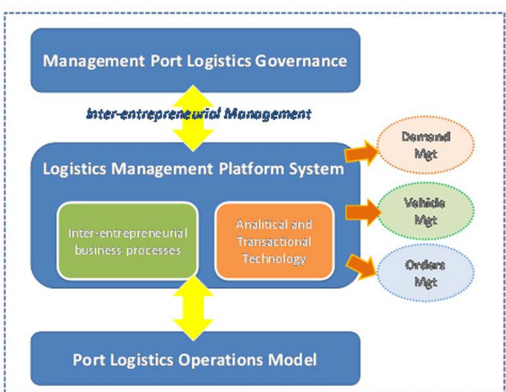

Figure 1. Collaborative Logistics Framework for a PLC.

The Management of Port Logistics Governance refers to the supra-structure of the PLC, which is based on the existence of a Port Community that facilitates the communication and integration of the different stakeholders of the PLC, including public policy makers based on a well-balanced and integrated stakeholders approach. The Port Community therefore provides a platform for the analysis and continuous improvement of the inter-enterprise processes of the PLC. The port community structure may consider the following strategic pillars: (1) infrastructure, (2) logistics, (3) port-city relationship and environmental issues.

The proposed framework articulates a governance to coordinate the work of multiple stakeholders, both public and private that participate in a collaborative environment. In this regard, issues that should be addressed are: utilization of logistic infrastructure in collaborative schemes, fee regulations, service quality, security (cargo and persons), models of penalties and incentives, and continuous improvement and innovation.

The Logistics Management Platform System, LMPS, serves to design and implement processes and technologies to achieve a more efficient and effective physical and documental flow in the PLC. The main focus is on those business processes that are not related to a single stakeholder and their coordination requires a collaborative approach in order to achieve good performance by the entire PLC. These business processes correspond to three scopes: demand management, vehicle management, and orders management, which can be addressed at a tactical and operational level based on transactional and analytical information systems. More details are provided in section 4.

The third element of the framework, the Port Logistics Operations Model is related to the type of infrastructure and operations model of the port system, which could be either centralized (a two stage system with a pre-terminal and a number of port terminals, in which external trucks are required to arrive at the pre-terminal and then be directed to the corresponding terminal), decentralized (a single stage system in which external trucks arrive directly to the corresponding port terminal) or hybrid (there is a pre-terminal but is not a mandatory stop for all the external vehicles, some of which arrive directly to the port terminal according to a defined set of business rules). The governance model may consider the role of the port authority that could be based on a landlord scheme.

The proposed framework can be used as a reference model to improve the integral competitiveness of the port and the related stakeholders. The framework also provides support for the processes of redesign and for technological projects such as Single Window Systems and Port Community Systems to facilitate trade and increase efficiency by reducing time and costs.

4. Logistics Management Platform System (LMPS) description.

In this section we present more details on the proposed LMPS. We first introduce in section 4.1 the inter-enterprise processes both individually and their interactions. Then in section 4.2 we present the proposal to manage the inter-enterprise processes based on information technologies, both individually and in a collaborative scheme.

4.1 Inter-Enterprise processes of the PLC

Inter-enterprise processes of the PLC are mainly related to three scopes: demand management, orders management and vehicles management. Decision making related to manage demand and capacity of the PLC can be addressed at tactical and operational levels. Figure 2 summarizes the main focus of the inter-enterprise processes at tactical and operational decision levels, and their interactions.

Inter-enterprise Processes / Decision Levels	Order Management Processes	Demand Management Processes	Vehicle Management Processes
Tactical		Demand Port Planning ⟷	Vehicle Port Scheduling
Operational	Execution & Data Flow ⟷		Execution & Vehicle Flow

Figure 2. Scope of the inter-enterprise processes and interactions.

Tactical level decisions rely on anticipation and collaborative planning of shared resources such as gate capacity and ground slot capacity at pre-terminals and terminals, as well as the access roads, with a medium and short-term horizon, preparing for the most likely scenario to occur, and adjusting the available resources of the port. As observed in figure 2, Demand Port Planning and Vehicle Port Scheduling activities belong to this category. Operational level decisions are focused on the day to day events management (very short-term), such as controlling the entry and exit of vehicles, executing a customs process, or the control of the physical and information flows. Execution and Control Data and Vehicle Flow activities belong to this category.

Figure 3 illustrates the interactions among the different scopes of the inter-enterprise processes, divided into planning, scheduling, and execution and control activities cycles. Consider for instance, the centralized operation model. The emphasis of this model is to improve operations at the pre-terminal and terminals to minimize congestion and long waiting times for the external trucks, as well as improve the efficiency on the resource utilization of each facility.

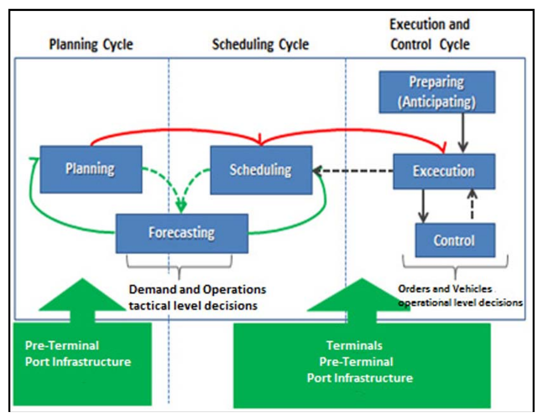

Figure 3. Collaborative Activities Cycles of the PLC.

As observed in figure 3, tactical decisions allow estimating demand and operations planning and scheduling for the corresponding ships to be served during a planning horizon. For each service a stacking window prior to the estimated arrival time of the ship is opened to receive export containers.

Hence estimations of workload flows are based on forecasts, which become real data as long as the arrival time of the ship is closer.

Based on that, operational level decisions related to the execution and control plans for orders and vehicle flows are performed and updated trough the planning horizon which creates interactions between tactical and operational cycles. The added value proposal is associated to the tactical activities at the pre-terminal which is the main source of congestion due to the lack of collaborative planning between the end users of the port (exporters/importers and the port terminals).

For each scope of the LMPS, there exists technological solutions to support decisions which could be either transactional or analytical systems. Analytical systems use heuristic and optimization models to analyze particular elements of the business and to support the decision-making processes, considering different types of constraints, costs, and its real structure, working with aggregated information (Demand Management System and Vehicle Management System). Transactional systems capture, store, and communicate basic data related to material and information flows, such as a customs authorizations, forwarding requests, etc. (Orders Management System and Vehicle Management System).

It is also important to highlight the interactions that exist among the different processes. Tactical decisions are closely interrelated because they are based on the demand that is estimated for a planning horizon. There will be some operations required to be executed in order to fulfill that demand, which should be planned and scheduled. On the other hand, at the operational level, those plans and schedules should be executed.

Systems to control information and physical flows are closely interrelated because the order management system must indicate to each vehicle when to move to the next stage and thus control the service times.

4.2 Technological Platform for the LMPS

The LMPS proposed as part of the framework includes a number of analytical (tactical) and transactional (operational) technologies. The objective of the analytical and transactional technologies is the collaborative management of common resources such as ground slots at pre-terminals and terminals, gate capacity, and aggregated information on workloads over a planning horizon. The intent of this is to increase the productivity and efficiency of the individual stakeholders of the PLC and the performance of the entire PLC. A transversal characteristic of the proposed technological tools is their integrative scheme based on the planning, scheduling and control of activities cycles, as was highlighted in section 4.1.

4.2.1 Demand Management System (DMS)

Activities related to demand management processes are mainly focused on the phases of forecasting and generation of useful information (expected workload). Managers of the terminal use this information for resource planning and short and medium-term scheduling (equipment, space, and human resources). Customs and customs agents use this information to anticipate workloads and to assign personnel to the different functions related to clearance processes. Coordination activities among all the stakeholders involved in the PLC allow improvement of the decision making process for their own resources and for the whole system.

Apart from the provision of basic infrastructure for the transfer of goods between sea and land, multiple services are provided by different agents at ports, such as cargo handling services including cargo consolidation, dispatching and reception of cargo, customs clearance, cargo warehousing, etc. Hence, the PLC must enhance the way information is handled to improve the coordination of terminals and task scheduling. For this, a standardization of the needed data and a collaborative technological platform that integrates the different activities within the PLC should be implemented.

The DMS proposed supports scenario analysis for planning and scheduling of resources in common areas, through the generation of medium and short-term demand forecasts with respect to service capacity. The DMS provides business intelligence to evaluate workload content for task scheduling scenarios and capacity analysis. It also helps to provide terminal managers and other stakeholders involved in the process of coordination with access to standardized information related to task scheduling.

Figure 4 presents a graphical representation of the different business processes supported by the DMS by means of three subsystems: weekly planning of common areas, task scheduling for a three shifts horizon, and scheduling of common areas.

The figure also illustrates the process for coordinating tasks in the terminal and the assignment of resources for customs activities.

Customs inspections (as well as quarantine or other type of inspections) could be performed either at the pre-terminal (for a centralized model), at each terminal or at an independent facility (for the descentralized model) and there should be good coordination with the terminals in order to efficiently segregate those containers requiring inspections and provide good estimations of workload requirements for those inspections.

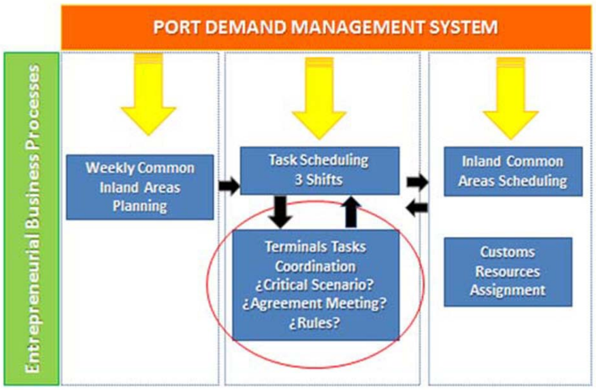

Figure 4. Main business processes involved in the DMS.

4.2.2 Order Management System (OMS)

The OMS aims to organize and coordinate the execution and control of physical and information flows at the port system and constitutes a tool that manages the exchange of information among stakeholders so as to enable anticipated requests or procedures to expedite the physical flow of cargo at the port.

This facilitates the monitoring of activities of the diverse firms at the pre-terminal and terminals, as illustrated in figure 5.

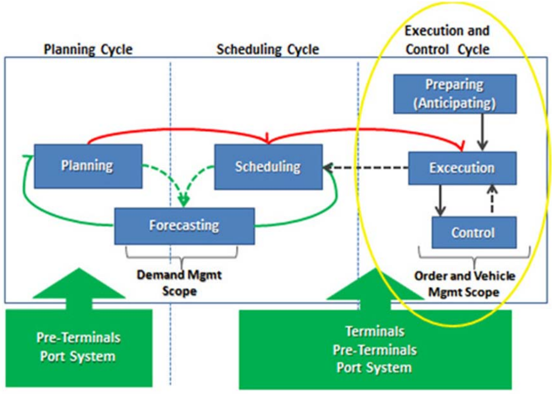

Figure 5. Order Management System as part of the LMPS.

As observed in figure 5, order management is directly associated to the Control Cycle, dealing with on real time information that updates tactical plans, based on the real workload face by the terminal in terms of order requests and vehicle flows at either the pre-terminal and terminals.

The main problems found in PLCs are long waiting times for documentation requirements and procedures, and a lack of integrated information management as a philosophy. Hence, the solution proposed is focused on displaying and integrating information, reducing paper based documents and duplication of information. The OMS defines a conceptual framework to manage the existing orders at the PLC so that export and import flows may be optimized.

The proposed OMS is based on the principles of independence of the physical flows (cargo and vehicle) with the documentation, anticipated customs and port procedures (so as to reduce clearance procedures), standardization and integration of documents, and the incorporation of an electronic platform for authorization procedures that can connect the multiple systems operated by the different stakeholders prior to the arrival to the port.

This solution is a first step for the implementation of a single port window, known as a Port Community System (PCS) that has been implemented in several well developed ports (Port of Singapure, Rotterdam, Valencia, Barcelona, etc.).

We propose the implementation of a single and standard document referred to as the Single Electronic Coordination Document (SECD), that includes customs and port information that is needed for the free flow of the truck and cargo once it arrives to the port. The SECD is a fundamental element for the integration of data among the various stakeholders and seeks to minimize the use of paper documents and double typing of data. It also allows visualizing the physical and documental status of the external and internal customers of the port.

The solution should provide information of anticipated documental procedures prior to the arrival of external trucks to the port and also display the status of the orders at the port, so that the stakeholders involved may have information for decision making and execution control. This could be part of a track and trace system of the port that allows visibility of the cargo for the different stakeholders of the port logistics chain.

4.2.3 Vehicle Management System (VMS)

The VMS should be conceptualized as a support system for coordinating the vehicles at the port and managing vehicle orders. There are two main vehicle flows to coordinate: (a) vehicle flows from and to the hinterland to the port terminal (full containers) and vehicle flows from and to empty container parks; (b) internal vehicle flows and cargo flows within the port. For the first vehicle flow (a), solutions related to Vehicle Booking Systems (VBS) should be implemented, so as to control and reduce congestion and provide more efficient resource capacity utilization of the port terminals, as well as better service standard levels to the external trucks in terms of truck turnaround times.

Management of traffic flow within the port (b) is a shared task among operators and port coordinators (such as the Port Authority) and their efficiency and productivity are critical factors for the customers in terms of service times and associated costs. Tasks at the terminal are of two general types: receiving export cargo and dispatching import cargo. Cargo can be received and dispatched either containerized or as breakbulk cargo. Consolidating and unconsolidating cargo activities could be performed at the port terminals at the Cargo Freight Station area, and corresponds to another type of tasks.

Vehicle flows for the different tasks within the port system should be controlled and monitored so as to avoid congestion and reduce service times. Depending on the complexity of the export and import cycles, there will be different arrival sequences of trucks to the port system, either concentrated at peak periods or previously coordinated with the customer based on booking and appointment systems. The complexity of vehicle coordination is exacerbated when in short periods of time, the arrival of a large number of vehicles for different export and import tasks occurs.

Accordingly, three main principles were considered for the proposed VMS:

• Synchronization between tasks and coordination of the vehicle flow. Tasks should be coordinated among operators and coordinators of the vehicle flows, such that workloads in the different stages of the vehicular circuit are balanced based on specific business rules, both centralized and decentralized according to the logistics operations model of the port. For this, the VMS should support the administration truck flows between the pre-terminal and terminals, authorizations, notifications, and traffic control, and support the physical and documental traceability of trucks.

• Simultaneity of requirements. Along the time horizon, there will be simultaneous and concurrent requirements. Therefore, a synchronized dispatching of vehicles as a function of the different active tasks at the port is required. Each active task has its own requirement of trucks to execute the corresponding activities, and hence, business rules should be defined to manage vehicle flows within the system.

• Visibility of relevant information for vehicle management. Coordinating the work of the various stakeholders within the port requires information on the status of trucks and cargo, the state of the active tasks, the container slot utilization, and the status of requests for the dispatching of trucks to each active task.

Coordination of tasks and orders is based on the utilization of container slots in the port. Along with the visualization of the physical state of the truck, it is necessary to control the utilization level of slots at both the pre-terminal and terminals, which allows coordinating the reception of vehicles that are waiting in previous stages to be serviced. Figure 6 present the cycles in which the VMS provides support, which are related to the execution and control of the arrivals and dispatching of vehicles. These activities involve intensive use of resources in common areas (pre-terminal) and terminal areas, which is an important factor regarding the main problems associated to congestion and delays at the port.

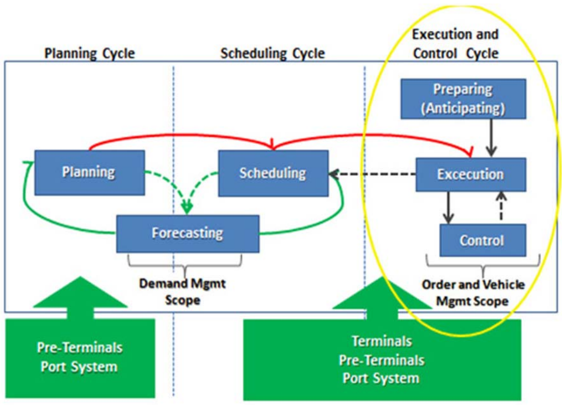

Figure 6. Vehicles Management as part of the LMPS.

The proposed VMS is presented in figure 7. The VMS architecture consists of two layers. At a tactical level, the parameters for the operations and resource planning and scheduling are set (based on a simulation model) that in turns, will be an input for the operational level in which traffic within the port will be coordinated and controlled.

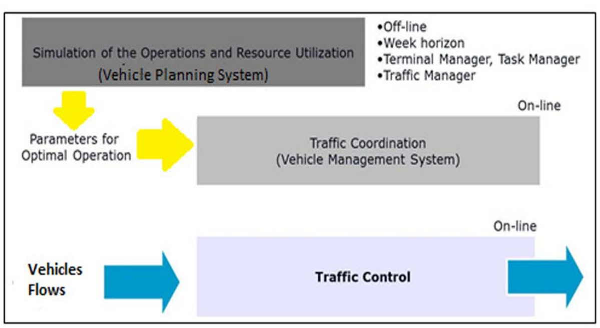

Figure 7. Vehicles Management System Architecture.

5. Case Study of an application of the Collaborative Framework for a Chilean port logistics chain.

We consider a Chilean Port Logistics Chain that operates in the Central Region of Chile. According to the proposed framework, we present a description of each of the three elements for the port system considered. International trade operations in Chile are highly dynamic, evidence of the current integration with world markets. Maritime transport is the most significant mode in Chile, with more than 90% of the cargo transferred through maritime port terminals.

The central region of Chile concentrates more than 60% of the volume transferred within the country and two main Container Ports provide public service. Both are the closest ports to the capital of the country, Santiago (within 100 kilometers), and share the same hinterland. The efficiency of the PLC is a fundamental competitive element.

Management of Port Logistics Governance

In terms of the Management of Port Logistics Governance, a Port Community was established several years ago in which the different stakeholders are gathered, acting as a platform for communication and collaborative analysis of the current processes and continuous improvement opportunities. The Port Community has participated in the process of port modernization both in terms of infrastructure and technology. The Port Community is structured into three committees: the strategic committee, the forum, and the operational committee and operates with work-tables that meet under a defined schedule.

Port Logistics Operations Model

The PLC considered is currently operating under a centralized logistics model with two port terminals and a common pre-terminal (a two stage port system). The Port Authority operates under a landlord scheme, where the two terminals are each operated by a private terminal operator, but one of them recently given in concession (early of 2013) and previously operated by the Port Authority under a multi-operator model. The physical configuration of this port system is common to several Chilean ports due to the lack of space at the terminals.

Some advantages that a centralized logistics model has brought to this port are: integration with access routes, displacement of truck congestion from the terminals to the pre-terminal, reduction of congestion in the city surrounding the port, as well as a reduction of cargo dwell times at the terminal yards, which have very limited storage space.

Logistics Management Platform System

The proposed system integrates three interrelated business cycles: the port planning cycle, with a planning horizon of a maximum of a week or 21 shifts, each of 8 hours; the resource scheduling cycle, with a time horizon of 2 days, the execution and control cycle, in which the focus is on the management of service orders and the control of the vehicles, cargo, and the associated documentation.

a) Demand Management System

Anticipated information related to the workload content of the different areas of the port, considering the pre-terminal, terminals, and the active and prospective tasks within a planning horizon is required.

Hence a demand management system is proposed with the aim to forecasting demand on a determined planning horizon.

The DMS considered two types of forecast models to estimate workload content: static and dynamic (see figure 8).

The static forecast model works with a planning horizon of one week and provides aggregated information on workload content for the PLC in terms of the currently active and prospective tasks to be executed.

The dynamic forecast model estimates workload content for active tasks at the port for the next shift. Both forecasts models should be updated and can be related also to a Truck Appointment System.

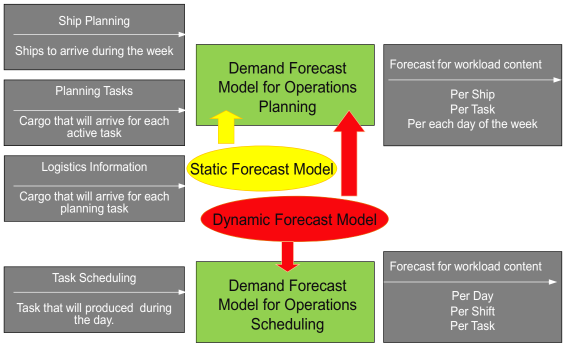

Figure 8. Demand Management System Architecture.

b) Order Management System

In order to implement the OMS, we consider the direct dispatching of import container flows, incorporating the functionalities of anticipated procedures, the integration of information in a single document (SECD), and traceability.

The OMS incorporates the required orchestration to control and execute activities within the PLC, integrated with the VMS that will be described below. Figure 9 presents an example of the relationship between the OMS and the related activities for this flow, as well as the systems of the stakeholders involved.

c) Vehicle Management System

The port system under consideration lacks of coordination with its hinterland and road access to the gate of the terminal. This impacts the service variables such as the vehicle times in system, asset opportunity costs, and service quality.

Synchronizing coordination and operations is hampered by a lack of standardization in procedures, a lack of accountability in the use of common areas for parking, inefficiencies in the operation of tasks, a lack of technological support, and paper based documental procedures.

The proposal for the VMS is based on a Kanban system that relies on the principles of the Just in Time philosophy [33], in which execution and control activities are based on a pull system.

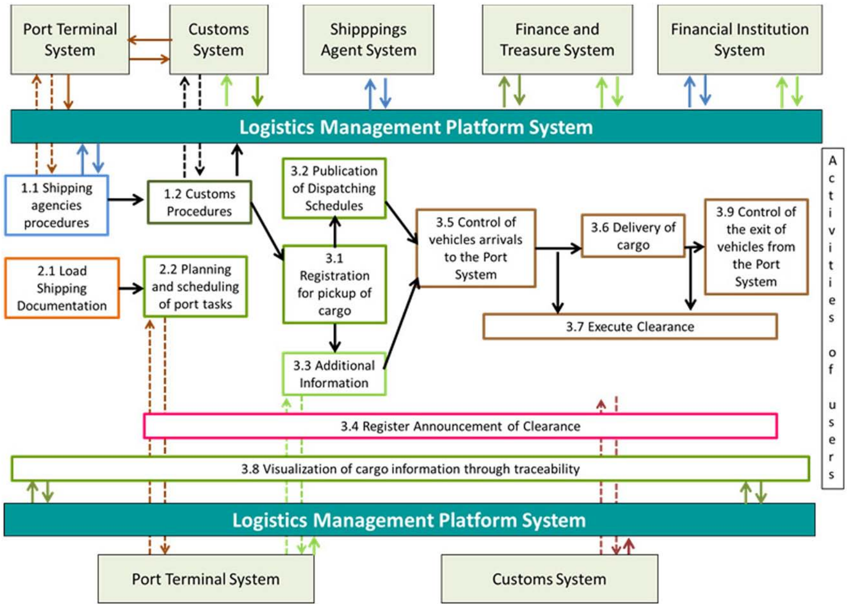

Figure 9. Orchestration of the direct dispatching of import containers flows within the OMS.

Thus, the last stage of the process activates the material requirements or flows for earlier stages, achieving production in the right amount and at the precise moment that it is needed. In this case, requirement flows consist of the external trucks that arrive to the pre-terminal and wait until the corresponding terminal requests them to deliver or pick up a container.

Monitoring activities should provide basic control information, both for the trucks and for the status of the pre-terminal and terminals, allowing an efficient synchronization of vehicles in the different stages of the process.

In order to estimate the operational parameters, a simulation model was implemented, modeling the port system as a queuing network with two stages (see figure 10), with pre-stacking and stacking zones.

A common area for parking slots in the pre-terminal and an assigned area for parking slots in the pre-stacking and stacking areas are considered in the system, as well as a buffer area of parking slots that is used for vehicles waiting to be served.

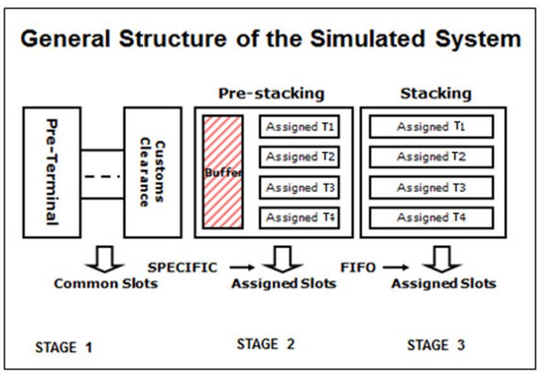

Figure 10. General Structure of the Simulated System.

The simulation model evaluates different parking space configurations with respect to the number of slots in the terminal, in the pre-stacking area, and in the buffer area. The performance indicators utilized were the average waiting times for the vehicles in the port system and the utilization of space.

Given that the main congestion problems arise at the fruit season (January to April), we consider a sampling of truck arrivals during that period and analyzed only the fruit logistic chain. Based on data published by the port authority, service times for external trucks at peak periods are about 8.58 hours on average in 2009 (Port Authority of Valparaiso, 2010). This considers only when the truck enters to the pre-terminal, waits for the service at the terminal (which includes a service times of 2 hours and 42 minutes on average) and departs. Hence, waiting times at the pre-terminal could be about 6 hours. This could be due to external and internal factors and the objective is to understand the internal factors that could reduce waiting times.

The simulation model considered 73 tasks during which 17,317 trucks arrive to the system, from which 53 tasks corresponded to the main container terminal and 20 to the second terminal previously operated by the Port Authority. Considering the same service times at the terminals, simulation results show a reduction of about 1 hour of waiting times at the pre-terminal on average, which resulted in 17,000 truck-hours reduction per month.

Further improvements can be achieved if the vehicle management system includes a Truck Appointment System so that trucks provide anticipated arrival information to the port and the port terminal managers perform tactical capacity planning and better resource utilization to increase standard service levels to the users.

6. Conclusiones and Recommendations for further research

A Collaborative Logistics Framework for a port logistics chain is presented based on the application of SCM principles that rely on an integral improvement of the multi-enterprise operations, based on the integration of the business processes of the PLC with its stakeholders. This new approach aims to provide a reference model for the coordination of the PLC in terms of infrastructure, common resources, and the information that supports collaborative decisions making.

The proposed collaborative framework comprises three main dimensions: the Management of Port Logistic Governance, (b) the Logistics Management Platform System (LPMS) and (c) the Port Logistics Operations Model. The framework is focused on the design and implementation of the three inter-enterprise business processes of the PLC: demand management, orders management, and vehicles management. These collaborative processes are developed at a tactical (planning and scheduling) and operational (control and execution) levels. The global objective of these inter-enterprise processes is the coordination of common resources and the reduction of operational variability.

The LMPS is implemented based on three collaborative information systems: the demand management system, the orders management system, and the vehicle management system. These systems allow the administration of the cycles of planning and scheduling of common resources of the PLC, and the control and execution cycles for those operations required for the import and export flows at the PLC.

The proposed framework has been validated with respect to a real PLC in Chile. The Management of Port Logistics Governance is based on the existence of a Port Community that provides a platform for coordination and continuous improvement of the inter-enterprise processes, facilitating the physical and information flow among the private and public stakeholders that are involved in international trade processes.

A key principle considered in the framework is the anticipation of information related to workload cargo in order to support the synchronization of activities among stakeholders involved and the demand flows, as well as to support decision making related to the assignment of resources. Furthermore, it is fundamental to improve coordination between the CLP and the hinterland in terms of implementing a Vehicle Booking Systems (VBS) that may enhance better resource utilization at the terminal and the minimization of truck turnaround times. VBS may also potentially impact the transport chain by providing information that allows the generation of round trips at the port and street-turn opportunities at the hinterland (match empty equipment needs so they can interchange empty containers without first returning them to an empty container park), which in turn, minimizes empty trips and congestion at the PLC.

For further research we propose to analyze the impacts of a Truck Appointment System for improving vehicle and information flows at the port, such that service times at the port system may be reduced and external trucks may be able to increase their productivity. Roundtrips or "double appointments " at the port terminals could be also explored (i.e. a truck delivering an export container and picking up an import container).

Also, as further research, the impacts on resource utilization and efficiency of internal operations based on a Truck Appointment System along with the proposed collaborative framework could be analyzed. The VMS proposed could be also implemented for a descentralized logistics operation model in order to analyze impacts in terms of congestion and pollution at the access of the port with the corresponding adjustments for this type of system.

Acknowledgements

This research has been performed within the scope of the Project FIC-P59 "Improvement of competitiveness standards of the logistics service network of Arica and Parinacota" of the Industrial Engineering Area, sponsored by the Regional Government of Arica and Parinacota.

References

[1] R. Gaurav, "Closed loop transport management", Logistics & Transport Focus, Vol. 6, No.9, 2004, pp. 44-7.

[2] Ch. Feng, and Ch. Yuan, "Application of Collaborative Transportation Management to Global Logistics: An Interview Case Study", International Journal of Management, Vol. 2, No. 4, 2007, pp. 623-822.

[3] A. Gunasekaran, K. Lai, and T.C.E. Cheng, "Responsive supply chain: a competitive strategy in a networked economy", Omega, Vol. 36, 2008, pp. 549 – 564.

[4] E.A. Morash and S.R. Clinton, "The role of transportation capabilities in international supply chain management", Transportation Journal, Vol. 36, No.4, 1997, pp. 5-17.

[5] G. Steffanson, "Collaborative logistics management and the role of third-party service providers", International Journal of Physical Distribution and Logistics Management, Vol. 36, No.2, 2006, pp. 76-92.

[6] T. Notteboom, and J.P. Rodrigue, "Re-Assessing Port-Hinterland Relationships in the Context of Global Commodity Chains", In: J. Wang et al. eds: Inserting Port-Cities in Global Supply Chains. London: Ashgate, 2007.

[7] R. Narasimhan and J. Jayaram, "Causal Linkages in Supply Chain Management: An Exploratory Study of North American Manufacturing Firms", Decision Science Journal, Vol. 29, No. 3, 1998, pp. 579-605.

[8] M.T. Frohlich and R. Westbrook, "Arcs of integration: an international study of supply chain strategies", Journal of Operations Management, Vol. 19, 2001, pp.185-200.

[9] C. Armistead and J. Mapes, "The impact of Supply Chain Integration on Operating Performance". Logistics Management Information, Vol. 6, No. 4, 1993, pp. 9-14.

[10] A. Pires, G.Putnik, and P. Ávila, "A survey analysis of the resource selection models in Agile/Virtual Enterprises", Journal of Applied Research Technology. Vol. 10, 2012, pp. 416-427.

[11] H. Stadtler, "A framework for collaborative planning and state-of-the-art", OR Spectrum, Vol. 31, 2009, pp. 5-30.

[12] J. Sutherland, "Collaborative Transport Management Creating Value Through Increased Transportation Efficiencies. Business Briefing: Pharmagenerics", Transport and Logistics Packaging, 2003, pp. 88-91.

[13] T.M. Simutupang, and R. Sridharan, "The collaborative supply chain". International Journal of Logistics Management, Vol. 13, No, 1, 2002, pp. 15-30.

[14] Ch. Chandra and S. Kumar, "Supply chain management in theory and practice: a passing fad or a fundamental change?", Industrial Management and Data Systems.Vol. 100, No. 3, 2000, pp. 100-114

[15] C.J. Corbett and U.S. Karmarkar, "Competition and Structure in Serial Supply Chains With Deterministic Demand". Management Science. Vol. 47, No.7, 2001, pp. 966-978.

[16] T. Efendigil, S. Önut, and E. Kongar, "A holistic approach for selecting a third-party reverse logistics provider in the presence of vagueness", Computers & Industrial Engineering, Vol. 54, No. 2, 2008, pp. 269-287.

[17] M.G. Cedillo-Campos and C. Sánchez-Ramírez "Dynamic Self-Assessment of Supply Chains Performance: an Emerging Market Approach", Journal of Applied Research Technology. Vol.11, 2013, pp. 338-347.

[18] K. Cullinane, D.W. Song, and R. Gray, "A stochastic frontier model of the efficiency of major container

terminals in Asia: assessing the influence of administrative and ownership structures", Transportation Research, Vol. 36A, 2002, pp. 743-762.

[19] J. Tongzon and W. Heng, "Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals)", Transportation Research Part A, Vol. 39, 2005, pp. 405–424.

[20] T. Notteboom, and J.P. Rodrigue, "Port regionalization: towards a new phase in port development". Maritime Policy & Managemegnt, Vol. 32, No. 3, 2005, pp. 297-313.

[21] G. Araujo De Souza, A.K.C. Beresford and S.J. Petit, "Liner Shipping Companies and Terminal Operators: Internationalisation or Globalisation?", Maritime Economics & Logistics Vol. 5, 2003, pp. 393–412.

[22] R. Gaurav, "Closed loop transport management", Logistics & Transport Focus, Vol. 6, No.9, 2004, pp. 44-7.

[23] P.W. De Langen, "Analysing the Performance of Seaport Clusters", in: D. Pinder and B. Slack (eds) Shipping and Ports in the 21st Century, 2004, pp 82-98, London: Routledge.

[24] P.W. De Langen and E.J. Visser, "Collective action regimes in seaport clusters: the case of the Lower Mississippi port cluster", Journal of Transport Geography, Vol.13, No. 2, 2005, pp. 173-186.

[25] D.W. Song and Ph.M. Panayides,"Maritime Logistics: A Complete Guide to Effective Shipping and Port Management", London: Kogan Page, 2012.

[26] M.R. Van der Horst and P.W. De Langen "Coordination in hinterland transport chains: a major challenge for the seaport community", Maritime Economics & Logistics, Vol. 10, No. 1, 2008, pp. 108-129.

[27] C. Ducruet, C. Rozenblat and F. Zaidi, "Ports in multi-level maritime networks: Evidence from the Atlantic (1996-2006)", Journal of Transport Geography, Vol.18, No. 4, 2010, pp. 508-518.

[28] J. Tongzon, Y-T Chang, and S-Y Lee, "How supply chain oriented is the port sector?", Internatinoal Journal of Production Economics, Vol. 122, 2009, pp. 21-34.

[29] Ascencio, L.M., González-Ramírez, R.G., Torrejón, P., Technical Report No. 2- Port Logistics Community of San Antonio. Pontificia Universidad Católica de Valparaíso, 2010.

[30] B. Almotairi and K. Lumsden, "Port logistics platform integration in supply chain management", International Journal of Shipping and Transport Logistics, Vol. 1, No. 2, pp. 2009, pp.194-210.

[31] T.E. Notteboom, and W. Winkelmans, "Structural changes in logistics: how will port authorities face the challenge?". Maritime Police & Management. Vol. 28, No.1, 2001, pp. 71-89.

[32] D. Simchi-Levy, P. Kaminsky and E. Simchi-Levy, "Designing and Managing the Supply Chain. Concepts, Strategies and Case Studies". Mc Graw-Hill, Second Edition, 2003.

[33] W.J. Hopp, and M.L. Spearman, "Factory Physics-Foundations of Manufacturing Management", Irwin, Homewood, IL, 1996.