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Original Paper

An Application of Design Research to an Offshore-Supply Port Operation

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Abstract

This article presents a method for intervening systemically to structure port operations using Business Problem-Solving. First, the concepts associated with logistics and supply chain are presented in order to establish the basis for the proposition that ports be regarded as links in a chain. From that integrating perspective, methods and techniques can be applied more appropriately to port operations and contribute to surmounting partial approaches. Theoretical frameworks are then proposed to characterize and analyze how a particular port operates, with emphasis on decisions and processes that guide cargo movement and resource allocation necessary for the cargo cycle. The proposed method is applied to a private port which supports all the oil rigs of a basin in southeast Brazil, and through it are conducted operations that provide offshore logistical support. Completion of the method's problem definition, analysis and diagnosis stages culminates in the proposal of a new integrated model of scheduling.

Keywords

port, logistics, method, design research

1. Introduction

Among the activities required for offshore oil exploration – which is gaining increasing importance in discussions relating to the pre-salt deposits (JONES & CHAVES, 2011) – upstream and downstream logistics activities feature prominently (EDWARDS & WOO, 2006). The former activities (the subject of this article) are those necessary to supply offshore installations, and the latter, those carried out in order to bring fuels to the end consumer.

Edwards & Woo (2006) stress that upstream logistics planning is complex as a result of various factors. In the first place, although the cost of operating offshore support vessels is very high, the cost of halting extraction activities for lack of supplies can be much higher. Supply storage space on oil rigs is limited, and there are climate and stochastic factors involved.

The growth of oil exploration off Brazil's coasts is beginning to run up against the constraints of Brazilian port infrastructure (FERRO & TEIXEIRA, 2009), which was already being signaled as saturated by FERRAZ (1986). With constant discoveries of new oil reserves, and the first pre-salt fields coming on line, the trend is for the volume of cargo transported to increase by more than 60% by 2016 (ALBUQUERQUE, 2010). That increase in demand prompts calls to expand port capacity, which can be addressed by extending existing port installations and/or building new ports. Whatever the approaches chosen, all entail solutions to structure port operations management, and not incremental add-ons to the existing model of functioning.

Taneja *et al.* (2010) identifies the main functions of ports as being: (1) providing appropriate facilities for efficient cargo throughput; (2) offering vessels appropriate sea access best suited to their most efficient operating cycle; (3) ensuring vessel safety on access, departure and within the port basin, as well as safety of life and limb within the port confines; and (4) ensuring appropriate, efficient environmental protection. These functions alone already pose major challenges for achieving efficient port operation (BICHOU, 2007), and to them must be added the explosive demand originating in offshore operations on pre-salt fields (JONES & CHAVES, 2011).

Alderton (2008) argues that an efficient port must minimize vessel laytime, that is, the sum of the times taken for the vessel to berth, load/discharge and be released. Port efficiency is also evaluated by operating performance, existing infrastructure, and levels of operating safety. Efficiency is generally measured using performance indicators, which, as an example, focus on the number of vessel movements per hour, and the number of movements per total terminal area. This kind of performance indicators however leads to a partial view of operations efficiency, losing sight of the overall logistics approach, which affects total productivity (NOTTEBOOM & RODRIGUE, 2005).

These approaches are insufficient to meet the need to formulate a solution to structure port operations. The literature on port operations centers on discussing models of regulatory framework, and models for pricing and selecting private ports (ALDERTON, 2008). That focus can be explained by the centrality of ports as external actors, as service providers. This is not the case with the operation in question, which because it is so high-volume, and specific and critical to the business, is verticalized.

In that context, this article proposes to present a logistics- and supply chain-related theoretical framework, and to relate it to proposals in which the port is treated as part of that chain. To the extent that a port is understood on that integrative approach, methods and techniques – those of operations scheduling for instance – can be more appropriately applied, and contribute to surmounting partial approaches (BICHOU & GRAY, 2004).

On that view, this study proposes to establish a method for systemic intervention to structure port operations. As will be described in the course of the article, the Business Problem-Solving (BPS) method was applied at a private port that supports all the oil rigs in a basin in southeast Brazil, and through which offshore logistic support operations are conducted. This port is under pressure to rethink its activities, at the same time as it has to deal with the constraints of the town where it is sited. The article goes through the problem definition, analysis and diagnosis stages, culminating in a proposal for a new model of integrated scheduling.

In order to set out that content, the article is organized as follows: first, the theoretical frame of reference, including the concept of logistics and supply chain, is set out, followed by a description of the ports, and the proposal by some authors that port operations be approached from a logistics standpoint. Second, the methodology employed and the research problem are stated. Third, a practical application of the BPS cycle in the port operations supply chain is described, its study object being the planning and operations to serve offshore units. Lastly, some final remarks are offered on issues relating to the proposed method and its applicability, as well as assessments of the study outcome in terms of the organization of the case object.

2. Theoretical Framework

2.1 Logistics and Supply Chain

Logistics is a relatively new field in business. Although many of its concepts are in widespread use, it is only in the last 20 years that the concept of logistics has come to be seen as an integrated set of activities within a systemic operations process (BALLOU, 2007). Accordingly, there are various ways of defining logistics, depending on the literature considered. The Council of Logistics Management (in BALLOU 2007) states that logistics can be defined as "the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of conforming to customer requirements".

Ballou (2007) argues that this definition suggests logistics is a process, meaning it includes all the activities that are important to making goods and services available to consumers. The definition thus implies that logistics is part of the supply-chain process. Chopra & Meindl (2003) regard the supply chain as consisting of all the stages directly or indirectly involved in filling a customer order. The supply chain includes not only a manufacturer and its suppliers, but also carriers, warehouses, wholesalers, retailers and the customers themselves. Within each organization, such as a manufacturer, the supply chain includes all the functions involved in filling an order. Those functions include, but are not limited to, new product development, marketing, operations, distribution, and financial services to the customer.

Simchi-Levi (2008) define supply chain management as "a set of approaches used to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed in the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying customer level requirements".

The logistics process permeates the whole supply chain involving a firm, both as regards its internal processes, which have to be managed within the firm, and the external processes, relating to suppliers and customers outside the firm's boundaries. Logistics is a system of interdependent activities, while the logistics process is the overall process that integrates all these activities, crossing the firm's boundaries and involving all the links in the production chain (INTERNATIONAL, 1997).

Stank, Keller & Daugherty (2001) identify the key concepts behind this definition as being cycle compression, cost reduction, process integration, planning and control, collaboration agreements and relationships of trust, focus on the customer, value creation and value chain analysis, and a system perspective. Some studies have already made headway towards applying these concepts in an integrated fashion (MASON & LALWANI, 2006; TANG, 2006).

2.2 The Port from a Supply-Chain Standpoint

Brazil's port sector is the second most important in the national transport system, after the highway sector (LACERDA, 2005). It is one of the most important modals for Brazil's industry and logistics (MARCHETTI & PASTORI, 2007).

Ports can also be defined as points of integration between land and sea modes, with the additional function of buffering the impact of cargo flows in the local routeway system by storage and physical distribution (ALDERTON, 2008). From the logistics standpoint, the port is regarded as a channel where intermodal transports intersect and, at the same time, the site where a logistics center operates with supply chain resources and personnel (Bichou, 2007). The port is also considered one of the few places that foster networking among various supply chain actors and channels.

Notteboom & Rodrigue (2008) divide port operations into two types: the main operation, which consists in goods movement as such (loading, discharging, storage and tax clearance); and the additional complementary operations, which enable goods movements to take place, such as goods identification, customs procedures, damage inspection, and information systems (HELLSTROM, 2009).

Valentine & Gray (2001) define ports as complex organizations with a diversity of inputs and outputs, embodied in various different physical, access, logistic, and legal features. Bichou (2004) notes the ports are considered complex, dynamic entities, where many activities are pursued by a variety of actors and organizations to serve a variety of other actors and organizations. They are often very specific and differ greatly from one another, which raises their level of complexity still further. Another conception of support, proposed by Bichou & Gray (2004: 47), states that "ports are complex and multipart organizations in which institutions and functions often intersect at various levels".

Magala & Sammons (2008) explain the importance of conceiving of ports from a logistics standpoint. Bichou (2007) regards that perspective as highlighting the relationship among the links in the logistics chain, and associates the degree of process integration with the efficiency of the logistics operation. The supply chain management approach is fundamental to designing, managing and integrating the various operations in such a way as to achieve the main goal of port operations, which is to optimize the flow of goods.

Bichou (2007) offers a proposal for orienting port operations that is separated into operational and strategic levels. At the operational level are the movements, operations and processes relating to a network of activities. It is conceptualized in terms of channels, which are pathways "tracing the movement of a cargo-shipment across a typology of multi-institutional and cross-functional cluster alignments", and flows, which are "the derived transactions (business interactions) between various functional-institutions within each channel. Thus, the nature and number of channels and flows will depend on each port or terminal, and may change over time and space".

The strategic level, meanwhile, is concerned with establishing long-term strategies (for example, traffic forecasting and strategic planning) relating to external actors. For example, management of empty packaging (reverse logistics), which can also be explained in terms of the carriers' strategic decisions. In this case, the emphasis on the logistics channel suggests that the choice of container transport network, including the choice of port, should be made at the level of the logistics provider (e.g., carrier) and not at the level of the company (e.g., shipper or manufacturer) or industry (e.g., container trade).

Accordingly, in logistics terms, the port is a channel where intermodal transport intersects and, at the same time, it is where a logistics center is operated with resources and personnel. Bichou also identifies ports as one of the few places that promote networking among several supply chain actors and channels, which can be represented as in Figure 1.

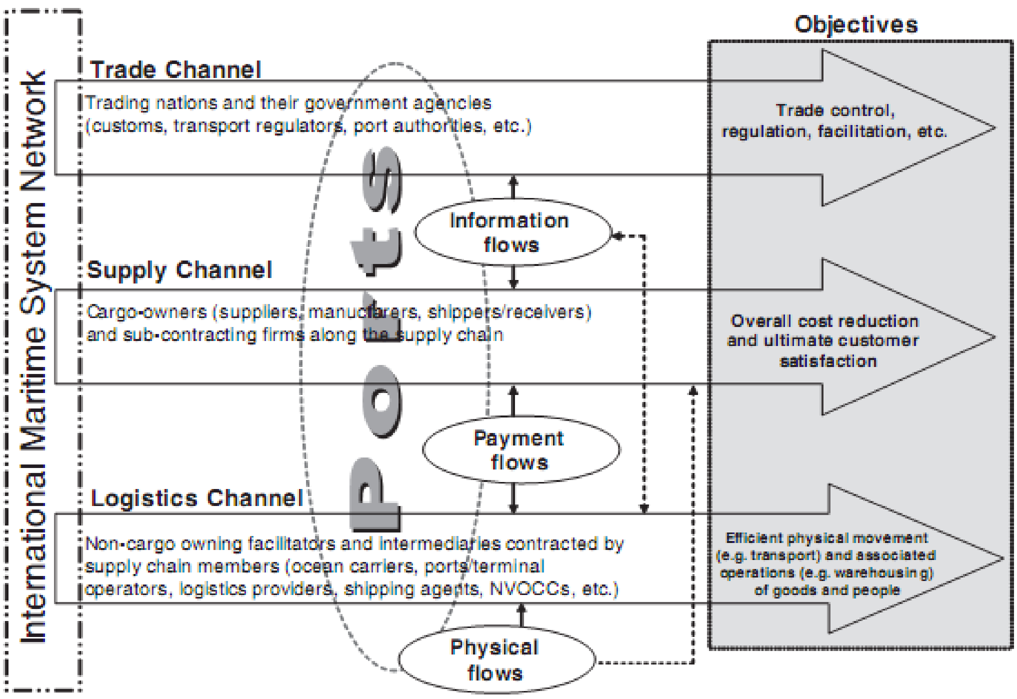

Figure 1. Channels and components of the port system

Source: BICHOU (2007:587)

3. Research Question and Methodological Approach

Lakatos & Marconi (1990) describe a working method as a set of systematic rational activities that guide and underpin the generation of valid knowledge, thus steering the course to be followed. This section sets out the proposed research method, which is based on the theoretical framework above, and intended for practical application to the port operations of a supply chain.

3.1 Design Research and Business Problem-Solving

Design science, derived from the sciences of the artificial proposed by Simon (1996), seeks to develop multidisciplinary knowledge directed to solving problems that are important from the practical point of view, focusing mainly on the process used to arrive at the solution (VAN AKEN, 2005). Such knowledge will be used by professionals called "designers" to design and implement custom solutions to a problem in their field of activity (VAN AKEN, 2004; VAN AKEN, 2005; DENYER *et al.*, 2008). The knowledge generated in approaches using design research is more pragmatic than the scientific knowledge generated by other descriptive research methods (VAN AKEN, 2005; DENYER *et al.*, 2008).

The method used in this study is business problem-solving (BPS). BPS was developed to assist management students, whose training is directed to a analyzing, and proposing solutions to, existing problems. In that respect, it was developed not to produce a design of "what is", but rather to propose a design of "what could be" or "what should be", seeking to increase the performance of a business, department or firm, following a more operational logic, related to business process efficiency or efficacy.

VAN AKEN (2007) examines the "regulative cycle" proposed by Van Strien in 1997. Figure 2 shows the basic process that guides this BPS cycle. The process is usually accomplished through a design in which, jointly and in collaboration with representatives of the organization, the designer develops a solution focused on improving the organization's performance.

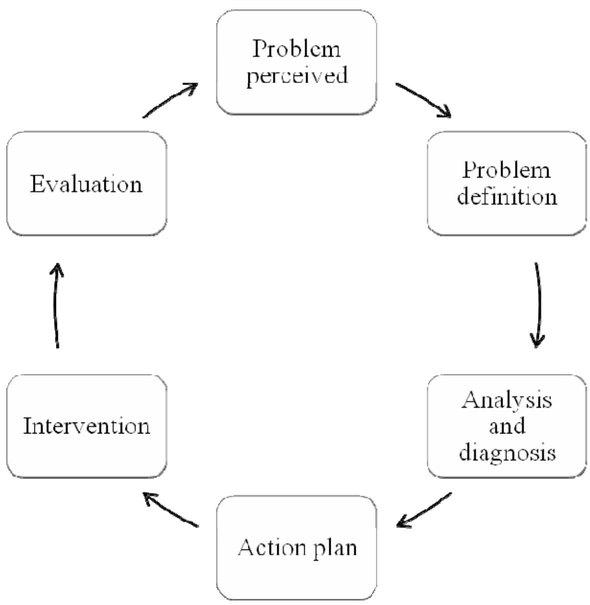

Figure 2. The Business Problem-Solving regulative cycle

Source: VAN STRIEN in VAN AKEN (2007)

The process (or project) starts with definition of a problem perceived by the organization. That definition, considered one of the most important components guiding the solution to the problem, is formulated collaboratively by the designer and the stakeholders involved in the process (KEYS, 2007). The following stage is considered the analytical part of the process, in which quantitative and qualitative research techniques can assist in interpreting the problem and developing a diagnosis, always considering the specific organizational context. The “action plan” stage involves developing the solution to be applied to eliminate or mitigate the problem identified, along with a plan for intervention in the organization. It is at this stage that the literature can once again assist by offering solutions that can be used, by way of existing construction principles and technological rules. Lastly, the introduction and evaluation stages involve applying the solution defined previously and evaluating whether or not the expected results have been achieved (VAN AKEN, 2007).

3.2 The Perceived Problem: Need for Solutions that Structure

The problem examined in this study was perceived in Brazil's second-largest port in number of berthings. The port is part of the logistics support structure of the fourth-largest energy corporation in the world – according to the agency Platts (2011), one of the world leaders in information on energy and commodities – and is the third-largest oil and gas corporation, according to a study by the consulting firm PFC Energy (2011).

This port serves as support for all the oil rigs in a basin in southeastern Brazil, and through it operations are conducted to provide offshore logistics support. Through the port’s six berths, a series of products are embarked, from equipment needed for offshore exploration and production to supplies to maintain the company's resources. Particularly important are bulk shipments of diesel and heavy materials, which call for large equipment to tow and position rigs, lower anchors and cables, nearly all loaded and transported by vessels that need specific infrastructures in order to operate (VARGAS & COUTINHO, 1997). Figure 3 shows the position of the port in question in the supply chain.

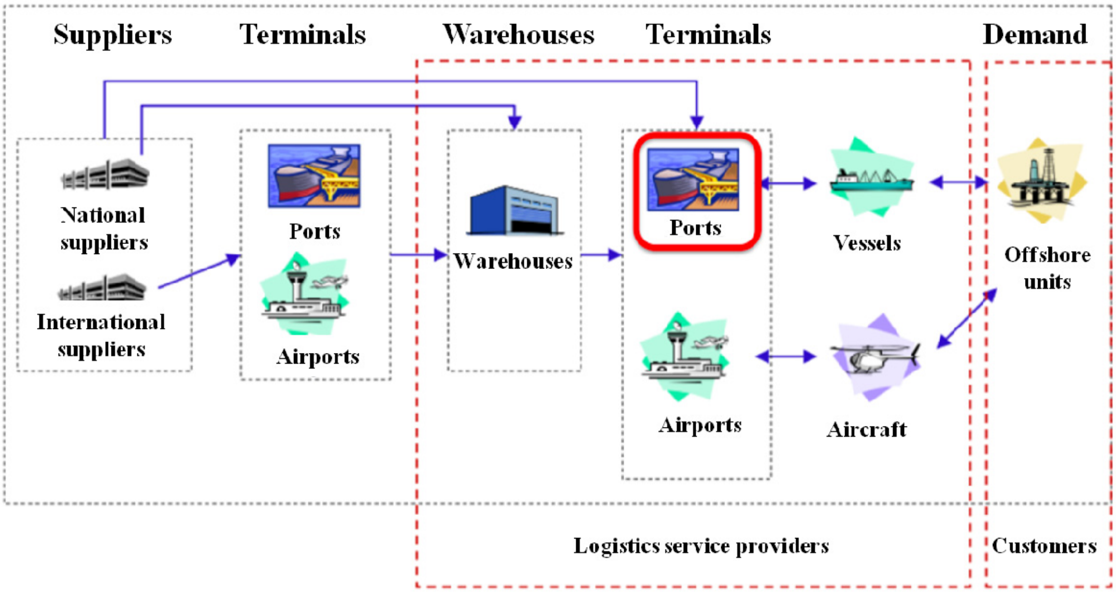

Figure 3. Position of the port studied in the supply chain

Source: the authors.

The town that today is the center of the oil and gas exploration industry in southeast Brazil was previously a small town with an economy built basically around agriculture (sugarcane), cattle farming and fishing. According to Brazil's official statistics agency (IBGE 2010), it is the Brazilian municipality that has developed most from the 1970s to date. Unprepared for the impacts resulting from migration processes, it seen its population grow by some 440% in 36 years, at an annual average of 12.23%, from 47,000 in 1974 to 206,000 in 2010.

The offshore oil and gas exploration industry currently involves about 60,000 workers in firms directly connected with exploration, plus another 50,000 working indirectly (COSTA LIMA *et al.*, 2010). The most important local impacts include settlement of risk and preservation areas, the growth of shantytowns and poor outlying neighborhoods with no infrastructure, growing demand for public services, increasing violence and drug trafficking, rising cost of living, real estate speculation, and collapsing traffic systems (TAVARES, 2010). Traffic flows today represent, on average, 25,000 automobiles and 700 trucks per day. This scenario has led the city government to pass decree restricting cargo vehicle traffic to certain hours.

On the one hand, there are boundary conditions intrinsic to the town where the port is located: constraints on geographical expansion, both physical and imposed by environmental regulations, and constraints on materials flow throughputs, including the traffic constraints in the town, as mentioned above. On the other hand, with the prospects of growth in offshore exploration, there are pressures to improve performance and to expand the port's capacity.

This situation is aggravated by expectations in relation to exploration of the pre-salt oil fields. Platts (2011) refers to the pre-salt discoveries as “one of the largest oil discoveries of recent decades”. Jones

& Chaves (2011) report it was possible to suggest that within probabilistic confidence levels of 95% and 5%, field sizes expected will range from 165 million barrels to eight billion barrels, and total accumulations will range from 115 billion barrels to over 288 billion barrels.

In the view of Claudio Paschoal, Distribution, Logistics and Transportation manager of the firm's research center, Brazil's current economic development requires that companies realign their strategies for production and logistics. Exploration of pre-salt oil will require that the firm's logistics capacity double, and expenditure to meet demand will grow in almost same proportion, according to its general manager for logistics, Ricardo Albuquerque. Logistics has to accompany the pace of growth in production, which will rise from the current 2.7 million barrels a day to 5.3 million barrels per day in 2020, representing a 7.1% yearly increase.

The firm estimates that logistics will grow by 30% in two years and by 100% in five years. Oil production will double in a decade, but in order for that to occur, logistics capability must double in a shorter time frame. The expectation is that, to meet the needs of pre-salt production, passengers transported will double from 750,000 to more than 1.4 million per year by 2016. The number of support vessels will also increase from the present 240 to around 500 by 2016 (COSTA LIMA *et al.*, 2010).

Given this growth outlook for the short and medium term, the firm faces the need to make a quantum jump. This is not possible without expanding infrastructure, considering the nominal capacities and the urban constraints. The company intends to build new airports, to expand existing ones, and – for its own account or in partnership – to build new port terminals around Brazil (ALBUQUERQUE, 2010). It should be stressed, however, that the better its operation in the existing ports, the smaller will be its need for new ports.

This paper avails itself of the structure for intervention provided by BPS in order to assist overall improvement in port operations, while helping address the challenge posed by pre-salt oil and respecting the urban constraints of the municipality in question. The sections below present a meshing set of methods derived from the BPS proposals, in order to address a complex problem, i.e., the endeavor to encounter a solution to structure the offshore logistics support operations of a firm in rapid expansion and facing explosive demand growth.

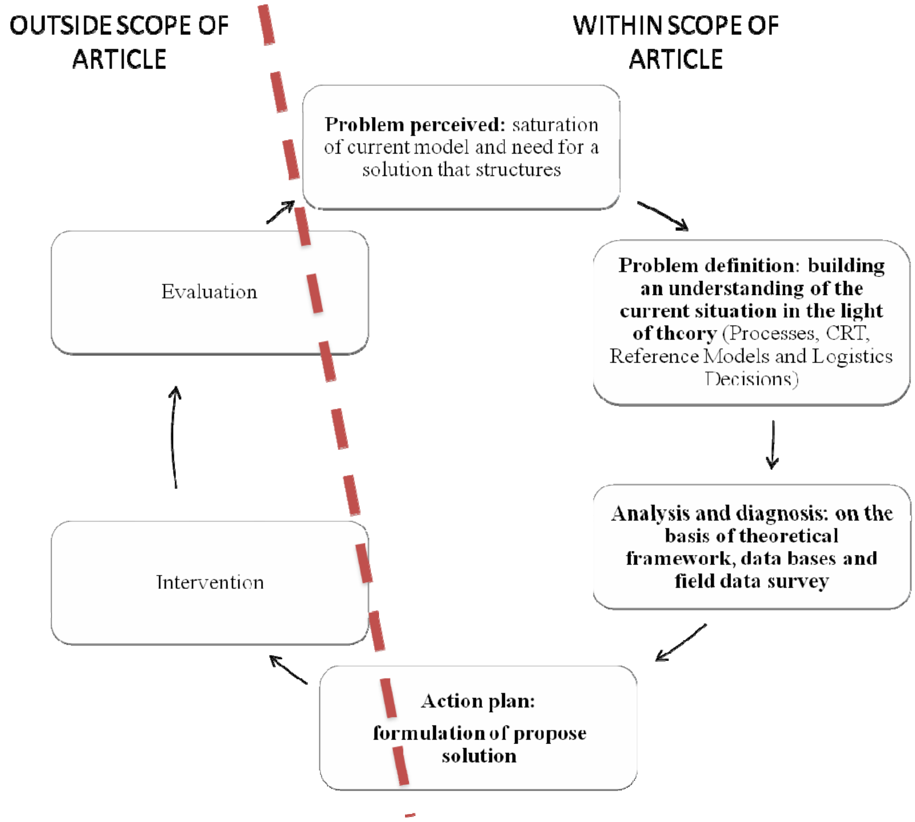

Figure 4. The research method in view of the Business Problem-Solving regulative cycle

Source: the authors.

4. Problem Definition: Building Understanding of the Current Situation in the Light of Theory

Once the problem was perceived, the definitions stage was begun by exploring the understanding of the current situation. That understanding was guided by the explicit formulation of the port's functioning in the light of theoretical frameworks which will be detailed in the sections below. The toolkit used included process mapping, representation according to a SCOR supply chain reference model, representation of the logistics decision-making network, and definition of the structure of the cause and effect relationships of the problems perceived by the process stakeholders. The information source used in all the methods was semi-structured interviews of the management staff involved with port planning and operation.

4.1 Process Mapping

A process is defined as a specific ordering of work activities in time and place, with a start, an end, and a clearly defined set of inputs and outputs (DAVENPORT, 2000). Processes can be understood better if understood as a logical and temporal structuring of actions and resources for the purpose of generating one or more products and/or services for the organization's customers (VILLELLA, 2000).

Process Engineering is designed to arrive, by identifying and representing organizational processes, at a critical analysis of an organization's processes, so as to permit improvement in its operations

(DAVENPORT, 2000). Once the interdependence among function-related activities is perceived, that insight permits and leverages discussion of the problems and their undesirable effects throughout the organization.

This approach seeks not just to optimize activities locally, but to contribute to improving the organization's end products and services. Process modeling is the main tool available for conducting organizational process actions. Its purpose is to represent processes so as to provide inputs for analysis with a view to improving the way the various organizational functions work together (VERNADAT, 1996).

After surveying data on the workings of the port, and particularly having semi-structured interviews of the firm's managerial staff as a source, it was possible to state the sequence of activities explicitly in a diagrammatic model. The process macro-flow was traced, contemplating the overall operation from the arrival of cargo at the warehouse through to loading at the port. Once the macro-process was mapped and validated, also in consultation with the managerial staff, it was classified by activity, actor, timing, systems, and indicators for each area.

The activities performed in the course of the macro-process were associated with their respective actors: warehouse operation – ARM; port operation – OPRT; cargo planning and control – PCC; and maritime cargo transport – TC. To make it easy to identify the activities under the responsibility of each actor, the flow is shown in colors in Figure 5: blue boxes are associated with ARM, green with TC, light blue with OPRT, and orange with PCC.

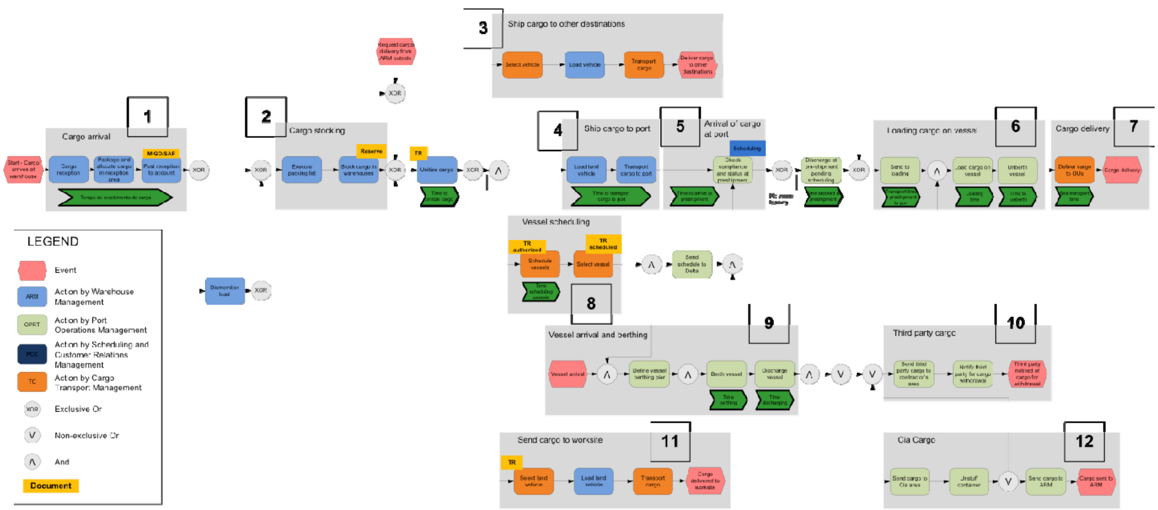

Figure 5a. Port operation macro-process: overview and content

Source: the authors.

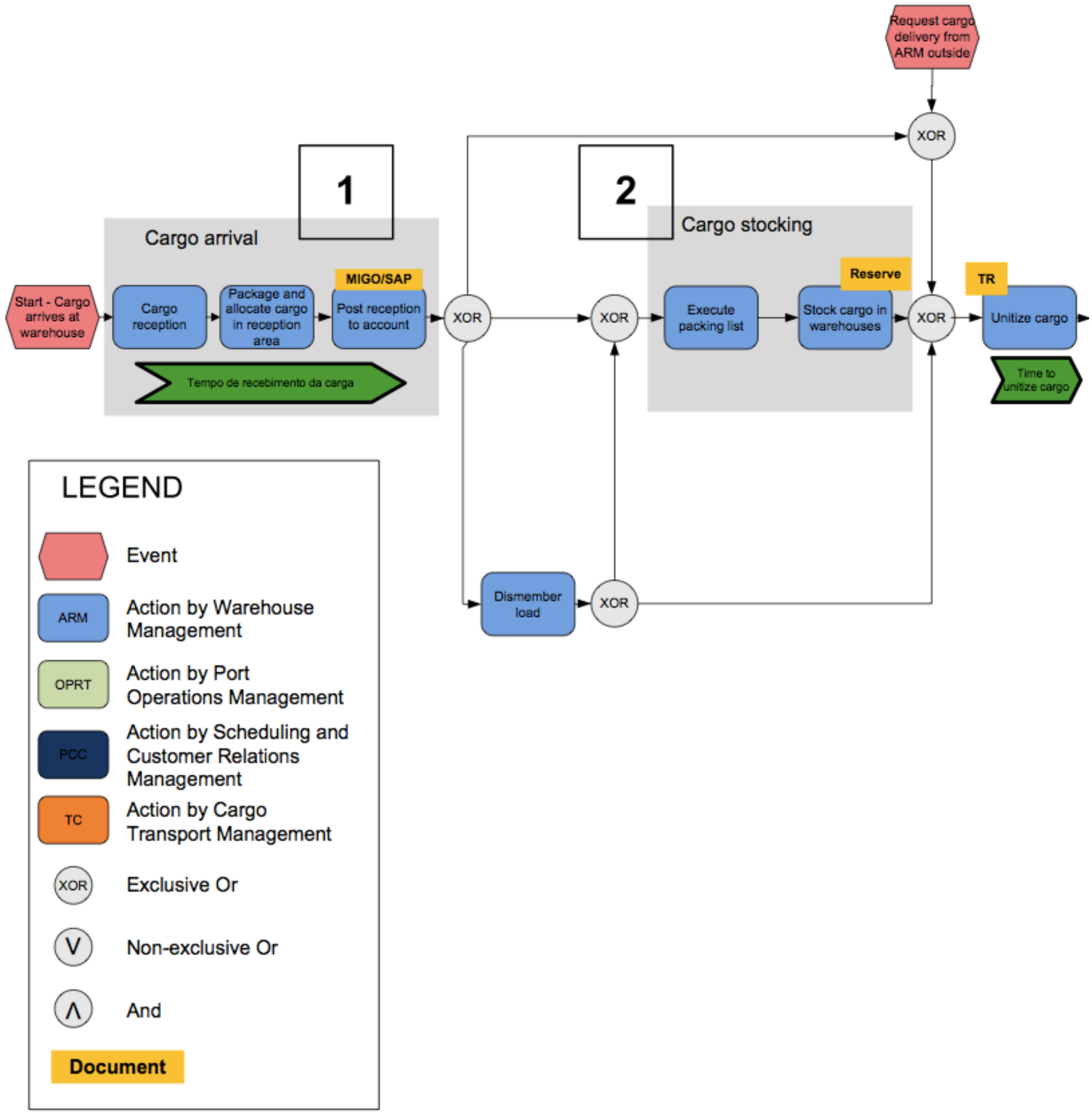

Figure 5b. Port operation macro-process: part one

Source: the authors.

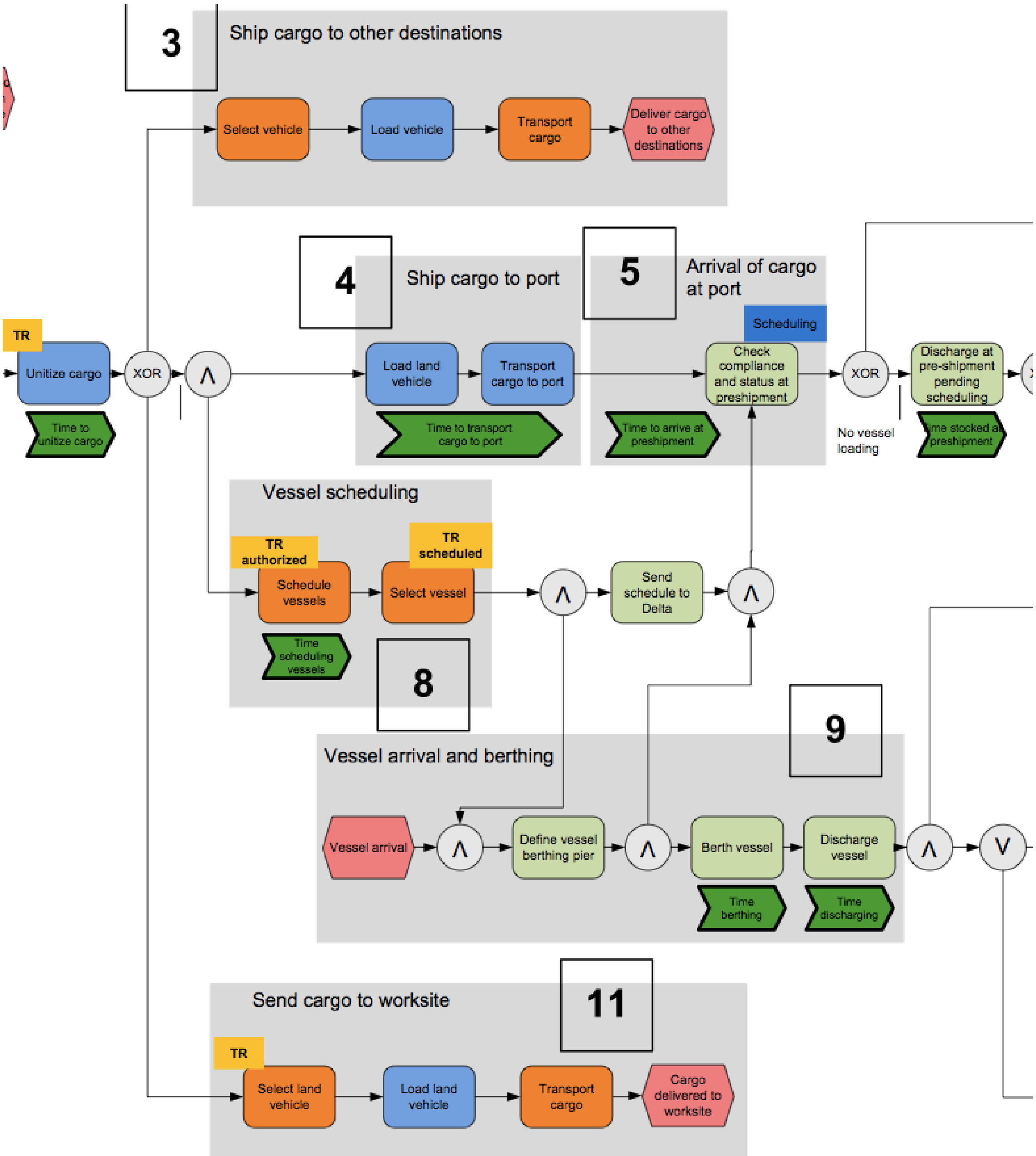

Figure 5c. Port operation macro-process: part two

Source: the authors

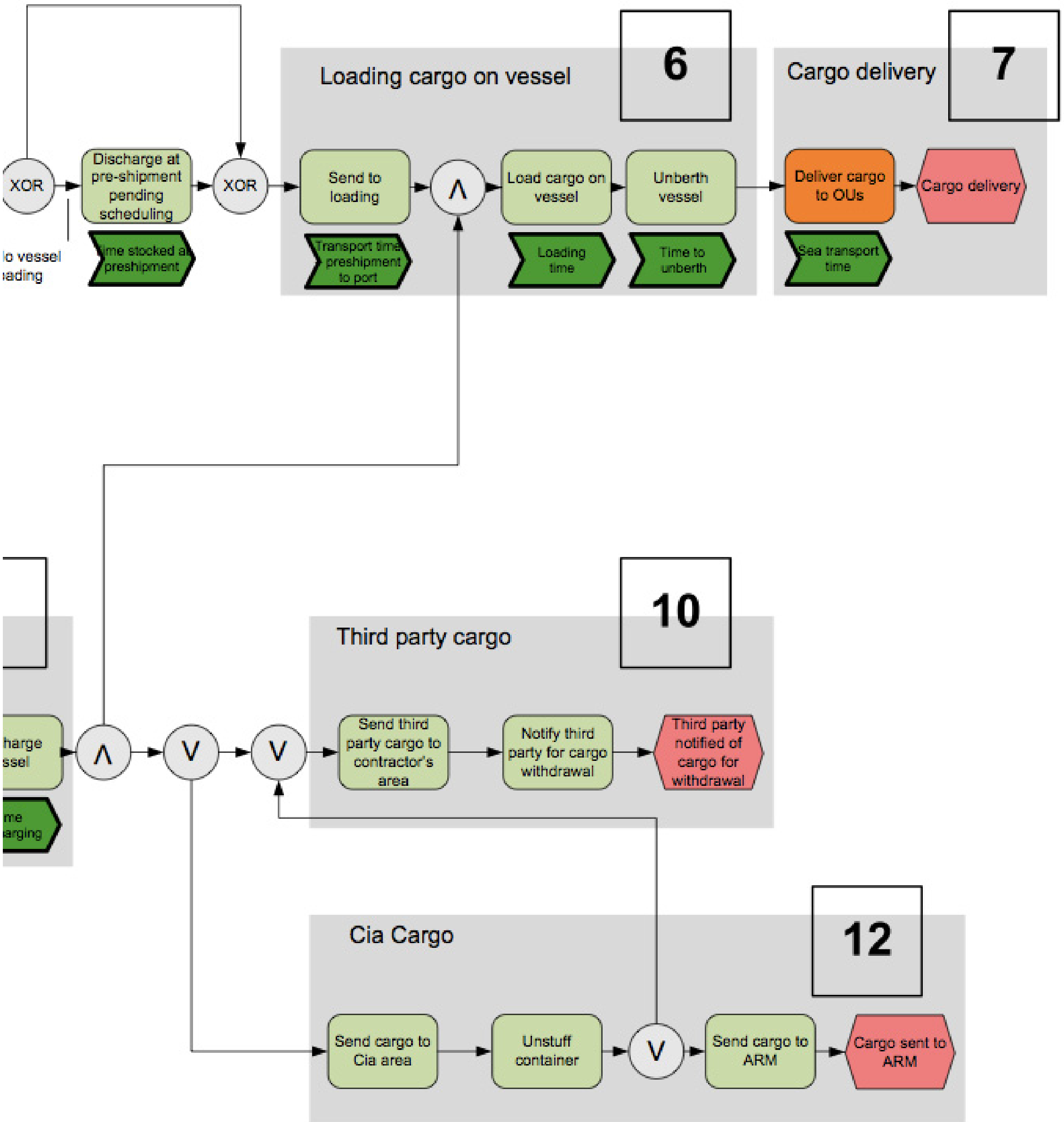

Figure 5d. Port operation macro-process: part three

Source: the authors.

By grouping the activities in the flow, it was possible to represent the main processes. These processes are shown in Figure 5 and highlighted in dark gray. The numbered processes in the image above are: (1) cargo arrival; (2) cargo storage; (3) cargo shipped to other destinations; (4) cargo dispatched to port; (5) cargo arrival at port; (6) cargo loaded on vessel; (7) cargo delivered; (8) vessel scheduling; (9) vessel arrival and berthing; (10) third-party cargo; (11) cargo dispatch to worksite; and (12) own cargo.

4.2 Supply Chain Operation Reference Model – SCOR

The Supply Chain Operation Reference Model (SCOR) was developed to meet the challenges of supply chain management. The SCOR model provides a single framework bringing together business processes, indicators, best practices and technological resources in a single conceptual structure. This supports communication among those involved in the supply chain, and improves the efficiency of their management.

SCOR is an operation model designed to describe all the stages involved in meeting a demand. It is strongly based on five primary processes: Plan, Source, Make, Deliver and Return. Using these primary processes, many supply chains, from the simplest to the most complex, can be modeled by SCOR, and thus make use of its propositions and prescriptions.

The model has three levels of detail. At the first level, the scope and content of the SCOR are defined, and competitive performance goals are set (Figure 6a). The second level is concerned with defining the supply chain configuration through which the firms implement the strategies (Figure 6b). At the third level, the firm's capacity to compete successfully on the market is defined (Figure 6c), which includes: process definitions, process input and output information, performance indicators, and best practices.

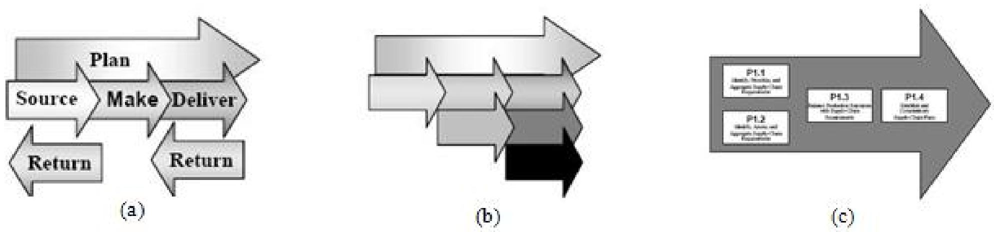

Figure 6. SCOR (a) Level 1, (b) Level 2, (c) Level 3

Source: SUPPLY-CHAIN COUNCIL (2006)

On the basis of the understanding of the supply chain obtained through the semi-structured interviews conducted for process mapping, a representative model of the port supply chain in which the company in question participates was constructed using SCOR notation. The model considered the following stakeholders: factories, firm's own warehouses, ports, and basins representative of major concentrations of offshore units.

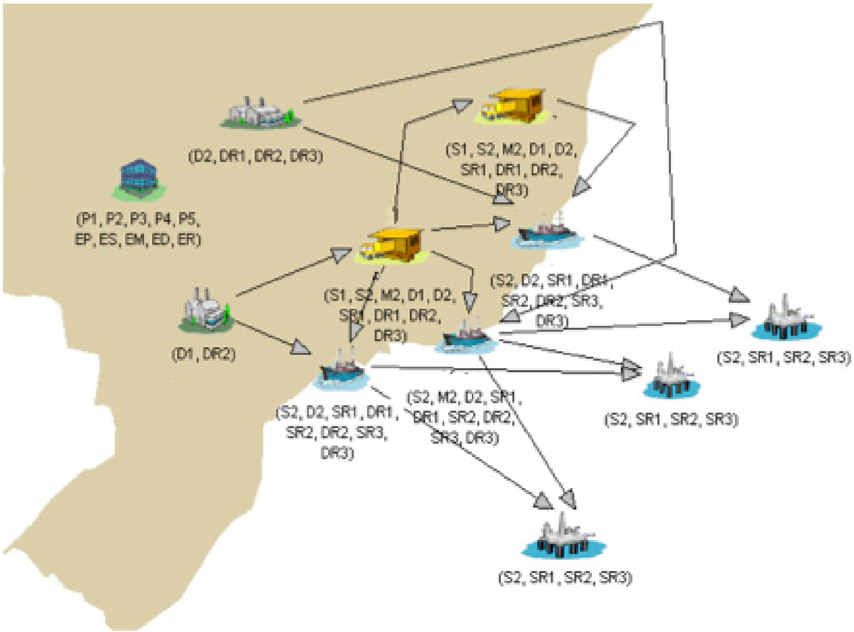

Figure 7. Modeling of stakeholders and flows

Source: the authors.

Once the stakeholders had been identified and the process types categorized, the process map illustrated In Figure 8 was developed using Xelocity ProcessWizard™ software, following the notation proposed by the SCC.

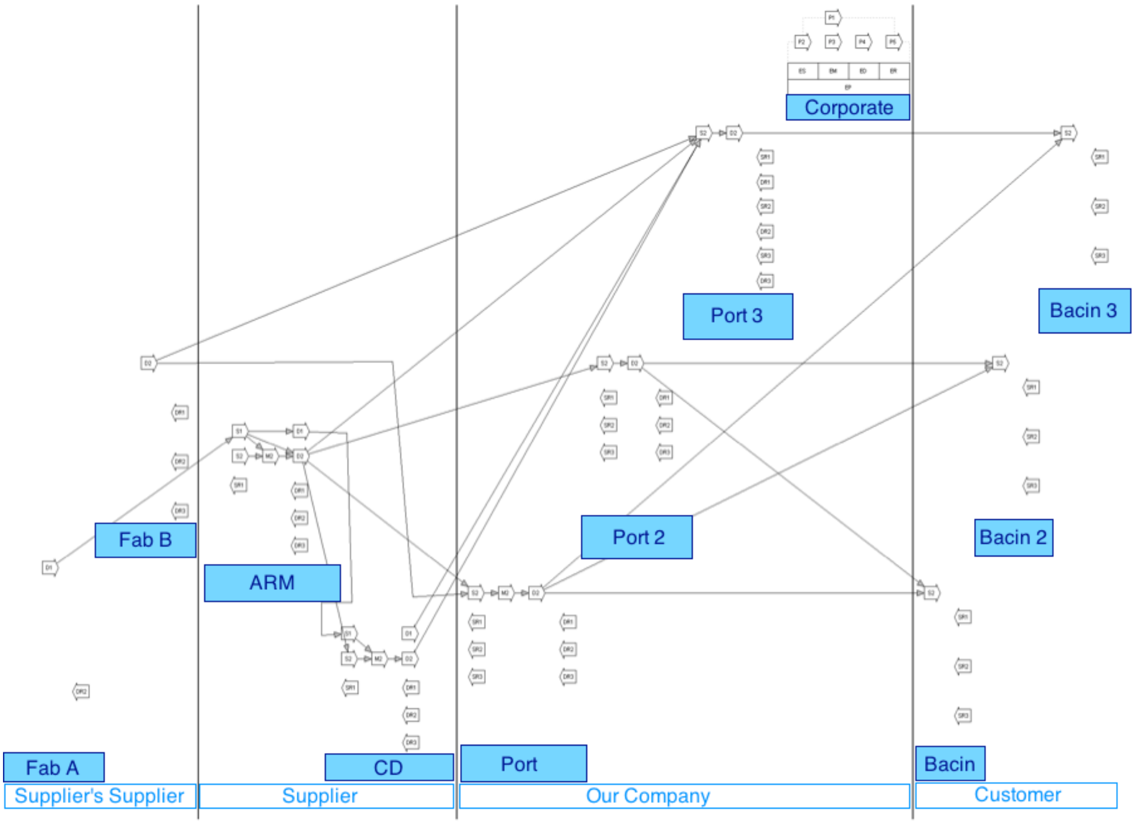

Figure 8. Macroprocess SCOR notation

Source: the authors.

4.3 The Network of Logistics Decisions

Riopel & Langevin (2005) in "The Network of Logistics Decisions" present a logistics operations decision-making framework based on a classification of decisions and the proposed substantial relations among them. The logistics decisions approach is designed to avoid classifying logistics activities, given that there is no consensus among authors on the subject as to what these activities are.

This framework focuses on categorizing decisions into a three-part hierarchy: strategic planning level, network level, and operations level, as in Table 1.

Table 1. Logistics decision categories

Strategic Planning Level
Network Level • Physical Facility (PF) Network • Communication and Information (C & I) Network
Operations Level • Demand Forecasting

- Inventory Management
- Production
- Procurement and Supply Management
- Transportation
- Product Packaging
- Material Handling
- Warehousing
- Order Processing

Source: RIOPEL & LANGEVIN (2005).

The strategic planning level considers decisions of a more strategic nature, in addition to those relating to strictly logistics areas. The key decisions at this level address performance goals (customer service) and the degree of vertical integration or outsourcing used.

At the second level, network decisions are broken out into two groups corresponding to the physical installations and the communication/information network. These are far-reaching structural decisions that involve considerable expenditure. The key decisions associated with physical installations address the installation network strategy, and the network design itself. The key points as regards communication and information decision making relate to creating and maintaining an efficient communication and information-sharing system throughout the logistics chain. Prominent here are systems integration, the degree of hardware and software standardization, and so on.

At the last level, operations decision making, the decisions discussed are short-term and narrower in scope than at the other levels. Accordingly, they are divided into nine groups: demand forecasting, inventory management, production, procurement management, transport, product packaging, material utilization, stocks, and order processing.

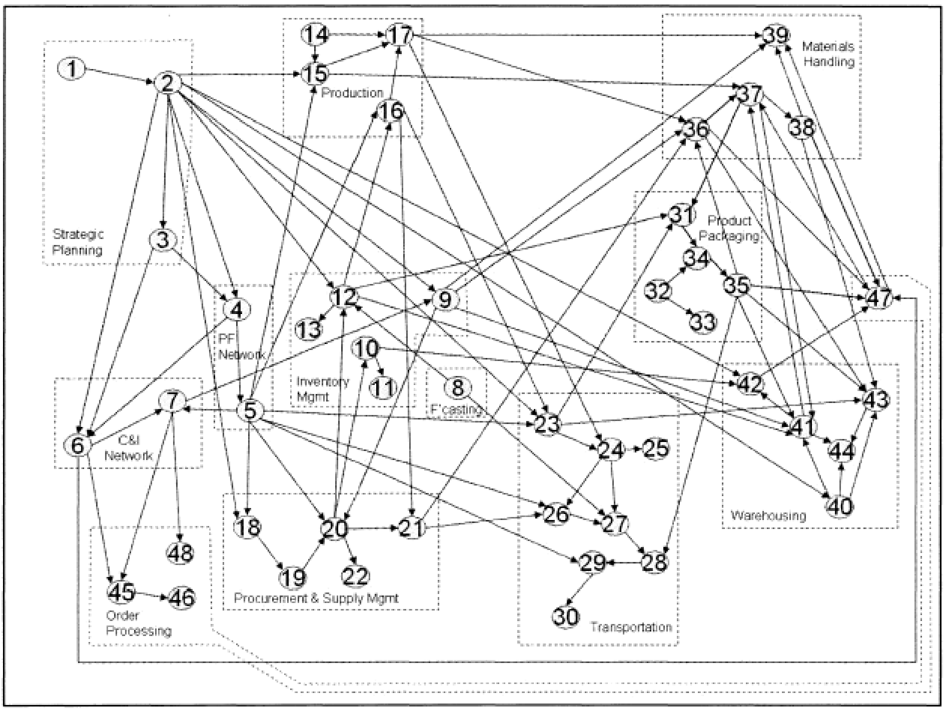

Figure 9. The network of logistics decision

Source: RIOPEL & LANGEVIN (2005).

The decisions represented by the numbered balls in Figure 9 are identified in Table 2.

Table 2. Logistics decisions

CATEGORY	DECISION			CATEGORY	DECISION	
Strategic Plan Level	1.	Definition of customer service		Transportation	23.	Transportation modes
	2.	Customer service objectives			24.	Types of carries
	3.	Degree of vertical integration and outsourcing			25.	Carriers
Physical Facility Network	4.	PF network strategy			26.	Degree of consolidation
	5.	PF network design			27.	Transportation fleet mix
Communication and Information Network	6.	C&I network strategy			28.	Assignment of customers to vehicles
	7.	C&I network design			29.	Vehicle routing and scheduling

Demand Forecast	8.	Forecast of demand magnitude, timing and locations		30.	Vehicle load plans
Inventory Management	9.	Inventory management strategy	Product Packaging	31.	Level of protection needed
	10.	Relative importance of inventory		32.	Information to be provided with the product
	11.	Control methods		33.	Information media
	12.	Desired inventory level		34.	Type of packaging
	13.	Safety stock		35.	Packaging design
Production	14.	Product routing	Material Handling	36.	Unit loads
	15.	Facilities layout		37.	Types of material handling equipment
	16.	Master production schedule		38.	Material handling fleet mix
	17.	Production scheduling		39.	Material handling fleet control
Procurement and Supply Management	18.	Procurement type	Warehousing	40.	Warehousing mission and functions
	19.	Specifications of goods procured		41.	Warehousing layout
	20.	Suppliers		42.	Stock location
	21.	Order intervals and quantities		43.	Receiving/shipping dock design
	22.	Quality control		44.	Safety systems
			Order Processing	45.	Order entry procedures
				46.	Order transmission means

Source: RIOPEL & LANGEVIN (2005).

Analogously to the modeling by SCOR notation, the decisions and the relationships observed among them were mapped on the basis of the information collected during the semi-structured interviews.

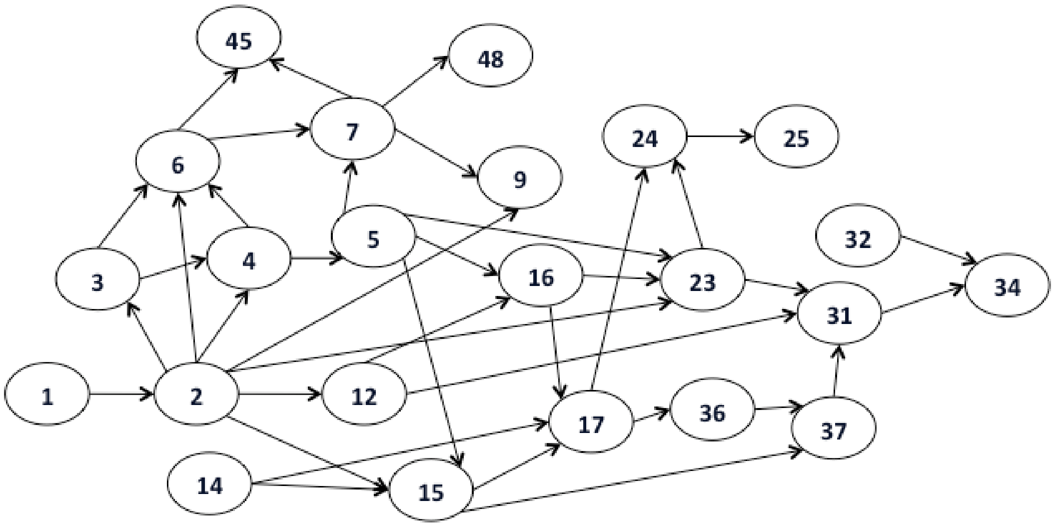

Figure 10. Map of logistics decisions (numbers indicated at table 2) in port operations

Source: the authors.

4.4 Current Reality Tree

Once the current status of the port operations was understood, the proposed method proceeded by constructing a systemic view of how the problems encountered in the various processes interrelate and impact system performance. For this purpose, it constructed a Current Reality Tree (CRT).

The purpose of the Current Reality Tree (CRT) is to define the key problems encountered in a specific system (Dettmer, 1997). Cox & Spencer (2002) describe a series of steps that assist in building the tree. Noreen et al (1996) explain that the logical links are indicative of sufficiency, i.e., for a given effect to occur it is necessary that the other occur (individually, simultaneously or both).

Cox & Spencer (2002) point out that a fully constructed Current Reality Tree provides mechanisms to: i) identify the impact of policies, procedures and actions on the organization; ii) communicate, clearly and concisely, the causality of such policies, procedures and actions; iii) identify clearly the key problem in a situation; and iv) permit a favorable climate of relationships to be created with respect to the problems, bringing all critical mass to bear on the key problem.

Scheinkopf (1999) warns of the need to look under the "pile of problems" faced in day-to-day activities in order to identify the policy constraints and paradigms that hinder improvement in organizational performance. For that purpose, building up the CRT makes it possible to identify these constraints, which are the key elements that cause most of the problems perceived. The method then ends by proposing improvements for these central elements alone with a view to implementing effective solutions and securing systemic gains for the organization.

Construction of the CRT revealed the main relationships among the problems perceived from the semi-structured interviews. Identification of these relationships arrived at certain groups – the clusters – that were regarded as having a stronger relationship with a single common object.

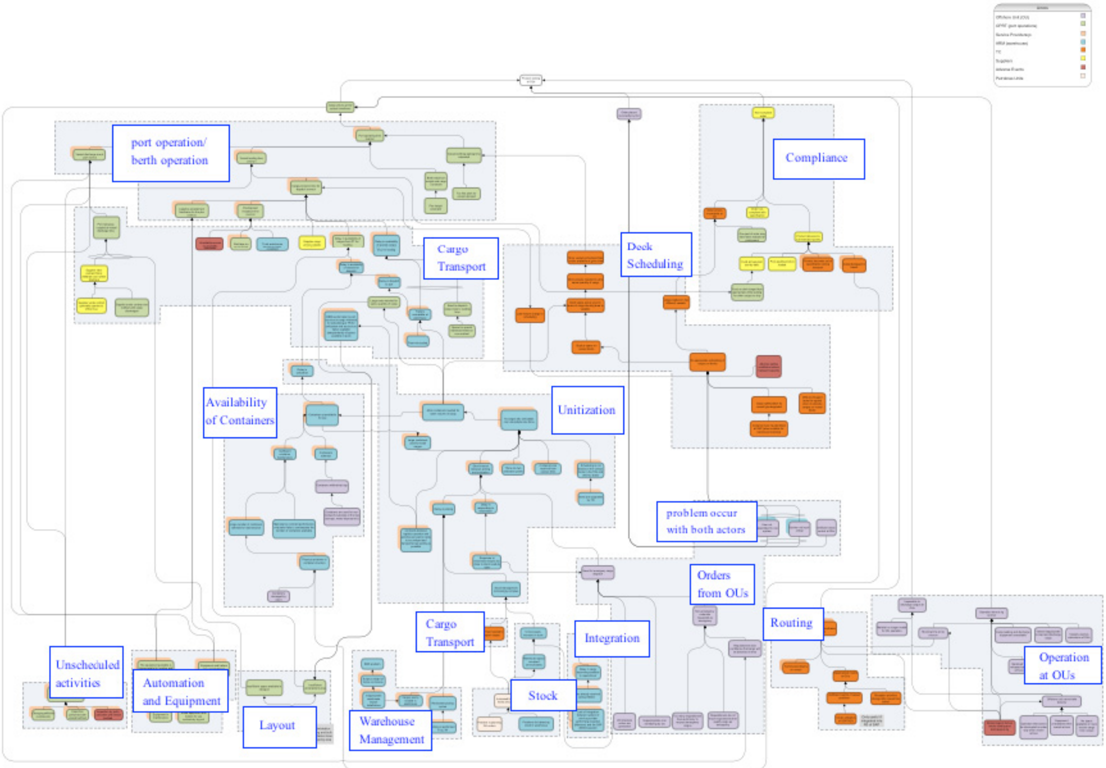

Figure 11. Overview of Completed Current Reality Tree

Source: the authors.

Using the CRT as a basis, 15 clusters were identified: (1) non-schedulable activities; (2) automation and equipment; (3) layout; (4) warehouse management; (5) stock/supply management; (6) integration of reception systems; (7) routing; (8) orders from offshore units; (9) operation of offshore units; (10) container availability; (11) unitization; (12) cargo transport; (13) deck space scheduling; (14) port operation/ berth operation/ port capacity; and (15) compliance.

According to the logic on which the CRT is constructed, the above objects of analysis are interdependent, as can be observed in aggregate form in Figure 12.

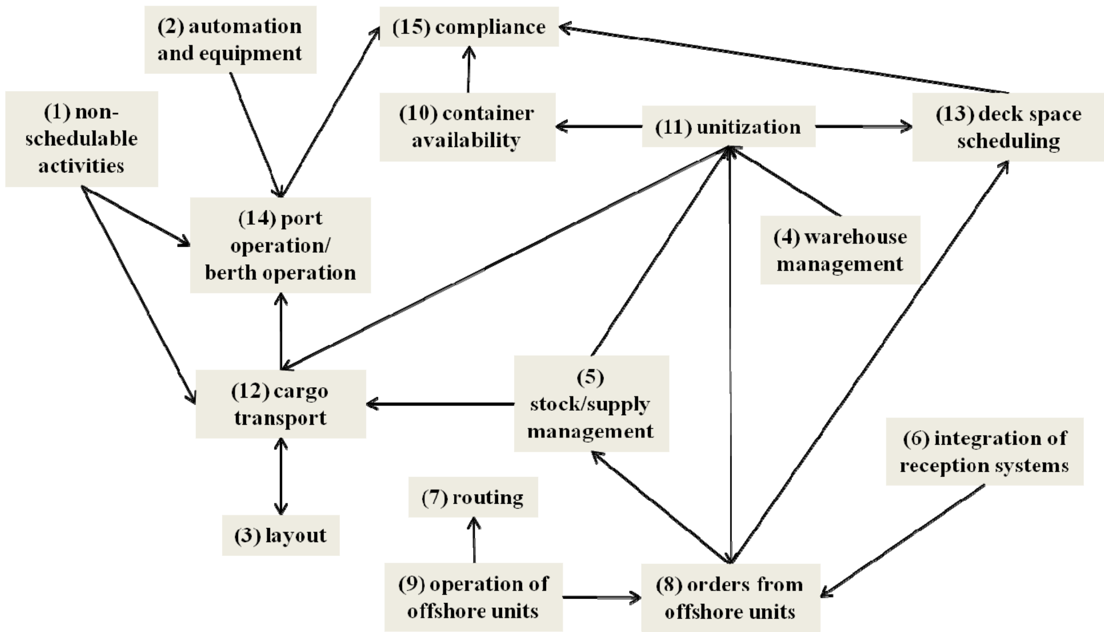

Figure 12. Relationship among the CRT objects of analysis

Source: the authors.

5. Analysis of Port Operations

Once the manner in which the organization functions had been stated explicitly, and the problems perceived by the management staff had been systematized, the study proceeded to the analysis stage. Before going into the description as such, a brief distinction should be drawn between two diametrically opposed approaches that can be used in analyzing operations. On the one hand is an approach that prioritizes specific points in the operation and seeks to aggregate them into more integrated models, which some authors term the bottom-up (BU) or micro view and, on the other, an approach that prioritizes a systemic view, which it seeks to dismember into specific processes, which is known as the top-down (TD) or macro view.

That distinction can be illustrated by the following examples: a discussion of the "productivity of unitization" (micro view) defines what port resources are necessary, and enters as an input into discussion of the model for networking among several ports and warehouses (macro view); a discussion of forms and modes of cargo segmentation at the specific port (macro vision) defines what cargoes will be unitized at a given port (micro vision).

In setting out the content of this study in the following sections the authors opted to exemplify the analyses permitted by the methods and by the association among the methods, such as the joint evaluation of the CRT problems (BU approach) and of the logistics decisions (TD approach).

5.1 Analyses Deriving from the Process Model

From the process map, a series of opportunities for improvements were identified. These were points at which the sequence of activities could be reviewed or a new activity created to permit improvement in port operations. One example is the current situation of port operations planning. From Figure 13 it can be seen that the scheduling consisted in:

- receiving a set of orders (transport requisitions) from the warehouse for supply to the offshore units (OUs), but without their being ordered by any criteria;
- filtering and selecting the transport requisitions (RTs) according to OU priorities, with the cargoes available in port and the available berthed vessels;
- allocating the RTs by vessel, in keeping with the vessel's fixed route; and
- authorizing loading and dispatch of the vessel, to serve the OUs.

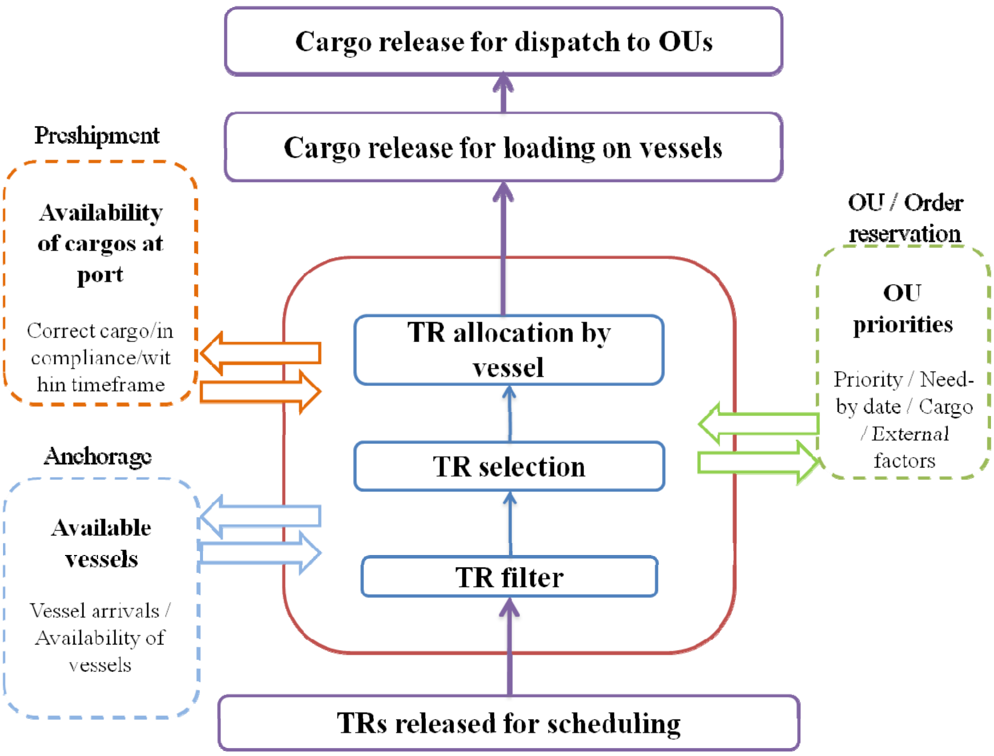

Figure 13. Cargo scheduling for dispatch to OUs

Source: the authors.

In this way, scheduling started after the TRs had been unitized and authorized, which aggravated delays in cargo delivery to the rigs. Other problems identified with this model included:

a) the cargos to be prepared/unitized do not obey any priority, any order, for release and dispatch to the port, for subsequent scheduling;

b) the TRs issued may not be priorities, and as a result, the cargos available in the port may also not be the ones needed, leading to reworking of deck space allocation, dispatch of vessels to anchorage (re-berthing), and berthed vessels awaiting cargo;

c) the vessels available are not always the ones needed, because on this model they follow fixed routes, which entails scheduling delays for lack of the appropriate equipment;

d) the scheduling had no demand forecasting system to cope with peaks in orders in the supply chain, and so on.

5.2 Analyses Deriving from the SCOR Model

The approach via the SCOR model proved promising and yielded significant perceptions as to port operation vectors for improvement. Of particular note were how easy it was to encounter highly applicable best practices and suggested metrics; the graphic representation of the chain under consideration, and the extent to which the modeling software facilitated the work; and the indication of possible capacity-building routes for port management staffs as regards the decisions that have to be taken.

For example, consider process S1.2 - Receive Product: the process and associated activities of receiving product to contract requirements. The following best practices were evaluated:

Table 3. Best Practices S1.2

Best Practice:	Bar Coding is Used to Minimize Handling Time and Maximize Data Accuracy
Definition:	Bar code interface for data collection devices. Generate bar coded receiving documents. Product serial number used as identifier. RFID

Best Practice:	Carrier Agreement
Definition:	Carrier agreements are agreements between a company and its domestic and global carriers specifying service levels, payment terms, and other conditions

Best Practice:	Deliveries are Balanced Throughout Each Working Day and Throughout the Week
Definition:	None identified

Best Practice:	Lean Methodology
Definition:	"Lean" thinking is a focus on creating process "flow" through the reduction of waste

Best Practice:	Six Sigma
Definition:	Six Sigma is based on a philosophy of driving for near perfect process performance

Best Practice:	Supplier Certification Programs are Used to Reduce (Skip Lot) or Eliminate Receiving Inspection

Definition:	Skip lot/sampling inspection logic

Best Practice:	Supplier Delivers Directly to Point of Use
Definition:	Electronic Tag tracking to Point of Use (POU) destination

Best Practice:	Vendor Managed Inventory
Definition:	VMI is a concept for planning and control of inventory, in which the supplier has access to the customer's inventory data and is responsible for maintaining the inventory level required by the customer.

Source: SUPPLY-CHAIN COUNCIL (2006).

5.3 Analyses Deriving from the Association between Process Model and Current Reality Tree

Once the macro-process had been stated explicitly and the problem perceptions systematized, the problems present in the CRT were distributed by macro-process stages. The problems are assumed to be connected with the activities and how they are performed. Below is an example of a set of problems associated with the activities of cargo delivery to the OUs. The colors of the problems around the activity in question are associated with the clusterization. It can be seen that problems of the Cargo Transport (orange), Suppliers (yellow), Offshore Unit (lilac), Port Operations (green), and Adverse Events (brown) types result in difficulties for proper performance of the cargo delivery process.

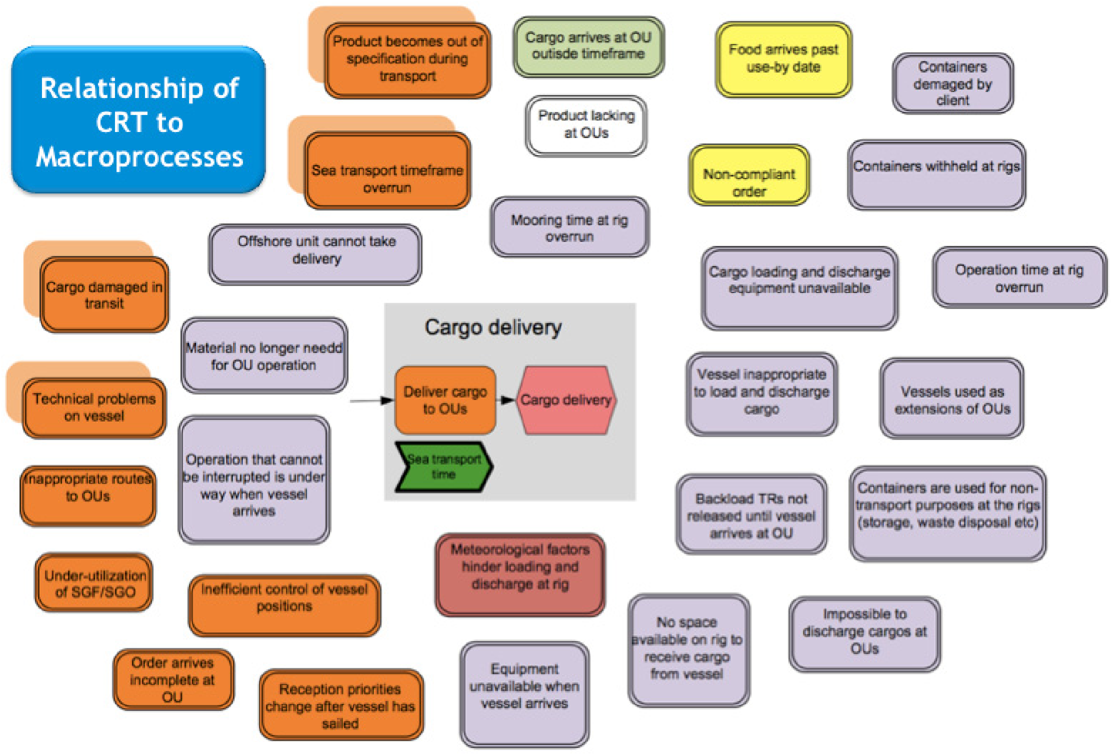

Figure 14. Problems associated with cargo delivery at the OUs

Source: the authors.

5.4 Analyses Deriving from the Association between the Process and Logistics Decisions Models

With the process and logistics decisions models ready, it was possible to associate the activities with the classification proposed by Riopel & Langevin (2005). From that matching, the definition emerges as to which activities result from applying each logistics decision-making process.

Again taking the cargo delivery process as the example, Figure 15 identifies the logistics decisions that define the existence of the activity, and those that shape how it is performed. These are: 11. Control methods; 24. Types of carrier; 25. Carriers; 29. Vehicle routing and scheduling; 36. Unit loads; 37. Types of material handling equipment; 39. Material handling fleet control; 41. Warehousing layout; 42. Stock location; 43. Receiving/shipping dock design; 48. Order follow-up procedures.

Figure 15. Identifying logistics decisions associated with cargo delivery to the OUs

Source: the authors.

5.5 Relationship between CRT and Logistics Decisions

As a logical consequence of the previous associations, the CRT problems were related to the logistics decisions throughout the macro-process. This matching made it possible to analyze predecessor decisions, i.e., to identify decisions that can be resolved, because there are no problems identified with their predecessors in the CRT, and decisions where there are problems.

Decisions where problems were identified included those relating to packaging types. Perceptions of problems recorded in the CRT included: containers are received from various companies; large containers are used for small cargoes; and the SAP is poorly identified on the container door.

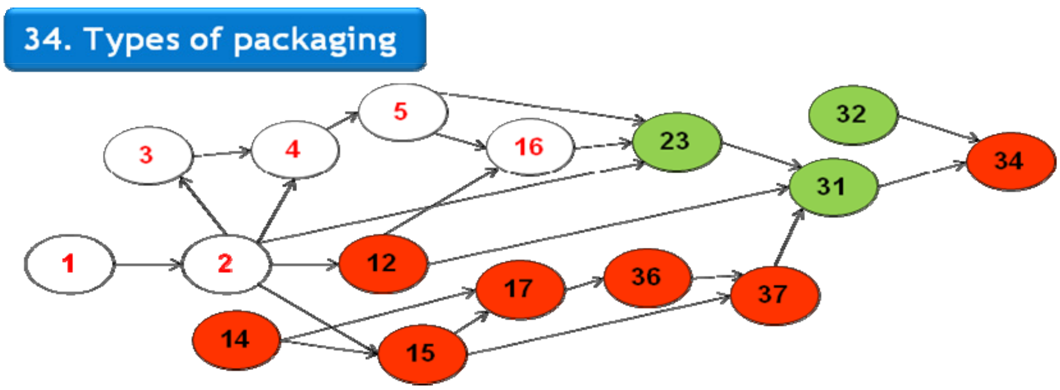

Figure 16. Map of logistics decisions that precede types of packaging

Source: the authors.

The approach via logistics decision-making processes assisted in developing a systemic analysis, and in the process of prioritizing and formulating solutions. Note the importance of the decision-making processes at levels 1 and 2 (7 processes) as a result of the precedence relationships; the relationship of the CRT problems with certain decision-making processes, indicating possible action priorities (problems are not comparable by "size", rather they are quite dissimilar); the relationship between the decision-making processes defined previously and the others (precedence relationships); and the indication of possible capacity-building routes for the management staffs in view of the decisions that have to be taken.

6. Information Gathering to Underpin the Proposed Solution

The analyses afford insights as to avenues to solutions, but are not enough to specify those solutions. In order to formulate the proposals, it is necessary to access more information expressing how the port operation functions, on which to base the formulation of solutions. To that end, data was collected in the field and extracted from the firm's data bases.

Desse, Newport & Rasheed (1993) identify data collection as key to qualitative research. The process of combining multiple sources of evidence is termed triangulation (Dubé & Paré, 2003). Mangan, Lalwani & Gardner (2004) add that there are various different forms of triangulation. Data triangulation was used in this study.

This data triangulation had its origin in three main sources: 1) interviews of managers and staff; 2) documentation containing historical data, and databases of operations records; and 3) direct observation of the operation.

6.1 Analysis of Cargo and Vehicle Movement in the Port

As a result of direct observation of the port operations, a set of more than 95,000 data items was recorded, from which a total of 22 analyses were conducted to identify the nature of the operations serving the OUs supported by this port. These will be described briefly by location where they were observed in the port, and by the respective operations carried on in each of the physical spaces.

6.1.1 Preshipment

Cargo is channeled from the warehouse to the port by company trailers or third-party logistics operators, setting up an almost continuous flow of cargo entering through the port gateway. On entering through the gateway, cargo is normally directed to the preshipment area. Trailers that enter the preshipment area perform different activities according to the cycle scheduled, as in Figure 5: recording arrival only (without cargo movement); discharging only; loading only; or discharging and loading.

Cargo is stocked in this area until the start of port operations relating to its loading and routing to its respective vessel. Cargo in the preshipment area is destined for vessels in one of the port's 6 berths. It is at this stage that the port's various resources and its capacity become extremely significant. Empty trailers are directed to the preshipment area, and with the assistance of operators and fork lift trucks, are loaded and routed to the corresponding berth for loading of the vessel.

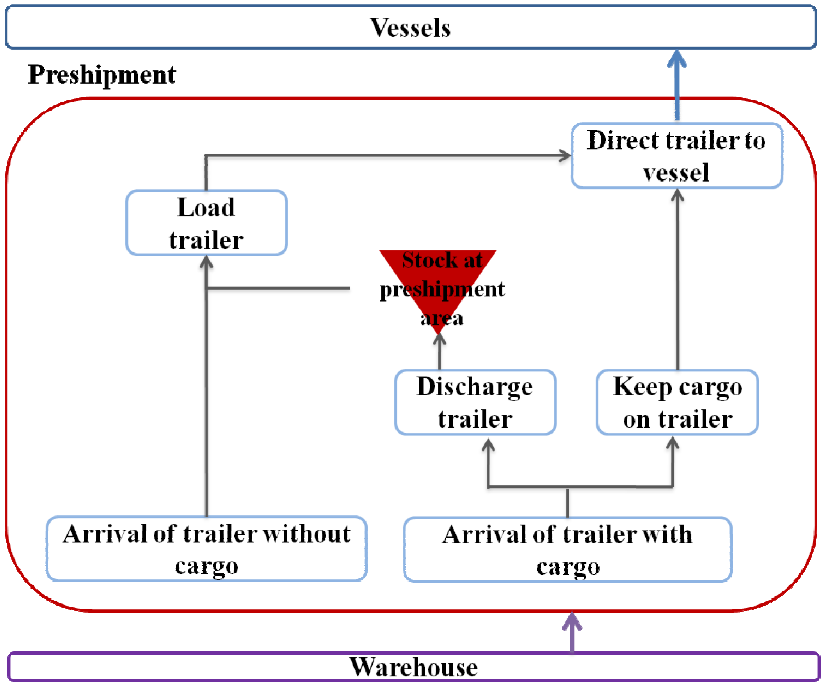

Figure 17. Pre-shipment cargo flows

Source: the authors.

From the data collected, according to the operations record definitions, it was possible to draw up a set of analyses as in Table 4.

Table 4. Preshipment area data recording and analysis

ANALYSES OF OPERATION IN PRESHIPMENT AREA	DATA RECORDED IN PRESHIPMENT AREA	
• Arrival rate in preshipment area • No. trailers entering prehipment area by interval throughout the day • Rate of trailers not discharging in preshipment area • Discharging time • Loading time • Trailer turnaround time in	Record of time bill of lading is received at reception counter	When truck driver hands bill of lading to clerk
	Record of truck occupation and number of volumes loaded (of trailers entering and leaving)	Typology: Container (S,M,L); Skid (S,M,L); Chemicals (S,M,L); Skip; Cage; Big Bag
	Record of discharging start and end time for each truck	From 1st fork lift discharging action (when it first touches the truck's cargo)

preshipment area • Turnaround time of trailers not discharging in preshipment area		From last fork lift discharging action (when it releases the truck's cargo in the preshipment area)
	Record of loading start and end time for each truck	From 1st fork lift loading action (when it first touches the preshipment cargo)
		From last fork lift loading action (when it releases the cargo onto the truck)
	Record of trailer departure time	When trailer starts to move to leave

Source: the authors.

6.1.2 Piers

As seen above, cargo in the preshipment area is destined for vessels in one of the port's 6 berths. When the trailer arrives at the pier, the loading operation is performed once again, this time to the vessel from the corresponding trailer. At this stage other resources, such as cranes, are used. In the opposite direction, vessels also arrive with cargos, which will be transported in the port by trailers that enter the pier empty. These cargos are discharged from the vessels and loaded onto the empty trailers, for transportation to the retroarea.

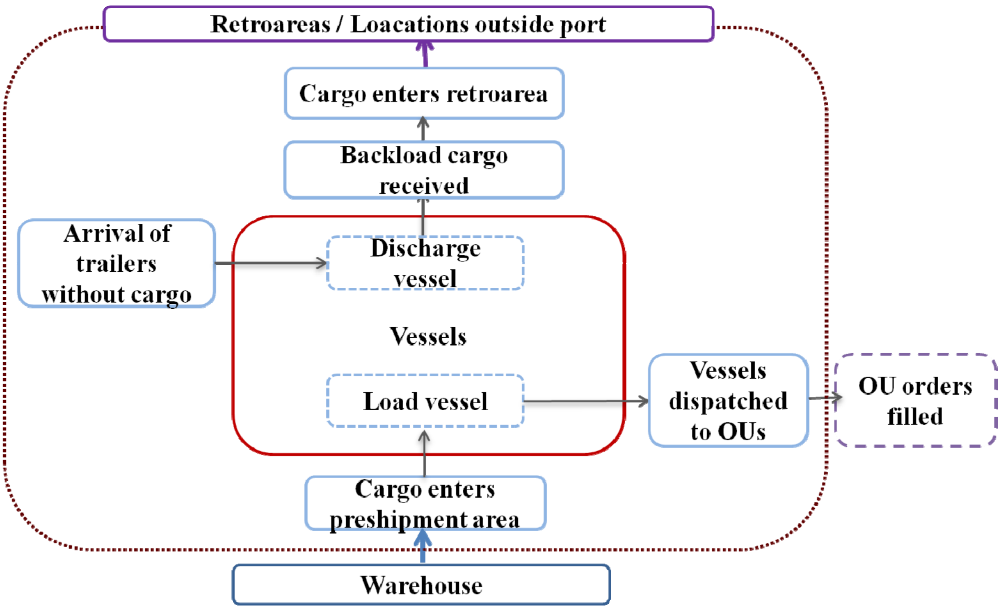

Figure 18. Cargo flow on the pier

Source: the authors

For analysis of the cargo movement operation on the pier, synthetic variables were defined as in Figure 19. Trailer turnaround time in the berth is given by the interval between its arrival and departure. The crane operation of moving cargo from trailer to vessel or from vessel to trailer is termed sling-loading. During the period that the trailer remains at the birth, there are intervals that do not represent cargo movement: the time while the trailer is waiting for the start of the first sling load, the time between sling loads, and the waiting time between the last sling load and departure from the berth. After the departure of one trailer, there is a lapse until the next trailer enters the berth or until loading and discharging are completed and the vessel can unberth.

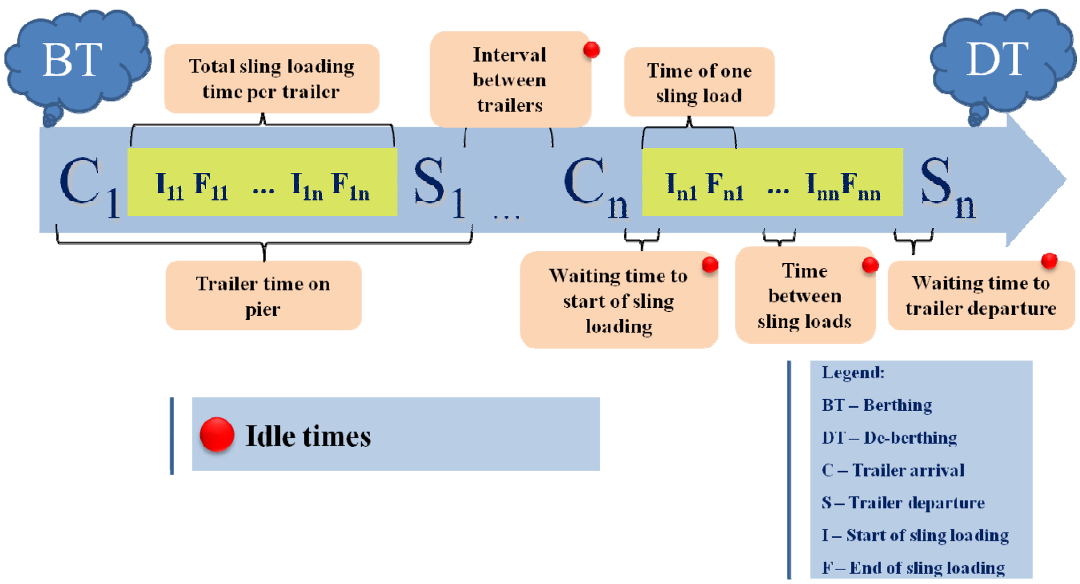

Figure 19. Times between vessel berthing and unberthing

Source: the authors.

Consistent with Figure 19, items and and orientation for direct observation were defined as follows:

Table 5. Pier data records and analyses

<table>
<tr><th>ANALYSES OF OPERATION ON PIER</th><th colspan="2">DATA RECORDING ON PIER</th></tr>
<tr><td rowspan="3">· Mean sling load time
· Mean interval between trailers
· Mean sling loads per trailer
· Mean time between sling loads*</td><td>Record of vessel berthing / unberthing start and end time</td><td></td></tr>
<tr><td>Record of trailer arrival time</td><td>From trailer stopping on pier</td></tr>
<tr><td>Record of start and end time of discharging/ loading each cargo volume</td><td>Vessel loading operation: from 1st and last crane movement for each volume removed from trailer to</td></tr>
</table>

· Mean time from trailer arrival to start of first sling load* · Mean time from end of last sling load to trailer departure* · Total sling loads time per trailer · Mean trailer turnaround time on pier • Idle time at berth (sum of times marked *)		vessel (I1: when crane sets sling on cargo, F1: end of sling load)
		Vessel discharging operation: from 1st and last crane movement for each volume removed from vessel to trailer.
	Record of trailer departure time	From 1st movement of trailer to depart pier

Source: the authors.

6.1.3 Retroarea

The retroarea is where cargoes originating in the OUs are stored. The backload operation caters to the returning cargoes. Once cargoes arrive at the retroarea, they may remain at the port (containers, for instance) or there may be cargos with a deadline for withdrawal by the external supplier (third-party retroarea cargos).

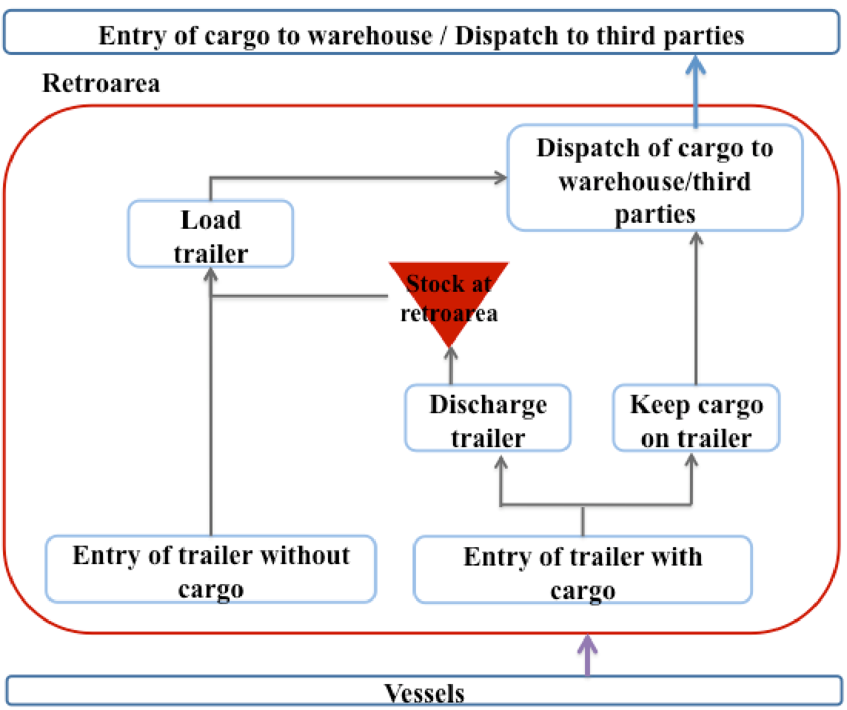

Figure 20. Retroarea cargo flows

Source: the authors.

The data to be corrected and the analyses to be performed were defined as:

Table 6. Retroarea data analyses and records

<table>
<tr><th>ANALYSES OF OPERATION IN THE RETROAREA</th><th colspan="2">DATA RECORDING IN THE RETROAREA</th></tr>
<tr><td rowspan="6">· mean flow of company trailers entering
· mean flow of third-party trailers entering retroarea.
· mean loading values
· mean discharging values
· maximum loading values
• maximum discharging values</td><td>Record of trailer arrival time</td><td>On passing the fence</td></tr>
<tr><td rowspan="4">Record of start and end time of loading/discharging of each volume</td><td>From 1st to last crane movement for each volume removed from trailer to retroarea.</td></tr>
<tr><td>From 1st to last fork-lift truck movement for each volume removed from trailer to retroarea.</td></tr>
<tr><td>From 1st to last crane movement for each volume loaded onto trailer.</td></tr>
<tr><td>From 1st to last fork-lift truck movement for each volume loaded onto trailer.</td></tr>
<tr><td>Record of trailer departure time</td><td>From 1st trailer movement to leave retroarea.</td></tr>
</table>

Source: the authors.

6.2 Analysis of Unitization: Example of Quantitative Analysis after CRT Prioritization

This object of analysis was selected in order to examine its importance in the cargo handling process in greater depth. The efficiency of unitization is directly related to the number of containers used and the proportion of their capacities occupied, which affects the areas occupied on the trailers, in the preshipment area, on deck on the vessels, and at the customer.

Table 7. Unitization data

Container unitization (mean)	· containers are unitized at only **34%** of capacity weight • containers are unitized at only **22%** of capacity volume
Volume and weight per delivery (mean)	· **2.23 m³** of container is unitized, in the knowledge that container capacity volume is **10.16 m³** • analysis of capacity weight concluded that **1,411 kg** are unitized per container, while capacity is **4,065 kg**
Delivery interval at same destination	• **1.4** days mean interval between deliveries to the same destination

Source: the authors.

Stated systematically, the causes and impacts in this regard were:

Table 8. Summary causes and impacts on unitization

CAUSES	IMPACTS
· number of emergency orders · small interval between picking and unitization · Different unitization points · Different cargo origins · containers unavailable • contractual refinements needed	· number of trailers for same cargo volume · number of vessels for same cargo volume · area occupied by same cargo volume • container availability

Source: the authors.

Sensitivity analysis indicated gains in impacted areas of the chain, as follows.

Increasing unitization density from 22% to 30% would yield a 27% gain in volume, which in turn would represent a 40% reduction in trailer journeys.

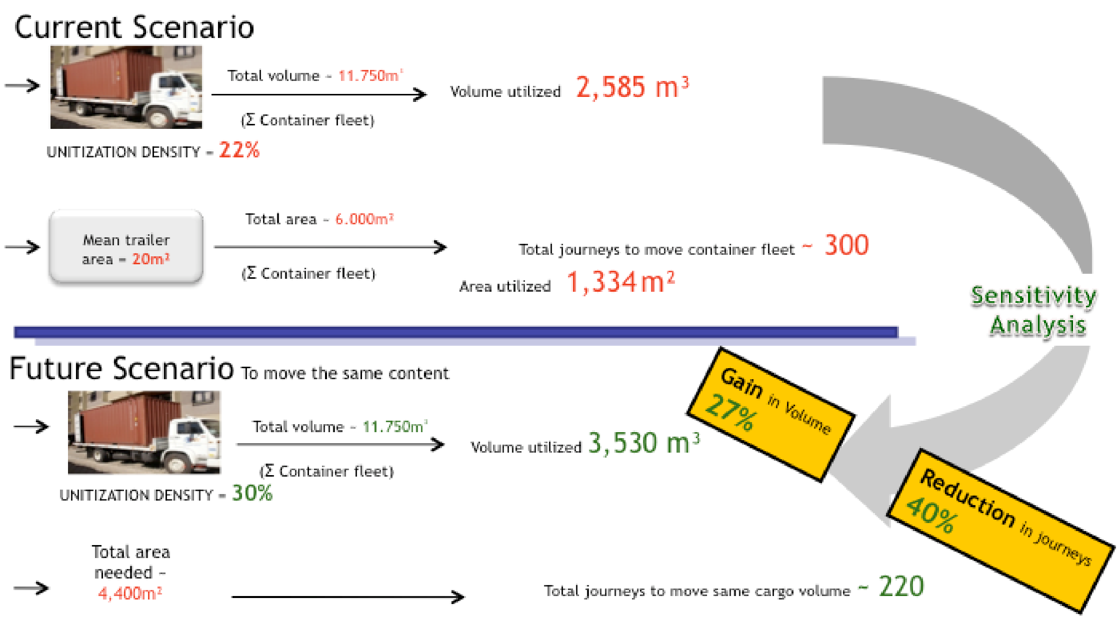

Figure 21. Sensitivity analysis (trailers)

Source: the authors.

The same 8% increase in unitization density would yield a 26.2% reduction in containers, permitting a gain of 887 m² in preshipment area.

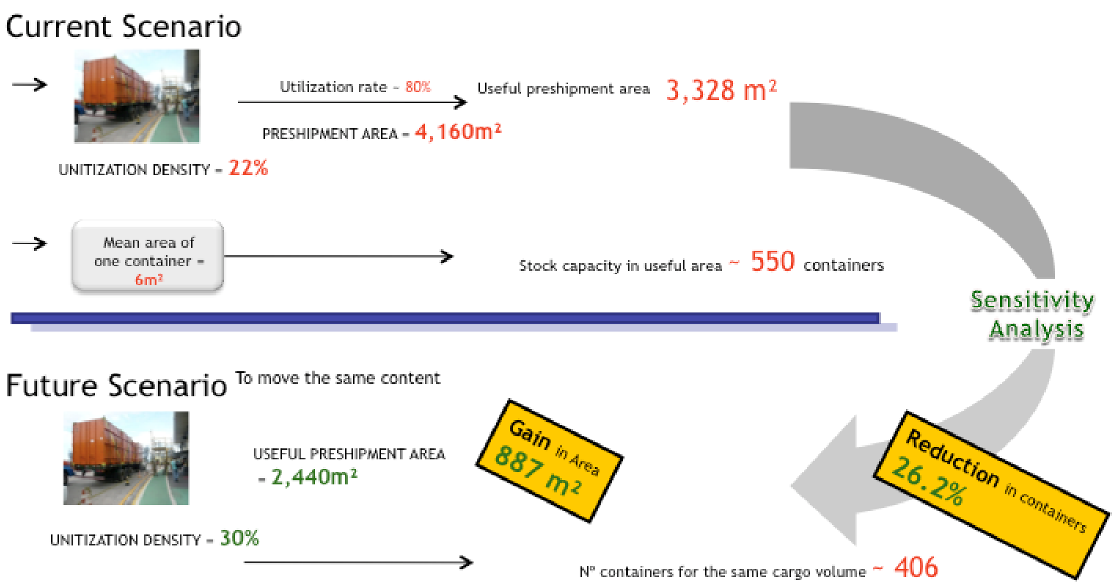

Figure 22. Sensitivity analysis (preshipment area)

Source: the authors.

As regards deck area, the 24.3% reduction in containers would yield a 116 m² gain in useful area.

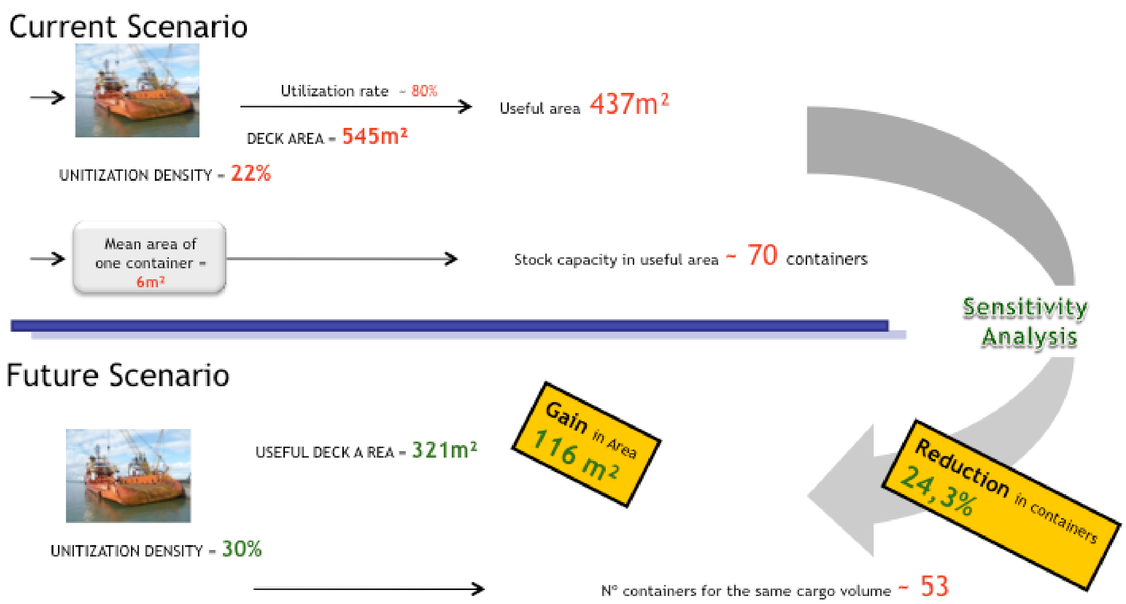

Figure 23. Sensitivity analysis (deck area)

Source: the authors.

This future scenario would represent a reduction from 750 to 550 containers, a gain of 27%.

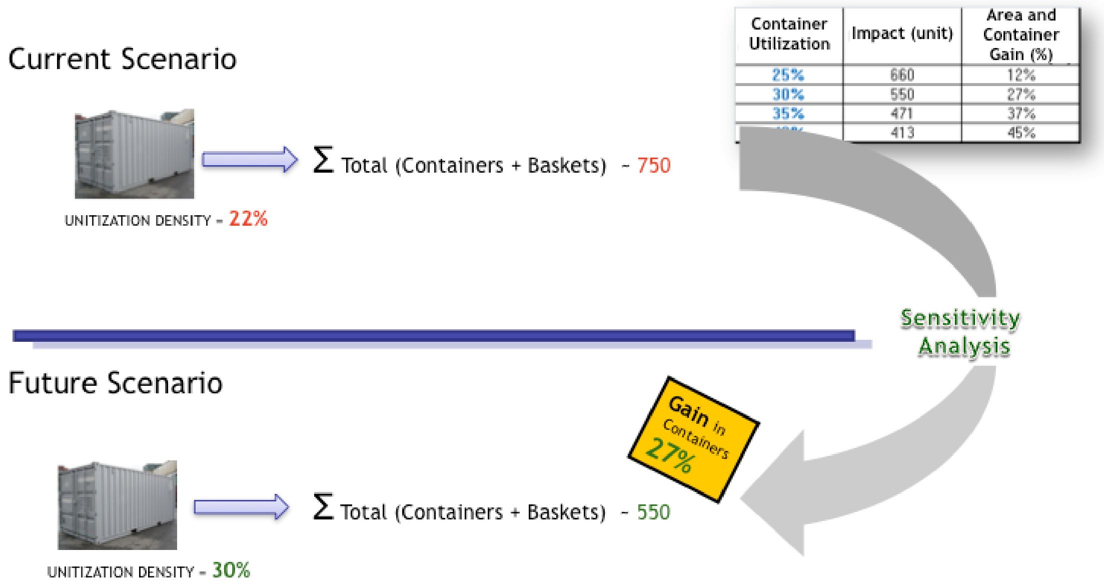

Figure 24. Sensitivity analysis (containers)

Source: the authors.

7. Proposed Future Situation

Having arrived at an understanding of the situation, and analyzed the problems, the method proceeds to the proposal stage. The research methods and the solution formulated are not the only ones possible. Dym *et al.* (2009) describe design problems as open-ended, that is, problems that have more than one solution: "they usually have several acceptable solutions. Uniqueness, so important in many mathematics and analysis problems, simply does not apply to design solutions. In fact, more often than not, designers work to reduce or bound the number of design options they consider lest they be overwhelmed by the possibilities" (DYM *et al.*, 2009: 10).

7.1 Proposal for Integrated Operations Scheduling

The proposal to develop an integrated operations scheduling model responded to the need to formulate a solution that would enable the bottlenecks encountered to be eased and the process of serving the offshore units improved in an integrated manner. This would guarantee delivery to promised deadlines; reduce total vessel loading/discharging time; guarantee maximum resource utilization; ensure stocks were kept at minimum levels; and permit greater control over port operation performance.

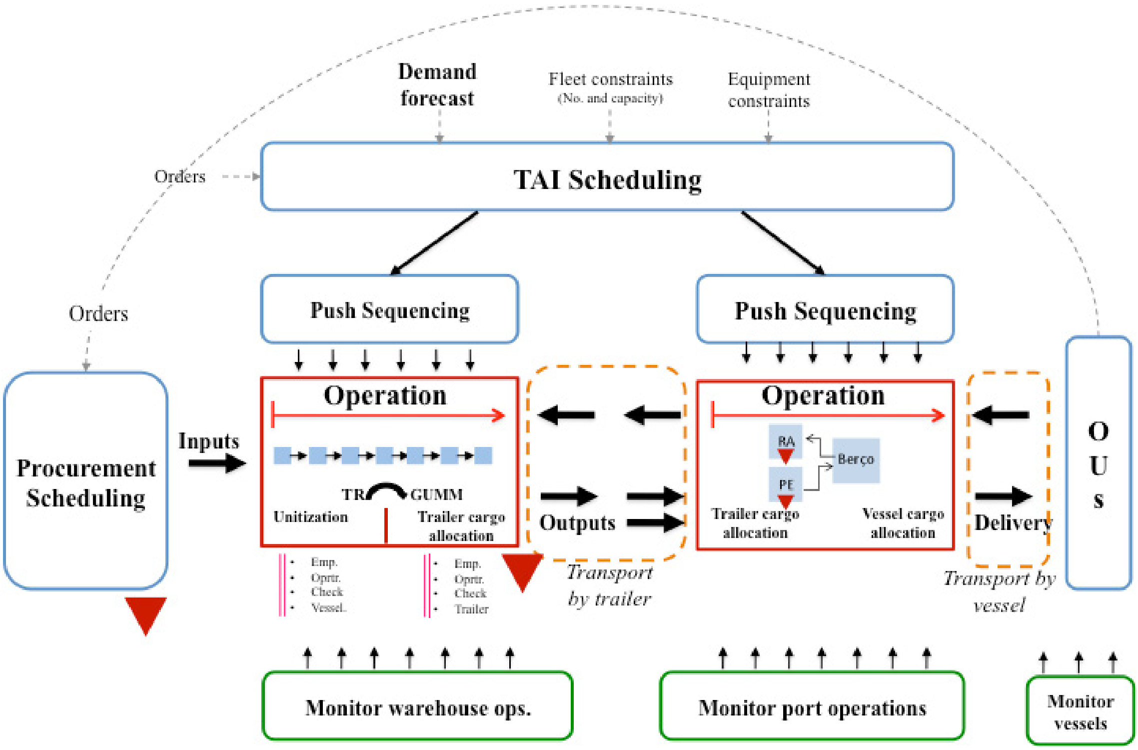

Figure 25. A systemic view of port logistics

Source: the authors.

In the light of the literature mapped and the case analysis, a future integrated scheduling model was developed, anticipating a strategic role for the position of scheduler, and affording that position a more comprehensive view of the resources involved. In that model, in addition to receiving demand forecasts, the scheduler would decide what reserves have priority, issue transport requisitions, and order cargos hierarchically for unitization, so that they are transported to the port according to the needs established at the start of process.

Another possibility suggested, which would not entail discarding the present format, would be vessel routing without fixed routes. By using operations support systems, new routes that minimize transport time would be generated at each round of scheduling. The new scheduling design would thus be:

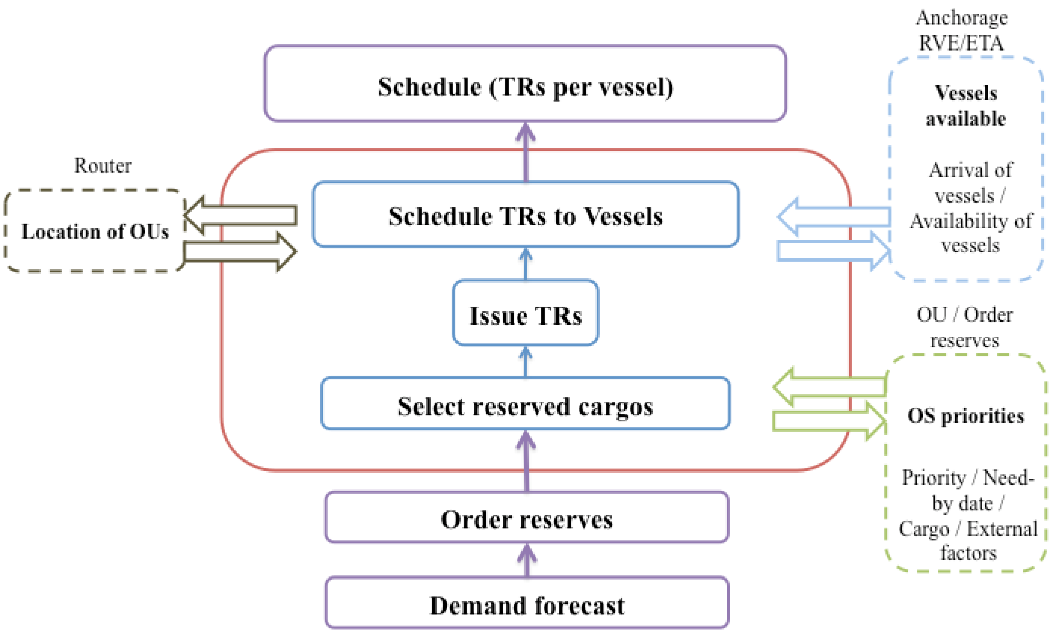

Figure 26. Redesign of OU supply scheduling model

Source: the authors.

Operation push sequencing, which would be triggered at the warehouse when cargo is unitized, was established to support this model. The sequencing would then indicate cargo allocation to trailers, and would sequence each trailer by vessel previously scheduled to receive cargo at the port. This would allocate cargos to vessels, and for that purpose should be supported by an operations monitoring model. This operations monitoring would involve providing information on the human and physical resources (equipment such as cranes, forklifts, trailers and vessels) necessary to perform the sequencing. In addition, in order to complete the sequencing, the cargo allocation rules, waiting times, and the sequencing time would also have to be known.

The diagram below shows the new integrated scheduling and sequencing model:

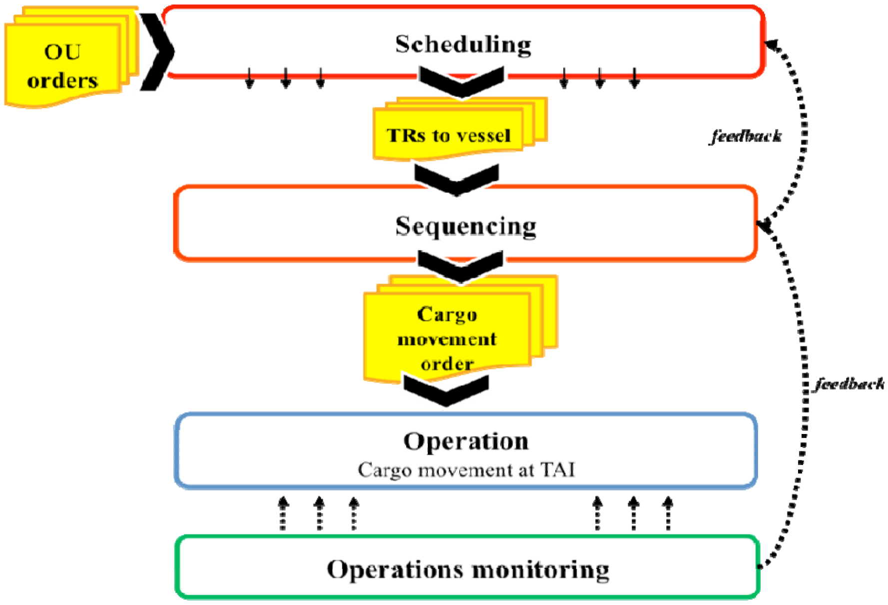

Figure 27. A proposed integrated scheduling and sequencing model

Source: the authors.

This proposal for integrated scheduling and sequencing was designed to ensure offshore supply deliveries within agreed timeframes, reduce total vessel loading/discharging times, ensure maximum resource utilization, and permit greater control over port operation performance.

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