A Multi-Agent Based Approach for Risk Management in a Port Container Terminal

Lorena Bearzotti and Rosa Gonzalez

Abstract

The growth of foreign trade and globalization emphasize the weaknesses of extended supply chain in front of occurrence of disruptive events that impact differently (deviation, disruption, disaster) the normal operation, in some cases the consequences are temporary but the worst scenario is when the event produces a permanent cessation of its activities. Then the ports are a strategic actor because if they have problems with their operations the others in the supply chain will be affected negatively, so the ports resilience determines the level of resilience of multiple supply chain in which they participate.

Because of this it is necessary to have tools that provide support to the process of risk management in order to have proactive and reactive, responses to the different disruption events that may occur in its operation. In this paper a multi-agent approach to risk management in container terminal is presented.

Keywords: risk management, event management, multi-agent system, container port terminal
1. Introduction

The transfer and storage of containers at port terminals has been growing in recent years. This situation has forced the port terminals have information systems with the goal of to improve the functioning, efficiency and level of customer service. This is achieved through a combined effort of all actors involved in the operations of a port terminal.

The study to improve the operations of a port terminal is necessary because it is a key node in multiple global supply chains, so any problems in the port may affect related organizations. The port terminals are essential in the country import and export processes. Ports are interfaces between different modes of transport and are typically combined transport centers where the products are manipulated, manufactured and distributed. An efficient port requires not only infrastructure, superstructure and proper equipment, but also good communications and a dedicated management team, qualified and motivated and trained workforce.

The container port terminals have a key place called "container yard" where the containers are temporary stored, so their administrators perform research and analysis aimed at improving its management.

In the yard management one of the problems to be addressed is the risks and disruptive events management. The risk and event management permit to analyze and understand the origin and consequences of disruptive events, as well as determine the answers that are provided against its occurrence. The ability of a system to respond to a disruptive event without losing their ability to function is known under the concept of resilience. (Mansouri, 2009; Sanchis, 2011). The event management is defined as the component of the systems management container terminal that reduces the gap between planning and execution, with the objective of minimizing the impact of an event on a plan that is running. (Bearzotti, 2012).

This paper presents a proposal for risk managing in the container yard of a port terminal. This proposal consists of a multi-agent focused on the analysis of
disruptive events and the generation of actions to reduce the impact of the event model. The paper is organized as follows, in the next section the problem description and review of the literature was performed. The proposed model is presented in section 3, while a case study is developed in Section 4. Conclusions and future work are presented in Section 5.

2. The Risk Management Problem in a Container Terminal

2.1 The Risk and Event Management Problem
Risk management is the identification, assessment and prioritization of risk after that the risk management includes the coordination and economical application of resources to minimize, monitor and control the probability and/or impact of disruptive events. Risk can come from uncertainty, natural causes, social causes, procedures, etc. The risk management goal is reducing the vulnerability and ensuring continuity.

The event management is understood as the component of risk management to reduce the gap between planning and execution systems in order to minimize the impact of an exception or deviation from a current plan allowing in turn the visibility and agility with a consequent resilient (Bearzotti, 2012, 2013). The event management is the activity en risk management process where the actions are analyzed when a risk is a certainty.

2.2 Risk and Event Management in a Container Yard
The port is a convergence point; today is a major node of convergence in international transport and trade, and it is the point of contact between land and sea transport. It needs to improve their process in terms of its agility and ability to respond to unforeseen events. For this, a system that can respond to changes and disruptions in the port terminal is very necessary tool to enhance resilience in the port.
The Container Port Terminal has three principal areas: Quay, Yard and Gate. These areas are related and if one of them has a problem may impact the others. But the Yard is the key element because a bad management in the Yard will be bad operations in Quay and Gate.

One of the main functions of a container terminal is the container transfer to and from ships at Quay. On the other hand the Yard also is related to the Gate giving and receiving containers either by truck or by train. For these operations, the Yard has resources that are used in function-oriented storage and movement of containers in the terminal planning.

In an ideal situation, the plans are executed without problem, but there is variability in the execution. Disruptive events cause deviations in the plan execution and in the expected result.

It is essential in the yard operation that plan will be with slack to handle events that occur in the plan execution. If the slack is used then the event consequences are minimized.

An event management system in the container yard seeks to mitigate the impact of disruptive events using slacks current plans, thus avoiding re-planning. An event management system can generate improvements in the administration of the yard and its relation to the Quay and the Gate.

2.3 Related Work

In this section the related work are presented, specifically to yard event management systems there is not many related work. There are papers related in the monitor and control area.

Gronalt et. al. (2008) present an study about risk in a container terminal. They propose a risk evaluation with three steps: 1) terminal description (internal factors, network factors and environment conditions); 2) risk identification and classification; 3) for each risk, to determine risk consequences. After that a vulnerability analysis is made.

Loh and Thai (2012) indicate the port role in the supply chain. They do an analysis related with the port risks and propose a holistic management model.
Najib et. al., (2013) propose a process for managing risks related to containers on drugs suspicion, establishing a set of rules for inspection. It proposes a framework for multi-agent systems focused on high-risk containers.

MOCONT (Monitoring the Yard in Container Terminals) (Bozzo et. al., 2001), is a monitoring and control system for a container port terminal. This system uses GPS with sensors to monitor container movements and their position. There are three modules: Location Module, Visual Identification Module and Synchronization and Communication Module.

Ngai et. al. (2011) propose a study case for the prototype: ICADSS (Intelligent Context-Aware Decision Support System), to monitor in real time the operations in the Hong Kong container terminal. This system uses a sensors network USN (Ubiquitous Sensor Network).

Zeng et. al. (2011) propose a mathematical model for events in Quay. First, the Berth Allocation Problem (BAP) is presented. After a disruption management is described.

Bearzotti et al., (2012) present an approach for supply chain event management. This work is focused in the mitigation of events in supply chain.

3. A Multi-agent Model for Event Management in a Container Yard

In this section a yard container port terminal event management multi-agent conceptual model is presented YEMS (Yard Event Management System). The PASSI methodology (Cossentino, 2003) is used in the model description.

The YEMS model has six agents: EIA (Execution Interface Agent), PIA (Planification Interface Agent), SEMA (Space Event Management Agent), REMA (Resource Event Management Agent), Resource Agent and RE (Relations with the exterior).

The PIA and EIA agents have the function of to interact with the planning system and execution system. The SEMA and REMA agents manage the events related with space and resources. The agent Resource represents the
resources in the Yard, its function is coordinating the tasks with the SEMA and REMA agents. RE agent is related with the Quay and the Gate to collaborate in the event management.

The next sections the different agents are presented and how they are related.

### 3.1 A Conceptual Model for Event Management

YEMS interact with the event management system in Quay and Gate, this is important when a disruptive event affect the terminal. In the Figure 1 the different subsystem are presented. In other hand YEMS is related with the planning and execution systems. There are agents specialized in these interrelationship.

![Fig. 1: Container Terminal Event Management System - Subsystems](image)

The YEMS receives the plan from Planning System and the events from the Execution System. When a disruptive event can not solve in the quay or gate, the event management in these subsystems sends a call for participation to YEMS.
3.2 Agent PIA

This agent performs the task communication between YEMS and planning level. Get updates and planning and communicating if an exception occurs. Upon receipt of planning makes the difference between planning and resource spaces, initializing the amount of resources that should be considered in the YEMS. PIA sends schedules to respective agents (Resource agent and SEMMA agent).

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Plan</td>
<td>Plan related with resources and spaces from Planning System, with this information it sends the information to SEMA agent and to Resource Agent.</td>
</tr>
<tr>
<td>Inform Exception</td>
<td>Send an exception message to planning system when a disruptive event cannot solved.</td>
</tr>
<tr>
<td>Consult</td>
<td>Consult if there is a change in the plan</td>
</tr>
</tbody>
</table>

Tab. 1: PIA Uses Case.

3.3 Agent Resource

This agent represents each resource within the yard and manages tasks. It contributes to cooperation and works with other agents. Check availability for additional tasks and delivery proposals for performing tasks. This agent contains two lists, a list of the tasks set by planning to have the first priority to be executed and a second list of tasks requested from other resources, which have made a second priority. These last recourse is performed only when the time available to perform them, that is, when not performing a task from the list of first priority.
Uses Case | Description
---|---
Check availability of resource | Review each resource and check availability for extra task.
Check task list | Check the task list searching for time to do an extra task.
Assign task | If there is availability, a task is assigned to the resource.
Enter resource | This UC register the information about the resources.

Tab. 2: Agent Resource Uses Case.

### 3.4 Agent SEMA

This agent manages the spaces within the yard. Get and set space planning and which are available. This manager check availability of spaces and allocating containers involved in an event. Also it participates in the cooperative when it comes to an external event. In the latter case provides alternative spaces according to features delivered by the request for cooperation. Also makes a negotiation with the resource agents when trying to coordinate a task either, mobilizing, positioning or removing a container. Finally a proposed solution delivery if they reach a settlement proposal or an exception if the search is negative spaces available.
### A Multi-Agent Based Approach for Risk Management

<table>
<thead>
<tr>
<th>Uses Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Event Space</td>
<td>The Agent EIA notifies about an event related with the space in the yard.</td>
</tr>
<tr>
<td>Manage Space Event</td>
<td>With the information, the agent begins the process to find an action plan.</td>
</tr>
<tr>
<td>Check space availability</td>
<td>This UC finds spaces in the yard.</td>
</tr>
<tr>
<td>Assign space to container</td>
<td>This UC register the information about the container in the available space.</td>
</tr>
<tr>
<td>Send proposed solution</td>
<td>Notify to EIA the new plan.</td>
</tr>
<tr>
<td>Send exception</td>
<td>If there is not solution, it sends the information about the exception to PIA agent.</td>
</tr>
<tr>
<td>Manage external event</td>
<td>Receive information. Consult space availability and inform propose to RE agent.</td>
</tr>
<tr>
<td>Initialize spaces</td>
<td>Receive planning information. Set availability of spaces.</td>
</tr>
<tr>
<td>Coordinate Task</td>
<td>Coordinate task of moving and positioning with resource agents.</td>
</tr>
</tbody>
</table>

Tab. 3: Agent SEMA Uses Case.
3.5 Agent REMA

This agent manages the resource events. Get the event and consulting resource availability of a resource agent to perform additional tasks, thus distributing the tasks of the affected resource among other resources. If negotiations are successful make a settlement proposal and sends it to EIA agent, otherwise make an exception and sends it to the PIA and EIA agents.

<table>
<thead>
<tr>
<th>Uses Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Resource Event</td>
<td>The Agent EIA notifies about an event related with the resource in the yard.</td>
</tr>
<tr>
<td>Manage Resource Event</td>
<td>With the information, the agent begins the process to find an action plan.</td>
</tr>
<tr>
<td>Check resource availability</td>
<td>This UC finds resources available in the yard.</td>
</tr>
<tr>
<td>Assign space to container</td>
<td>This UC register the information about the container in the available space.</td>
</tr>
<tr>
<td>Send proposed solution</td>
<td>If a solution exists notify action plan.</td>
</tr>
<tr>
<td>Send exception</td>
<td>If there is not solution, it sends the information about the exception to PIA agent.</td>
</tr>
</tbody>
</table>

Tab. 4: Agent REMA Uses Case.

3.6 Agent RE

This agent is responsible for communication with the external actor (or Quay Gate) when requested cooperation to resolve an event that occurred in its domain. Receives the request and determines whether cooperation is a request
for space, or resource allocation. For the first two sends an availability check to the respective agents (SEMA or Resource) in the case of an application for allocation refers to the allocation request either one or more spaces or containers of a task to one or more resources. This allocation request may be a response to Quay Gate or a proposal previously submitted by YEMS space before the application or resource.

<table>
<thead>
<tr>
<th>Uses Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Request</td>
<td>Quay or Gate sends a request.</td>
</tr>
<tr>
<td>Send Request</td>
<td>Send the request to SEMA or REMA</td>
</tr>
<tr>
<td>Order Allocation</td>
<td>Request allocation of spaces or tasks to a resource. This action is in response to the proposal previously submitted by this agent to the request for cooperation from the outside.</td>
</tr>
<tr>
<td>Send proposals</td>
<td>Receive proposals from the SEMA agents and REMA and then sent to external stakeholders.</td>
</tr>
</tbody>
</table>

Tab. 5: Agent RE Uses Case.

3.7 Agent EIA

The agent in charge of receiving events from the monitoring system and communicate them to the corresponding agents is. Also manages the congestion event, negotiating with external actor Gate entrance dwell time of containers (or trucks) yard to thereby relieve it.
<table>
<thead>
<tr>
<th>Uses Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Event</td>
<td>Get captured by the monitoring system event. The YEMS consults to establish what type of event it is. It requests a data update to PIA agent.</td>
</tr>
<tr>
<td>Notify Event</td>
<td>Send the request to SEMA or REMA</td>
</tr>
<tr>
<td>Congestion Management</td>
<td>If the data indicate that the event is an event of congestion, then this use case takes over.</td>
</tr>
<tr>
<td></td>
<td>According to a set time of &quot;backwardness&quot; of operations in patio, sends a request to terminate the entry of vehicles through the Gate of the use case Send request time, for a period equal to time set as &quot;backwardness.&quot;</td>
</tr>
<tr>
<td>Analize time proposals</td>
<td>Analize the answer sends from Gate for the extra time.</td>
</tr>
<tr>
<td>Notify action plan</td>
<td>Notify the answer plan to execution system</td>
</tr>
</tbody>
</table>

Tab. 6: Agent EIA Uses Case.
4. Study Case: San Antonio Port

This preliminary model has been tested with information from the container port terminal in San Antonio Port. Some events were simulated and the behavior of model analyzed. Yard port terminal operations planning and execution was developed. This scenario consists of a window of 40 hours of operation of the terminal. It has created a planning yard detailed spaces and resources with their respective missions to store and mobilize import containers and export terminal. It considered the arrival and departure of six ships with the respective containers to be unloaded and loaded at these for this schedule.

After establishing the overall planning, involving the shipping planning, yard planning and spaces, we proceeded to simulate the execution of operations to carry out the provisions of this general planning. For the simulation of the execution of operations Monte Carlo simulation was used to establish statistical distributions among other things, the arrival times of containers between the Gate, service times by Reachstackers container, the working times of Gantry cranes (on the Quay), and so on, always under the care of these details were as representative of the reality of a terminal of its kind. And then the simulation was done considering various events. In the event presentation pre and post-event state is detailed, highlighting the main changes resulting from the implementation of the action plans offered by the YEMS.

5. Conclusion and Future Work

In this paper the risk and event management problem in the port terminal container yard is presented and a model is obtained. In the Supply Chain, a port terminal is a strategic actor which converge multiple global supply chain. Because of this is important propose a solution to the risk and event management in this domain. The events impact in a terminal can cause considerable losses and impact on other actors in the global supply chain. It arises is why the interest in having information systems that enable the
management of disruptive events within a port terminal. This model emerges as a precedent in the development of a software solution that is able to provide timely and effective plans deviations answers.
A multi-agent called YEMS model has been developed under the PASSI methodology. This multi-agent model was designed to manage internal events (resources, space and congestion) and external events generated in the Quay Gate and subsystems. The main agents are: EIA (this agent is the interface between YEMS and Execution System, it receives the disruptive events and notifies the plan changes), PIA (it is the interface with Planning Systems; it receives the plan and notifies the exceptions), SEMA (it manages the space on yard events, also it participates in the coordination process when an extern event is received), REMA (it is similar to SEMA but it has to manage events related with resources), Resources (this agent represents the resources in the yard, there will be an resource agent by each resource considered in the plan) and RE (the relationship with the other sub-system is carried out by this agent). This model offers the first action oriented in the disruptive event mitigation process.
The future works include the model implementation and the model validation with a study where the proposal will work with real events in a simulated environment in first place. In the future and with the alliance with a port terminal the information system will be test in a real environment.
Another future work is developing the risk and event management in the gate and quay, and the three model integration.
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Wolfgang Kersten, Thorsten Blecker and Christian M. Ringle (Eds.)

Next Generation Supply Chains
Next Generation Supply Chains

Trends and Opportunities
Preface

Today's business environment is undergoing significant changes. Demand patterns constantly claim for greener products from more sustainable supply chains. Handling these customer needs, embedded in a sophisticated and complex supply chain environment, are putting the players under a constant pressure: Ecological and social issues arise additionally to challenges like technology management and efficiency enhancement. Concurrently each of these holds incredible opportunities to separate from competitors, yet also increases chain complexity and risks.

This book addresses the hot spots of discussion for future supply chain solutions. It contains manuscripts by international authors providing comprehensive insights into topics like sustainability, supply chain risk management and provides future outlooks to the field of supply chain management. All manuscripts contribute to theory development and verification in their respective area of research.

We would like to thank the authors for their excellent contributions, which advance the logistics research progress. Without their support and hard work, the creation of this volume would not have been possible. We would also like to thank Sara Kheiravar, Tabea Tressin, Matthias Ehni and Niels Hackius for their efforts to prepare, structure and finalize this book.

Hamburg, August 2014

Prof. Dr. Dr. h. c. Wolfgang Kersten
Prof. Dr. Thorsten Blecker
Prof. Dr. Christian Ringle
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This volume, edited by Thorsten Blecker, Wolfgang Kersten and Christian Ringle, provides valuable insights into:
- Innovative and technology-based solutions
- Supply chain security management
- Cooperation and performance practices in supply chain management