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Dynamic and synchromodal container consolidation: the cloud computing enabler

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Abstract

Since the container became the dominant unit and driver of change in world-wide freight transport, the optimal utilization of container capacities has become a key challenge of the supply chain management. Fragments of customer orders often arrive to the final destination via different, sub-optimal routes which impose increased delivery times, costs and CO_2 emissions to the global supply chain. This work describes how cloud computing is an enabler for addressing the issue of dynamic and synchro-modal container consolidation at the Piraeus Container Terminal, the fastest growing port in Europe according to recent studies.
A significant barrier to an efficient container consolidation at port terminals is the reduced visibility and information exchange between related stakeholders on real-time location and status of a container and its contents. This is due to a multitude of reasons: the lack of a common standard for information exchange, competition matters, absence of trusted service providers collecting data, information shared on a next carrier basis without disseminating information to the rest stakeholders. Well-defined trigger points on standard routes may be reported by the carriers (e.g. arrival and shipment of goods, credit releases) and will allow for better monitoring of shipments and introduction of Key Performance Indicators for route evaluation and carrier performance.
This work proposes a cloud-based information portal as an ICT enabling technology used as a single point of reference by supply chain stakeholders; the latter will use this portal to feed it with real-time information from existing platforms so that a better visibility for all parties is enabled. This portal will implement accessible interfaces with parties of each step of the transport process (e.g. interface with the customer, warehouse, next-leg carrier) using standardized formats as far as possible. It will allow

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for a flexible parameterization per customer and for a straightforward incorporation of regional special requirements, as is the constraint of single customer per container applicable in some countries. This portal will permit a better visibility level for end-customers, promote standardization of logistics processes, offer an increased profitability for cloud services providers, improve their activities expansion, as well as accelerate customs process handling. Nevertheless, even though cloud technology is mature enough, the trust level of stakeholders in security and reliability of such solutions needs to increase for a wide deployment.

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Keywords: Container; consolidation; cloud computing; palette; supply chain; multimodality

1. Introduction

Worldwide traditional manufacturing models and processes have started to radically change in the recent years. Incentivised and supported by the latest advances in additive manufacturing, online ICT (Information and communication technologies) collaborative tools, e.g. IoT (Internet of Things), cloud services, SaaS and Paas (Software and Platform as a Service) architectures and lately 3D printing, today's industry giants as well as startups are increasingly incorporating the model of customized and distributed manufacturing. The geography of a single ODM (Original Device Manufacturer) is no longer a constraint. Distributed manufacturing decentralizes traditional manufacturing and has a significant impact on supply chain strategic planning. Supply chains are redefined due to a combination of specialized additive manufacturing technologies, open source advances and online collaboration. Within this framework, the challenge of optimised and efficient container consolidation in large maritime transport hubs and container terminals, very often accompanied by a palette of added value services such as packaging, bundling, handling, becomes more and more relevant but at the same time complex.

1.1. Motivation

A significant barrier to an efficient container consolidation at container terminals is the reduced visibility and limited information exchange between all related stakeholders, i.e. shippers, carriers, warehouse management systems, forwarders and container terminal operators on real-time location and status of a container and its contents. This is due to a multitude of reasons: the lack of a common standard for information exchange, competition matters, absence of trusted service providers collecting data, information shared on a next carrier basis without disseminating information to the rest of the stakeholders. For instance, shipments are usually monitored at order level and unit quantity. This information is practically useless to warehouses since it is almost impossible to track packaging dimensions of every single product passing through the warehouse. If number and type of pallets used per order was available in advance, then planning and consolidation of shipments would have been easier and faster. This information is available at the manufacturing site but rarely passed on to the carriers. Moreover, multimodal transport involves a number of carriers till the goods reach their final destination. Well-defined trigger points on standard routes may be reported by the carriers, i.e. arrival of goods, shipment of goods, start of processing, duel times, credit releases, customs authority releases etc. and will allow for better monitoring of shipments and introduction of KPIs (Key Performance Indicators) for route evaluation and carrier performance.

This paper describes the objectives, features and benefits for a cloud-based information portal which will be used as a single point of reference by relevant supply chain stakeholders; the latter will use this portal to feed it with real-time information from existing systems/platforms so that a better visibility for all parties is enabled. This portal should implement accessible interfaces with parties of each step of the transport process, e.g. interface with the customer, warehouse, next-leg carrier etc. using harmonized/standardized formats as far as possible, e.g. EDI (Electronic Data Interchange) gateways, SSM (Shipment Status Message) gateways. It will also allow for a flexible and seamless parameterization per customer/end-user as well as for a straightforward incorporation of regional/local special requirements, as is the constraint of single customer per container applicable in some LEVANT countries. This portal will permit a better level of visibility for end-customers, promote standardization of logistics processes,

offer an increased profitability for data/cloud services providers and improve their activities expansion, as well as accelerate customs related process handling.

1.2. Paper Structure

The remainder of the paper is organized as follows: Section 2 presents a literature review of the main ICT tools and platforms necessary for the efficient operation of a container terminal operating as a multimodal hub with particular emphasis on recent integration tools which have been proposed to target interoperability across a supply chain. Section 3 describes the case study which is examined, i.e. the container consolidation at Piraeus Container Terminal focused at destinations with relatively small freight volumes. Section 4 lists and explains the main features and benefits of a cloud based information portal which targets to serve as a federation of individual platforms used by collaborating stakeholders. Finally, Section 5 concludes the paper.

Nomenclature

EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
ERTG	Electrified Rubber Tiered Gantry
FFA	Field Force Automation
FFM	Fleet and Freight Management
GNSS	Global Navigation Satellite Systems
IaaS	Infrastructure as a Service
ICT	Information and Communication Technologies
IoT	Internet of Things
KPI	Key Performance Indicator
LEVANT	Eastern Mediterranean Region including Cyprus, Israel, Lebanon, Jordan, Syria
ODM	Original Device Manufacturer
PaaS	Platform as a Service
PLC	Programmable Logic Controller
PCS	Port Community System
RFID	Radio Frequency Identification
RMG	Rail Mounted Gantry
SaaS	Software as a Service
SAN	Storage Area Network
SCE	Supply Chain Execution
SSM	Shipment Status Messages
TEU	Twenty-foot Equivalent Unit
TM	Transport Management
TOS	Terminal Operating System
VPN	Virtual Private Network
WMS	Warehouse Management System

2. Literature Review

For a fully functional container terminal to be able to operate efficiently and accommodate intermodal and synchro-modal traffic, a broad set of different ICT software and platforms are necessary to support and monitor related activities. These can be generally categorized in the following clusters according to the Perego et al. (2011) classification:

- Transport Management (TM) tools: Decision support tools in transportation planning and optimisation, with typical functionalities including carrier load tendering, routing and scheduling, shipment tracking and tracing, and freight payment and auditing (Gilmore and Tompkins (2000); Tyan et al. (2003)). Track-and-trace systems are becoming more and more popular for freight transport, in most of the cases provided only as informative tools; sometimes, however they are also accompanied by modules performing route optimization using complex algorithms from predictive analytics or machine learning domains.
- Supply chain execution (SCE) tools: Tools designed to manage and automate information exchange and real-time management during the actual execution of a distribution schedule according to Giaglis et al. (2004). In this category belong classic tools for warehouse management, i.e. Warehouse Management Systems (WMS) as well as Enterprise Resource Planning systems (ERP). Even more importantly, the Terminal Operating Systems (TOS) may be classified under this category and are tools of primary importance to the supply chain, controlling the movement and storage of cargo/containers in and around a container terminal or port.
- Fleet and freight management (FFM) tools: Tools providing vehicle travel times, service times, delivery points visited and other parameters, e.g. load temperature, as real-time input to dynamic vehicle management functions so that a fleet of vehicles may be efficiently managed. Vehicle tracking devices with positioning capabilities such as Global Navigation Satellite Systems (GNSS) fall under this category, as well as the increasingly popular Container Security Devices (CSD) explained in a Worldbank (2015) report.
- Field force automation (FFA) tools: Tools enabled by mobile technology and supporting the integration between remote workforce and corporate business processes (Rodina et al. (2003)).

The vast majority of the aforementioned solutions are targeting to solve specific operational and optimisation issues. Nevertheless, they are mainly proprietary, tailored for the needs of specific stakeholders of the logistics chain and are incapable of solving a global issue as is the container consolidation that requires interoperability and information sharing among various and diverse members of the supply chain around a container terminal. In order to bridge this gap, a number of solutions have been proposed recently in order to facilitate integration among the aforementioned tools and corresponding stakeholders. The scope of the following review of such tools has mainly a container port as the epicentre; specialized integration tools referring to other means of transport hubs, such as airports or large distribution centres are beyond the scope of this paper.

- Port Community Systems: According to the definition of the International Port Community Systems Association IPCSA (2014), “PCS is an electronic platform that connects the multiple systems operated by a variety of organisations that make up a seaport or airport community. It is shared in the sense that it is set up, organised and used by firms in the same sector – in this case, a port community.” PCS are key enablers for the transition of ports all over the world and their countries towards the Single Window environment; they are usually modular systems facilitating interactions among players within a port community regarding exports, imports, transshipments, dangerous goods and consolidations. Most of them allow for an EDI-based information exchange, customs declarations, electronic handling of information regarding import and export, tracking and tracing across the supply chain.
- Supply Chain Control Towers: A supply chain control tower is a central hub with the technology to use supply chain data to provide enhanced visibility for decision-making aligned with strategic objectives. The control towers have been enabled by cloud-based technology and accommodate a broad set of services collecting and aggregating orders, shipments, inventory and status. They take advantage of order and transportation management software applications and facilitate data exchange between carriers, logistics service providers and senders and receivers of goods and have been successfully adopted by many ICT companies in the field of logistics (Ceva Press Release (2011), Kuehne+Nagel (2015)). They may be implemented in different architectures, e.g. at centralised locations for many customers in a shared environment or dedicated on-site or remote for a single customer.

In recent years, a number of publications have advanced the use of cloud computing in logistics processes. Nevertheless, to the authors' best of knowledge this has not been examined nor applied to port terminal operations such as container consolidation. In particular, Schuldt et al. (2010) identified the potential of cloud computing to facilitate autonomous control in logistics and allow for scaling autonomous logistics applications based on dynamically arising logistics demands. A four-layer architecture is suggested:

- Infrastructure as a Service (IaaS) option, where the logistics users may use a scalable hardware platform from the cloud service provider to install their own logistics ICT tools;
- PaaS option, where a software platform is provided which offers a given set of services, usually in an agent-based implementation; the cloud service provider is the administrator of the software platform;
- SaaS option, where a complete implementation of software agents for autonomous control in logistics is provided; the user delivers only process information;
- Process as a Service option, which does not only provide a software implementation for autonomous logistics but also a platform that integrates logistics service providers that execute the services demanded.

Moreover, Holtcamp et al. (2010) introduced the "Logistics Mall platform" with the aim of providing a market place for logistics services and processes together with a cloud based access and execution environment. The Logistics Mall consists of two components: mall marketplace and customized access framework: the former is a specialised Web shop for logistics IT services and logistics process support, whereas the latter implements a logistics specific SaaS layer and provides a customer company of the Logistics Mall with a user specific framework for access to multiple logistics applications and is designed for public use.

3. Piraeus Container Terminal Case Study Description

Piraeus Container Terminal SA is a wholly-owned subsidiary of COSCO Pacific Limited. It is principally engaged in the development, operation and commercial utilization of the Piraeus Container Terminal (PCT). It currently operates Pier II & III with a total capacity of 4,8M TEUs per year. It has recently initiated construction works for the west-bound expansion of Pier III that will increase the annual capacity to 6,7M TEUs per year seeking to become the leading port in the MED area. In PCT, innovative ICT tools are considered a vital factor for the port development. Several projects have been implemented so far in the container yard, focusing on the improvement of monitoring and tracing containers and yard equipment, such as tracking of yard equipment, localization of containers, illustration of containers on the yard map, capturing of yard equipment data for further analysis. Current implementations of the aforementioned projects have been enabled by using the current cloud infrastructure of PCT. Data captured is stored on the Central SAN (Storage Area Network). Long term storage is vital for sustainability and since consumption trends and driving styles over time can reveal opportunities for fuel consumption and exhaust reductions. Initial data have shown a potential of 15% savings on yard trucks.

Currently, PCT uses a number of different ICT tools and platforms in order to perform the operations, security and management of the Port Container Terminal as well as support its interfaces with other transport modes such as rail- or truck-based transport. It is important to note that due to an increase in the TEU traffic of PCT in the recent years, the complexity of maintaining a hardware architecture sufficient to host these tools has become difficult to sustain. Moreover, as it is evident in what follows, these tools are not capable to cope with an efficient container consolidation process at least not in a holistic way that does not depend on separate proprietary solutions per single customer. In the remainder of this section the currently used ICT tools are described in detail.

- Terminal Operating System (TOS): PCT uses CATOS (Computer Automated Terminal Operating System) from Total Soft Bank. CATOS has a full suite of planning, operation and management system modules covering the total operations of the terminal and utilizing terminal resources fully. PCT uses CATOS to manage, plan and operate in the port terminal the different container flows and delivery by vessel, rail or import/export. PCT has installed monitoring hardware on all yard equipment. Container movements are confirmed by the drivers on

Straddle Carriers and Front Loaders. On Rail Mounted Gantries (RMGs) and Electrified Rubber Tiered Gantries (ERTGs) the terminal of CATOS has been linked with the equipment Programmable Logic Controller (PLC) management system and receives information regarding lock/unlock of the spreader twist locks. This way the loading and unloading of containers can be automatically confirmed without human intervention. The equipment PLC management system has the block-bay-row-tier information mapped to geographical coordinates and thus container placement accuracy is ensured.

Fig. 1. Automated gates at the Piraeus Container Terminal.

- Automated Gates: The AutoGate is based on a Driver ID card. It is a proximity RFID card with a unique number assigned to it. Drivers visiting the terminal have their personal Driver ID card and whenever they have to pick-up or deliver a container, the container job ID related to it is linked system-wise with a unique card number. During the pre-announcement process the customs broker or shipping agent defines the trucking company that will be picking-up or delivering a container. This can be done either by visiting PCT premises or submitting a web pre-alert file to a proprietary PCT web portal. Upon submission of the required data, container job IDs are created and distributed to trucking companies. Each logs in to a proprietary web portal after establishing a secure VPN tunnel with PCT internal network. This web portal is used by the trucking company to manage container jobs and assign them to Driver IDs. Functions that can be performed are as follows: link/unlink container job IDs to driver ID cards; view the status of a container job; view container job details; link/unlink container jobs to other trucking companies/drivers (e.g. independent drivers). A container job ID can be assigned to a different driver until it reaches the customs security gates and initiates the execution phase of the job. Upon arriving at the customs security gates the driver will have to use his card at the pedestals installed there. If there is a job linked to it, access will be allowed otherwise he will be instructed to leave the terminal. The truck then arrives at the Optical Character Recognition (OCR) portal shown in Figure 1 where it is photographed and truck and container data are captured (i.e. container number, truck license plate etc.). Finally, the driver confirms that data captured is correct and receives a paper slip with the location that he should drive to in order to complete his job. At the

same time, the TOS is informed of the incoming truck and a timer starts counting to prioritize the execution of jobs.

- Real-time web services: Port stakeholders have access to a variety of real-time web application accessible either via the PCT official web site at http://www.pct.com.gr or, for sensitive information, via the establishment of a VPN channel with PCT network. The services that are offered include: information about the short & long term vessel schedule; information on the progress of works on working vessels; gate information; scheduled or stacking container information; real-time information for container discharge to custom brokers; yard statistics. Moreover, an SMS service is available for yard statistics and real-time information for container discharge to custom brokers. The latter has proven quite useful since the discharge of a container is the trigger point that allows both PCT and the customs office to initiate the process for custom formalities and thus better serve custom brokers and end-customers as well as off-load the documentation departments of both PCT and customs. A screenshot from the web-service based portal is shown in Figure 2.

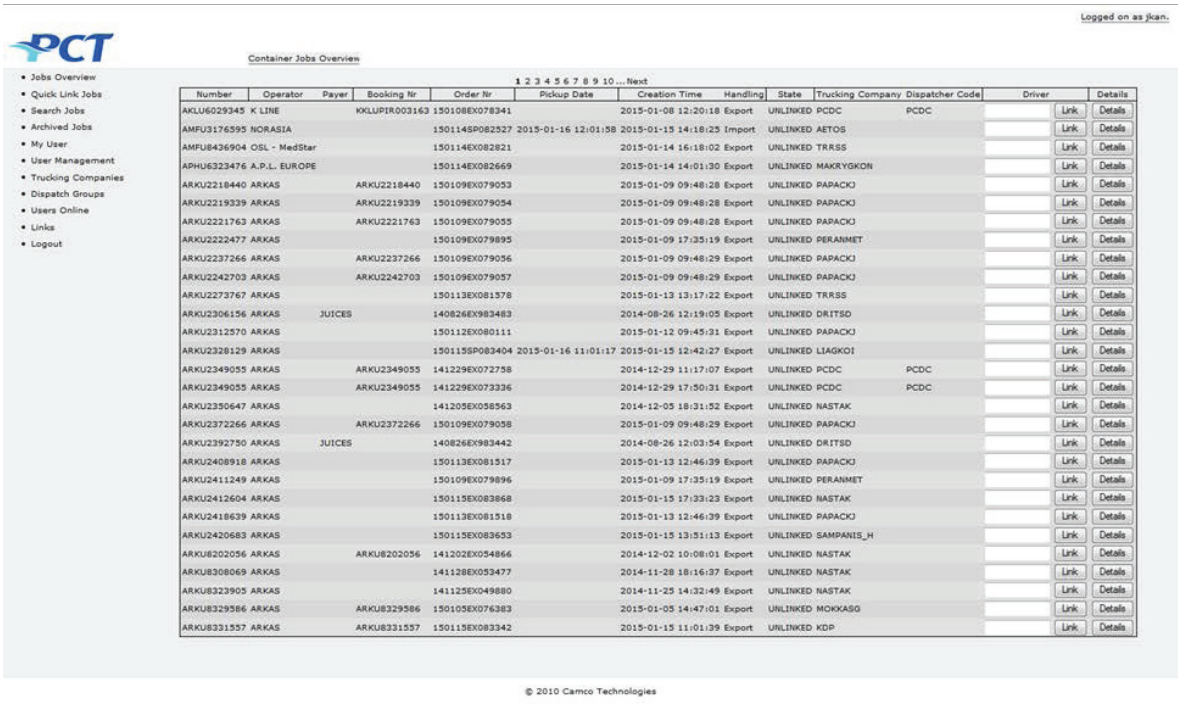

Fig. 2. Screenshot of web-portal for shipping companies to manage and monitor jobs.

- Custom-made planning platform for cargo: PCT has internally developed a proprietary java based hosting platform where the status of shipment for its major ODM clients may be tracked. The platform contains useful information on key parameters of the shipment status, such as: destination, carrier, transport mode (ocean, rail, truck, air), container or palette packaging, export/import/transshipment. The platform has an internal registry for Shipment Status Messages (SSMs), designating important trigger points to be reported i.e. arrival of container in the terminal, shipment of container, start of processing in the container terminal, credit releases, customs authority releases. This platform also has an active interface to the Warehouse Management System of the distribution centre located in the close proximity of the container terminal.

4. Features and benefits of the proposed cloud based information portal

For all aforementioned tools and platforms, it is not straightforward and cost-effective to maintain the related network and storage infrastructure. This fact has rendered legacy solutions – even the ones supporting integration activities, as are the PCS – incapable to support the resulting exponential growth in hardware infrastructure and sustainability requirements and to this end, a cloud based information portal is currently planned. This portal will gradually replace the current in-situ infrastructure and it will meet the scalability and efficiency requirements of a multi- and synchro-modal container terminal as is PCT.

In this cloud based architecture, the maintenance of the respective infrastructure may be hosted by a third party through a Service Level Agreement. More importantly, at the same time, collaborating external companies and organizations may use a subset of this pool of resources and services, according to access rights determined by the container terminal. This will be enabled by the concept of 'Information Profiles'. This concept is an extension of the notion of 'Logistic Service Profile' introduced in Hofman (2012) which contains a semantically supported description for each of the layers of the ontology proposed. In particular, the Information Profiles specify resource characteristics in terms of the type of data they share, both semantically and syntactically, metadata, etc; an Information Profile is the basis to search and find resources for all interconnected members of the PCT-centric supply chain. Through automatic transformation, the cloud portal will be able to transparently integrate totally diverse services; from logistics services, as is the management of credit holds/releases to traffic management services as is the notification of a motorway traffic management centre of the entrance of a truck fleet carrying cargo of specified criteria (e.g. dangerous cargo).

The aforementioned features allow that external stakeholders are only accessing - on a needed basis - sharable information granted by PCT. This is very important for many small and medium enterprises, such as shipping companies, that are collaborating with the container terminal and will thus be freed from the burden of managing the complexities of ICT applications. On the other hand, this architecture is able to accommodate the substantial amount of data from a multitude of end devices (e.g. track and trace systems, On Board Units, Road Side Units, legacy or IoT devices) which are necessary to keep up-to-date information on container and cargo status from and to all parties. It also has the capacity to accommodate data stemming from social media networking applications which are now in the forefront of logistics state of the art; truck drivers tend to use social media to provide updates on traffic status in an ever increasing rate (Telogis (2015)).

The traditional method of communication between shippers and carriers for containers passing through PCT is bilateral and partially fragmented. In essence, PCT would publish targeted SSM messages to corresponding stakeholders through the aforementioned custom-made planning platform through a hub and spoke fashion. During the last five years, PCT has become a container consolidation centre for the Southern Eastern Mediterranean region and beyond with a consequent exponential increase of multimodal traffic; thus, the network of next legs of each container journey through air, rail and truck has significantly expanded and so have the number of associated shippers and freight forwarders. This has a direct effect in the complexity of maintaining separate interfaces with all such organisations that, besides, have a different level of ICT automation; these interfaces are becoming increasingly challenging and ineffective for the container terminal to maintain. Through a cloud based portal, during all phases of goods being in transit, all concerned stakeholders are constantly updated by the portal on the status of each shipment. This includes palette information, which is fundamental for an efficient container consolidation at the terminal. Shipments are usually monitored at order level and unit quantity. This information is practically useless to warehouses since it is almost impossible to track packaging dimensions of every single product passing through the warehouse. If number and type of pallets used per order was available in advance, then planning and consolidation of shipments would have been easier and faster. This information was till now available at the carrier but rarely makes it to the freight forwarders.

This increased visibility enables PCT as well as its collaborating organisations to be in greater control of the consolidation process and more importantly be proactive in responding to exceptional events. The portal will also facilitate financial settlements and feedback/performance reviews. In this manner, all modes of transport connected with the container terminal (ocean traffic, air, rail and truck) may operate into an interconnected streamlines supply chain with the terminal as the epicentre. Associated benefits include a significant cost reduction and an increased customer service improvement, resulting to a win-win situation for all parties. Another benefit of the cloud

information portal adoption is its simplicity to manage and administer all previously described ICT devices, tools and platforms deployed, as the terminal and its stakeholders may rely more on the service provider (third party) instead of putting significant efforts on the internal IT department. This solution will also provide to PCT the ability to add and remove computing capacity on demand; this ability is crucial and very effective for the process of dynamic container consolidation, which naturally exhibits a great variance depending on time of day, season or after unexpected weather conditions. Only referring to two such examples, traffic seems to escalate on Fridays whereas it is much lighter during other weekdays, while it also seems to have peaks once bad weather causes the Suez canal to close for a few hours.

However, one major concern and challenge is security and reliability. The responsibility for the reliability and security of cloud infrastructure lies mainly with the technology service provider; issues still are challenging to solve and the trust level of stakeholders needs to be increased. Due to the security and privacy issues, the followed architecture is hybrid: it is a mixture of public and private cloud structure, in which critical for the container terminal activities are performed using private cloud and are only accessible from within the organization and thus more secured, while the non-critical activities are performed using the public or community-level (allowing access to the container terminal's external stakeholders, i.e. shipping companies, the customs authorities, AIS etc.) cloud.

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