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Automation in port container terminals

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Abstract

This paper introduces the concept of automation and port container terminals and addresses some general considerations vis-à-vis automation in this type of port facilities. It further advances current knowledge on this topic by introducing an automation philosophy that adapts the implementation of automation technologies currently available on the market to the particular needs of each PCT. Finally, it concludes by summarising the main advantages and challenges regarding the automation of PCTs.

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Keywords: automation, port container terminals, methodology, functional approach, process reengineering, advantages, challenges

1. Introduction

Industrial automation consists in the use of mechanic, hydraulic, pneumatic, electric, electronic and computerised elements or systems to control equipment and processes, thereby reducing the involvement of humans in such activities. This is possible to the extent that this is a systematic and repeated process that follows rules and conditions that can be identified and programmed. To this effect this discipline covers both the field instrumentation used for data gathering as well as the management of the aforementioned data and the control of operations.

It makes it possible to reduce human intervention in industrial activities, allowing for a higher control of the equipment and processes involved. This results in the standardisation of performance and service levels, the elimination of uncertainty in response times and the reduction in operational costs and human errors. These advantages, coupled by technological developments and given that the current volume of worldwide trade means that an economy based only on manual labour is nowadays unconceivable, convert automation into a global flow which is present, to a greater or lesser extent, in nearly all industrial fields.

The logistics sector and the supply chain are not oblivious to this reality. In this sense, it is important to note developments in the management of large transport infrastructure towards the total or partial automation of their processes.

In the port domain the greatest proponents of automation are port container terminals. This paper faces the automation of these facilities.

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2. Port container terminals

A port terminal is a modal interchange facility that usually has an inland storage area to coordinate the flow of the arrival of goods by sea or land (Montfort et al., 2001). Its objective is to provide the necessary means and organisation for the interchange of such goods between the land and sea transport mode to be carried out in the best conditions in terms of time, efficiency, security, respect for the environment and economics.

In addition, port container terminals (PCTs) have certain features that confer them the ability to reach a much higher level of systematisation than other types of freight terminals such as:

- The standardisation of the means of transport - containers;
- The standardisation of the manner in which freight is handled;
- The high level of interchanges taking place;
- The high impact of technology on the profitability of terminals.

This level of standardisation and specialisation is what allows for a high degree of automation of equipment and processes in this type of port facilities. The planning and management of this type of terminal manifests a radical break from the conception of conventional terminals.

3. Automation in PCT

The launch of the ECT Delta Terminal in the Port of Rotterdam in the Netherlands in 1993 introduced the concept of “automated terminals” to refer to the highest level of automation to date. It was equipped with Automated Stacking Cranes (ASCs) and Automated Guided Vehicles (AGVs), allowing it to manage, without operators, the handling of storage and interchange equipment respectively.

Since the nineties many PCTs have embraced automation, consolidating itself as a global and permanent trend in the sector. In fact European and Spanish port policies have for a long time supported automation initiatives (COM (2007) 616 final; MFOM, 2012). As such the technological advances and the management tools dedicated to automation account for a large share of the equipment and software market for this kind of terminal.

However, when implementing these commercial automation solutions it is necessary to consider the particular needs of the PCT in question with respect to the level of automation sought and its current level of development, as well as to fully understand trends in the automation of PCTs.

3.1. Level of automation: major and minor automation

Nowadays the term “**automated terminal**” is used to refer to PCTs which in reality have only automated the movements in the yard and dock-yard interchanges like the ECT Delta Terminal. In such PCTs crane-ship operations are still manual whilst the interaction between yard cranes and the inland transportation means of reception and delivery remain assisted by remote controllers. This is, however, only one of the many automated possibilities in PCTs.

An intermediate solution between automated and manual terminals is, for example, the partial automation or semi-automation of principal movements. The term “semi-automated terminal” is used for terminals where, whilst yard movements are automated, dock-yard interchanges are carried out by conventional equipment, or vice-versa.

Automated and semi-automated terminals implement **major or total automations**, resulting in automated equipment such as the previously mentioned ASCs and AGVs.

The term ‘semi-automated’ can however also refer to the use of equipment controlled remotely or the systematisation of some of the functions of the equipment through **minor or partial automations**.

Major or total equipment automations are the sum of a comprehensive and integrated group of technologies or systems which separately could be considered minor automations. Thus, at times, it is possible to completely automate conventional equipment by implementing the necessary low level automations following a **retrofitting** process. This is a solution for terminals in operation that have not yet depreciated their initial investment in equipment (Monfort et al., 2012).

The combination of various major and minor automations results in PCTs with different levels of automation.

3.2. Greenfield vs. Brownfield project automation

It is necessary to note that the decision to automate a port container terminal, as is the case in other industries, differs depending on whether we are looking at a terminal being newly developed –greenfield-, or at a terminal already in operation –brownfield-. As expected the implementation of automations in terminals already in operation is more complicated due to compatibility issues vis-à-vis the activities being carried out and resistance to change.

The automation of a terminal requires without a doubt its **instrumentation**, consisting in the installation of equipment, devices, field transmitters, control and supervision systems, transmission and data gathering systems and real-time software applications to carry out, supervise and control operations. This inevitably results in a temporary drop in the regular levels of operational performance and efficiency. On occasions this can cause a detriment to the capacity and level of service provided with its duration and magnitude depending on the automation in question. When it comes to major automations, such as the one implemented by Antwerp Gateway Terminal (Port of Antwerp, Belgium) which transformed its yard straddle carriers to RMGs (Rail Mounted Gantry cranes), or the one planned by Xiamen Yuanhai Container Terminal (Port of Xiamen, China) (Port Technology, April 2012), amongst others, they must be implemented by phases in order to allow the facilities to continue operating.

In these cases one needs to take into account that during a short or long period of time there will coexist in the terminal two ways of handling traffic flows. It is therefore imperative to ensure that the terminal operating system (TOS) implemented can process both kinds of operational modes, as well as to arrange for additional space to create a temporary overcapacity to avoid the saturation of the yard during the transformation. Likewise, it would be convenient to follow some recommendations when designing the automation process of a terminal already in operation such as using, if possible, only one type of horizontal transportation equipment, trying to segregate the flow of such equipment in the case of a mixed fleet, cutting the access to some parts of the terminal, allocating sufficient time in the implementation plan to test the system once completed, investing fully in the training of human resources and informing clients about the new facilities and procedures (Saanen, 2010).

Minor or partial automations are usually as well minor in terms of transformations. The abovementioned, together with the smaller investment required, make them most of the times the ideal option compared with major automations for terminals in operation.

3.3. Trends in PCTs automation

Finally, albeit the previously mentioned concept of "automated terminals" refers to terminals that have automated their storage equipment and the interchange between subsystems, this is only one of the many automation trends in PCTs and the general trend is headed for higher levels of automation that go beyond the borders of terminal yards to involve all operations.

In general terms this wider development includes:

- The automation of gates;
- The automation of yards; and
- The automation of quay cranes.

In fact the first automations implemented in PCTs and the most advanced automation systems in today's market are those related to the processes that take place at the terminal gates. In this sense efforts are still being made to improve data gathering systems in the terminal-logistics chain interface. This interest to automate data gathering is common for inland and maritime gates, although it is the former of the two that captures more volume of data due to the atomisation of transport means.

Yard automation is the most apparent and obvious trend in PCTs. For this reason these terminals, as argued several times previously, whose yard movements are totally or partially automated, are the ones known as automated or semi-automated terminals, respectively.

The automated technology of storage and transfer equipment is similar and handles the automation of the inventory of the stock of containers located in the yard and the monitoring of equipment in real time. It is evolving towards the design of handling systems that are increasingly more self-sufficient in operational and economical terms such as those composed by the combination of ASCs + AGVs, ASCs + ALVs (Automated Lifting Vehicles) or ASCs + AShC (Automated Shuttle Carriers), amongst others.

The list of automated and semi-automated terminals (Table 1) has not stopped growing over the past years and it will continue doing so given increased investments being made in automation projects and the construction of new automated terminals in different geographic areas. These port facilities dispose of state-of-the-art currently available yard automation technologies, even though not all of them have opted for the same technological solution in terms of design.

Table 1 – List de automated and semi-automated PCTs

Automated and semi-automated PCTs
ECT Delta Terminal (HPH) – Port of Rotterdam, The Netherlands- (from 1993) (A)
London Thamesport (HPH) –Medway Ports, United Kingdom - (from 1994) (S)
Hong Kong International Terminal 6-7 (HIT) (HPH) – Port of Hong Kong, Hong Kong- (from 1995) (S)
Pasir Panjang Bridge Crane Terminal (PSA) – Port of Singapore, Republic of Singapore- (from 2000) (S)
HHLA-CTA – Port of Hamburg, Germany- (from 2002) (A)
Patrick Terminals –Port of Brisbane, Australia- (from 2005) (A)
Tobishima Pier South Side Container Terminal (TCB) – Port of Nagoya, Japan- (from 2006) (A)
Wan Hai –Port of Tokyo, Japan- (from 2006) (S)
APM Terminals Virginia, Norfolk (APMT) –Portsmouth, United States - (from 2007) (S)
Antwerp Gateway Terminal (DPW) – Port of Antwerp, Belgium- (from 2007) (S)
Evergreen (EMC) – Port of Kaohsiung, Taiwan- (from 2007) (S)
Euromax Terminal – Port of Rotterdam, The Netherlands - (from 2008) (A)
TTI Algeciras (Hanjin) – Port of Algeciras Bay, Spain- (from 2010) (S)
Pusan Newport International Terminal (PNIT) (PSA y Hanjin) – Port of Busan, South Korea (from 2010) (S)
HHLA-CTB – Port of Hamburg, Germany - (from 2011) (S)
Tercat (HPH) – Port of Barcelona, Spain- (from 2012) (S)
Xiamen Yuanhai Container Terminal – Port of Xiamen, China- (from 2013) (A)
TraPac Expansion – Port of Los Angeles, United States of America- (from 2013) (A)
APM Terminals Maasvlakte 2 (APMT) – Port of Rotterdam, The Netherlands- (from 2014) (A)
Rotterdam World Gateway (RWG) (DPW) – Port of Rotterdam, The Netherlands- (from 2014) (A)
(A) – Automated Terminal; (S) – Semi-automated terminal

Finally, **quay cranes** are the elements of operations whose automation is less developed, although it is foreseen that they will be the equipment with the biggest technological advance during the coming years. To date efforts to automate quay cranes have resulted in minor automations which, implemented in factories at origin or by means of retrofitting, can mechanise some of the functions that until then depended on the ability of crane operators (Zrnić, Petković and Bošnjak, 2005). These are focused on the control of the movements of spreaders, both involuntary (sway and skew) as well as their pathway, and the connection between quay cranes and transfer equipment. In parallel, terminals and manufacturers are testing systems that would manifest a qualitative technological leap for the automation of STS cranes.

In 2014 the AMPT Maasvlakte 2 terminal will come into operation in the Port of Rotterdam (The Netherlands). This terminal will boast the highest level of automation reached to date, combining the automation of gates and yards with the nearly complete automation of the pathway made by the trolley and spreader of quay cranes. This will be assisted by remote control from the operations control tower at the terminal only in the last meters to the ship (WorldCargo News, June 2012).

However, even though the current trends in the automation of PCTs are heading towards a total effective automation of these facilities, there exist numerous possible options between the total automation and the conventional manual management of PCTs, including assisting equipment remotely.

For this reason, when designing the automation of a PCT, it is advisable not to dogmatise on the level of automation of the facility and is recommended to go through the process in a methodological and systematical manner as proposed in the following section with the aim of designing an implementation plan that meets the operational needs of PCTs.

4. Automation philosophy of PCTs

The automation solutions, as well as other types of technological solutions designed for PCTs, have traditionally been focused from a systematic point of view - describing the practical elements of systems and their main responsibilities, interfaces and interactions. This approach has led to talks on the automations of quay and yard cranes and inland gates and, as a consequence, of automated and semi-automated terminals.

This systematic approach however limits the design of solutions and prevents the operational departments of terminals, considered to be the main customers of such solutions, from understanding how they fit with the operations of the PCT. This can result in the acquisition and implementation of solutions that do not fulfil their needs and that do not adapt to the operational restrictions of PCTs.

To avoid this problem, as a state-of-the-art advance, a methodology for the automation of PCTs is proposed. It approaches the issue simultaneously from a functional approach of the automation and the reengineering of processes as a work discipline.

This combination provides a comprehensive and integrated vision of the operational problems of PCTs, detecting bottlenecks and identifying improvement ideas so that the formulation process of solutions can be exhaustive and adapted to real operational needs and expandable to other areas of improvement unrelated to automation.

Thus, even though the methodology of this report is mainly focused on the incorporation of innovating ideas in automation, it is also applicable and useful for the study of any standardisation and operational optimisation solution aiming to improve the efficiency in the use of the resources of PCTs, as is the case with technologies aimed at increasing energy efficiency.

The methodology is applicable to newly developed PCTs during the design phase of operating processes as well as to PCTs that want to automate their operations up to certain degree, even total automation.

4.1. Functional approach

The functional approach to the automation of PCTs addresses automation from the point of view of the commitment achieved by the automation technologies in the operations of PCTs. The goal of automation technologies is to reduce the intervention of human resources in operations. Human resources participate in operations in three areas: (1) the physical flow of containers through facilities; (2) the associated documentary flow; (3) planning and managing operations.

To this effect, depending on the function being replaced, the technologies can contribute to (1) the automation of the tasks being carried out, (2) the automation of information flows or (3) the automation of the decision making process, respectively.

The **automation of the tasks** being carried out consists in reducing the intervention of the operators of equipment in handling movements, making thereby infrastructure and equipment more autonomous. Even when it is not completely reduced, the minor automation of equipment introduces assistance systems for handling operations, increasing thus the productivity and safety and security of operations.

With respect to the **automation of information flows**, this is based on the reduction of human resources in the acquisition, transmission and management of information processes that allow for operations to be carried out, using interface, communications and information management software systems, respectively. Currently nearly all PCTs rely on technologies and tools that can automate up to certain extent their information management processes, TOS being one of them. Completely manual processing them given current levels of traffic flows would be unapproachable.

The automation of information flows in terms of real time information systems calls for a new way to manage PCTs, based on reliable and timely information, removing uncertainty in responses times and making it possible to take decisions in synchronization with the operations that are being carried out at any given moment.

Finally, the **automation of the decision making process** consists in removing the intervention and the human factor in the design process of operations at a strategic, tactical and operational level (Sapiña et al., 2010; Monfort et al., 2012). To achieve this it is necessary to implement software tools that would work together with the TOS and to introduce decision criteria at the planning and management level of operations, as well as processes to manage exceptions. These criteria may be defined through mathematic algorithms or simulation-emulation models.

In any event, it is necessary to note that a PCT whose equipment is automated to a certain level can work with manual information flows, or vice-versa. Likewise, the level of automation of the decision making mechanism may be also independent from the level of automation of equipment or of information flows.

4.2. Process reengineering

Process reengineering is a technique that was pioneered in the nineties (Hammer and Champy, 1993). It consists in a radical re-design of businesses processes with the objective of transforming them to take advantage of the technological and management innovations available on the market in order to adapt them to the environment and current needs, thus obtaining dramatic improvements in the results of activities (services, costs, etc.), susceptible to be measured through respective performance indicators.

To achieve this process reengineering is based on the understanding of the operations of productive companies or of services by studying their resources, understood as objects, and the existing relationship between them, understood as processes.

The objects are the business entities/realities which have some fundamental features that allow describing them based on observing them and studying their behaviour. These features are their identity, behaviour and how they can interact with objects to create processes.

A process is a group of activities or events developed by organised objects that take place or happen alternatively or simultaneously under certain circumstances with a particular purpose. Processes may be modelled through flow diagrams which represent the interaction of the objects that intervene in the process performing sub-processes or activities. With this objective it is appropriate to use the BPMN nomenclature (Business Process Model and Notation; OMG, 2011), which is a standard and graphic way to model business processes. Likewise, there exist IT tools such as Microsoft Office Visio that can systematise the generation of flow diagrams.

4.3. Methodology for automating PCTs

PCTs can be understood as a productive industry where the product is the passing of a container through them, with the final objective to complete a modal interchange or an inland or maritime transfer. In this sense, PCTs are susceptible to process reengineering as demonstrated by Barberá (2008) and Steenstra (2009) with the automation of APMT Virginia in Portsmouth, amongst others.

From the functional point of view and employing process reengineering as a tool, automation deals with the introduction of automation solutions, understood as new potential objects, substituting or complementing current objects, with the aim of modifying operations, information flows or current decision making processes, so that they do not need such a high level of attention and specific intervention of human resources.

This section presents a methodology that systematises this automation philosophy for PCTs. This methodology, based on Cuatrecasas (1999), consists of five stages:

1. Diagnosis;
2. Study of the available technologies on the market;
3. Design of viable solutions;

4. Selection of the most promising solution;
5. Definition of the implementation project of the most promising solution.

The first stage, the **diagnosis**, implies understanding the resources and operations of PCTs. A previous diagnosis is the starting point of any improvement process and in this case it is imperative in order to know what can be automated and, in consequence, to decide how to achieve it. It makes it possible to identify the scope for the design of viable solutions for generic solutions available on the market to adapt to. It is delimited on the one hand to the current restrictions of PCTs, this is to say to their resources and operations and on the other hand with the definition of the automation requirements of PCTs that must be reasonable and feasible and adapt to the real needs (technical and economical) of the operations department, as well as to the service demands of the clients of PCTs.

The objective of the **study of technologies available on the market** is to know their current state-of-the-art vis-à-vis the latest breakthroughs and to understand their operation and how they may adapt to the scope for the design of solutions as defined in the previous diagnostic. In this sense, Monfort et al. (2012) made great progress by gathering and arranging the technological and management innovations for PCTs available on the market. These must be understood and studied from a practical approach, as new potential objects to be introduced in the operating automation process of PCTs, from the perspective of how tasks are carried out, information flows or decision making processes.

It is important to note that the level of detail of the description of objects and processes must be in line with the level of automation required, being different when the automation is for certain equipment functions, or when what it is required is the automatic positioning of containers and equipment, for example.

The first two analysis stages provide the necessary information to design solutions that adapt to the scope for design of PCTs.

The **design of viable solutions** is the process reengineering in itself. It consists in the introduction in current processes of new objects corresponding to automation solutions as a complement or substitution of previous objects in order to implement automated processes in operations, information flows or decision making processes, depending on operational needs.

Given the extensive offer of automation solutions available on the market, the automation solution of a process may not be unique. In this case it is necessary to consider the different viable alternatives.

Among different viable designs it is necessary **to select the most promising or optimal automation solution** according to the technical and economic needs of PCTs. To do this a multi-criteria analysis is needed to transform such needs to criteria to configure and analyse them in order to find the best option.

Finally, the **implementation project** for the solution chosen as being the most promising has to be designed. That implementation project must take into account the limitations derived from the temporary compatibility of the implementation of technologies with operations and resistance to change.

5. Advantages and challenges of the automation of PCTs

The automation of PCTs is a strategic initiative that answers the three strategic needs that the modern business concept based on sustainable development of an activity requires in order to consider any terminal's strategy: improvement in operational performance, increase of safety and security, and contribution to environmental sustainability.

Improvements in operational performance are the essential incentive to automate PCTs. Automated terminals are more productive and allow operating with increased quay use and yard densities, resulting in a better use of available space and an increased facility capacity (Montfort et al., 2011). This is possible due to the elimination of uncertainty in responses, resulting in more organised and methodological operations with a higher capacity to prioritise operational changes that are less sensitive to external factors, using resources more efficiently and facilitating operational control, allowing for real-time decision making processes whilst minimising the need to shuffle containers.

However, the planning and operational management of automated PCTs is affected by the loss of flexibility which is inherent to the standardisation of automation processes. Planning operations makes it difficult to plan and manage unique scenarios that have not been considered previously and which require exceptions to be managed methodologically and efficiently.

Simultaneously, automation also **contributes to increased safety and security** of people and port facilities. Automation processes not only increase safety by reducing human errors in operation but also reduce the impact of potential accidents by creating a physical gap between people and the area where operations are physically being carried out. Minor automations also trigger reductions in the number of accidents given that they standardise the way that operations are carried out whilst minimising the importance of the professional ability of operators. Additionally, there exist automations specifically designed to improve security with regards to threats and criminal activities.

With respect to the **contribution to environmental sustainability**, even though automation has fundamentally been conceived to improve the productivity of PCTs, it also has an important impact on the global energy use of PCTs. From the energy efficiency perspective automating a PCT manifests one of the best improvements in management that can be implemented.

Automation helps to optimise operations in all aspects, minimising travels made by equipment, empty runs, shuffling containers, etc., directly prompting a decrease in energy use. In addition, in automated PCTs most of the equipment uses electric power sources, which are more efficient and reduce consumption, emissions and noise.

Likewise, from an environmental point of view, the better use of available space of automated PCTs with respect to conventional ones minimises the required area for handling a specific traffic flow. This in turn postpones the construction of extensions which consume material and energetic resources and produce environmental impacts related to the occupancy of the sea front by port infrastructure that affect the landscape and deprive society of using such spaces for other purposes.

At a social level automated PCTs have an impact that it is not always seen as being positive. The unavoidable loss of employment that a major automation entails causes conflicts with port employees or stevedores, who see how their labour conditions and stability are in danger, resulting in labour conflicts whose outcome is not always easy and which often end up in long negotiations with trade unions. For obvious reasons, the resistance to change of port trade unions is bigger in terminals already in operation than in terminals being newly developed.

Automation is however sometimes needed for safety or quality reasons or for other features or attributes related to the process being affected. Other times, in the case of minor automations, they do not eliminate any job position but simply facilitate the development of the operator functions in a more efficient or safer manner, or allow for new features thanks to the implementation of innovative technologies.

In any event, whilst it is certain that direct human intervention in operations is reduced through automation, the level of training necessary to carry out the tasks of the job positions involved increases significantly. For this reason, given that it implies a total change in the work system and management in comparison with the operations of a regular PCT, the automation of PCTs must be accompanied by a human resources plan. Such a plan is needed to facilitate the necessary reorganisation and training of employees working in the operations affected by automation.

Finally, from an **economic and financial profitability** point of view, the automation of PCTs signifies a reduction in the variable costs per container (OPEX) since labour costs are reduced by generating economies of scale in operations and maintenance costs are also reduced (PEMA, 2012).

However, automation requires a large capital investment (CAPEX) for the acquisition of solutions and for training human resources. For this reason the decision to implement strategic initiatives related to automation requires a viability study of the implementation plan to assess such initiatives.

In line with previous comments the automation of PCTs offers important advantages with respect to manual operations, but this process also faces numerous challenges in terms of planning and business and operational management that may compromise the success of such initiatives.

Tables 2 and 3 summarise the advantages, disadvantages and challenges previously presented in this paper. It is obvious that these would depend on the level of automation reached. The ones hereby exposed relate to the maximum level of automation possible to date, with their impact being smaller for lower levels of automations.

Table 2 – Advantages and disadvantages of automated PCTs

	Advantages	Disadvantages
Operational performance	• Increased operational productivity • Operating with allocations and high yard density: offering more capacity with the same space • Increased flexibility to adapt to demand peaks • More organised and methodical operations, reducing uncertainty in response times • Higher capacity to prioritise operational changes • Less affected by external factors and lack of stevedores • More efficient use of resources • More control of operations given the existence of continuous communication between control systems and the fleet of equipment, easing thereby the decision making process in real time • Less volume of shuffling operations required which can be planned in advance to be carried out without interfering with loading and unloading operations (housekeeping)	• Less flexibility for operational planning • New scenarios have to be previously planned • More difficulty to react when exceptions occur
Safety and security	• Increase in safety in PCTs given the reduction of risks to human resources • Incorporation of security systems	
Environmental sustainability	• Operating with electric equipment (less consumption, less emissions and less noise) • Best use of current spaces (fewer extensions)	• May generate labour conflicts (loss of job positions)
Economic and financial profitability	• Less variable operational costs • Less maintenance operational costs	• Require a (higher) capital outlay

Table 3 – Challenges of automated PCTs

	Challenges
Planning stage	• The port sector is traditional and reluctant to risk, which translates into resistance when facing investments in innovation • Trade unions are especially powerful in ports, meaning that automation can only be introduced after reaching agreements with them or when job positions are not at risk.
Operational stage	• Lack of information and incorrect or untimely information • Loss of flexibility in operational planning • Exceptions management • High maintenance requirements of equipment • Interaction of many systems, increasing the probability of making errors • Possibility of experiencing demand peaks

6. Conclusion

Automation is a global trend in port container terminals. However, the level of automation adopted in each terminal depends on different factors that are inherent to its status of development, the subsystem object of automation, and the yard operating system, among others. This results in a wide range of automation solutions for PCTs.

In order to identify the most suitable automation solution for a given PCT, a methodology that combines a functional approach of the automating technologies available in the market and the process reengineering of the terminal operations is recommended. This methodology represents a state-of-the-art advance since it enables to design automation solutions appropriate to the actual terminal operating requirements, optimizing in this way the investment and the use of resources.

Finally, when planning a PCT automation there are some advantages and challenges that need to be taken into account. Those depend on the level of automation designed/achieved.

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