IMPROVING AND ASSESSING LOGISTICS PORT OPERATIONS IN SOKHNA PORT. EGYPT

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ABSTRACT

Radio Frequency Identification (RFID) has enhanced the operation process of containerization of cargoes, as well as enhancing security and safety in international transshipment by ensuring the integrity of containers. It has already proved capable of increasing efficiency within container terminals by increasing the speed of the gate check process, and by providing real-time information of tens of thousands of containers stacked in container yards.

In this research, we aim at proposing improved procedures to be applied in a famous Egyptian port, Sokhna. These procedures would improve how this port works, and create a new integrated business model based on the RFID technology. We focus our study on containers, cranes and trucks. This new business model has proven successful elsewhere in improving efficiency and reducing cost. We also introduce some key performance indicators that use RFID in the proposed model to assess the performance of this port which is so important to the economy of Egypt.

Keywords: *Containerization, Ports KPI, RFID, Business model*

บทคัดย่อ

การใช้เทคโนโลยี RFID กับตู้คอนเทนเนอร์ ช่วยเพิ่มความปลอดภัยในการขนส่งระหว่างประเทศ โดยช่วยรับประกันความสมบูรณ์ของตู้ นอกจากนี้ ระบบ RFID ยังสามารถเพิ่มประสิทธิภาพภายในเทอร์มินอล จากการช่วยเพิ่มความรวดเร็วในกระบวนการตรวจสอบและมีการให้ข้อมูลเป็นปัจจุบันเกี่ยวกับตู้คอนเทนเนอร์ที่วางเรียงกันอยู่เป็นหมื่น ๆ ตู้ในลานเก็บ งานวิจัยนี้มีวัตถุประสงค์เพื่อเสนอกระบวนการปรับปรุงให้แก่ท่า

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เรือท้องถิ่นที่มีชื่อเสียง กระบวนการดังกล่าวสามารถปรับปรุงการทำงานของท่าเรือและสร้างรูปแบบธุรกิจแบบองค์รวมใหม่ โดยใช้เทคโนโลยี RFID งานวิจัยนี้มุ่งเน้นศึกษาตู้คอนเทนเนอร์ ปั้นจั่นและรถบรรทุก ซึ่งรูปแบบธุรกิจใหม่นี้ได้รับการพิสูจน์ว่าสามารถปรับปรุงประสิทธิภาพและลดต้นทุนได้สำเร็จ งานวิจัยนี้ยังนำเสนอตัวชี้วัดความสำเร็จที่ใช้เทคโนโลยี RFID เพื่อประเมินการทำงานของท่าเรือสำคัญในประเทศอียิปต์

INTRODUCTION

Meeting container traffic's massive demand, ports find themselves needing to enhance capacity. Pure physical expansion is constrained by a limited supply of available land, especially for ports in urban centers, and by escalating environmental concerns. In this context, expanding port capacity by improving the productivity of terminal facilities appears to be the only viable solution. How to improve productivity sufficiently to accommodate a large portion of the anticipated increase in container traffic, however, presents a particular challenge to terminal operators and port authorities (Le-Griffin and Murphy, 2006).

In this context, RFID came to the rescue of ports and the shipping industry, emerging as one of few technologies capable of dealing with these issues. RFID-enabled containerization can help comply with regulations and requirements, and enhance security and safety in international transshipment, by ensuring the integrity of containers. It also, has already proven its capability of increasing efficiency within container terminals by speeding the gate checking process, and it provides real-time location-finding of tens of thousands of containers stacked in various container yards. With the possibility of incorporating sensors to add an extra layer of security, this may greatly improve the overall operation of a port.

The RFID system has been implemented in many big ports around the world such, as the Port of Singapore, the Port of Busan, Rotterdam Port, the Port of Long Beach, the Port of Hong Kong, the Port of Chennai, the Port of Chinghai, and many other ports. All these seaports use the RFID technology to develop some practical solutions for certain operational problems. As this research will clarify, each port must develop the most appropriate solution for its existing problems. This research proposes a developed solution that can create a new integrated business model based on the RFID technology, to handle and operate the most important and uncontrollable mobile components inside the Sokhna seaport (containers, cranes and trucks). Specifically, it targets:

1. Cost Reduction
2. Time Saving
3. Mistake Reduction
4. Increasing productivity

This new business model has been tested by using the Arena simulation model, allowing these two author researchers to create and run experiments to predict and measure the enhancements of, and contributions to, the business environment.

LITERATURE REVIEW

Radio Frequency IDentification (RFID) marks items with tags that contain transponders that emit messages which are readable by specialized RFID readers, and which include a sort of identification number. A reader retrieves information about the ID number from a database, and acts upon it accordingly. RFID simply extracts the data present in the memory chip, and makes it available for further processing (Ayyer, 2012).

RFID technology is gaining an ever increasing interest, becoming significantly critical in many industrial fields – including shipping and container ports (Hakam et al., 2012). The application of this technology in a port aims at reducing cost, time and errors, and increasing control, visibility and security of container operations. Tagging each container with an RFID tag can help in real-time identification and tracking of containers by a variety of strategically placed readers, thus reaching new levels of traceability and control. In the long run, such a system will increase the productivity of a port by reducing the handling time for each container (Watfa et. al, 2013).

RFID has been applied to different industries such as healthcare (Ahsan et al., 2009; Sajid and Ahsan, 2016), security and control applications (Shepard, 2005), patrolling logs (Glover and Bhaṭṭa, 2006), airline baggage handling (Glover and Bhaṭṭa, 2006), people tracking and warehousing (Zhou et al., 2017). Moreover, RFID has been used in logistics applications such as shipping and container ports (Hakam et al., 2012) and tracking perishable food (Haass et al., 2015).

RFID application in ports has increased port productivity by reducing the handling time for each container (Watfa et al., 2013). Wang et al. (2009) noticed that delivery of information in a container terminal, despite being vital to the development of container transportation, was still conducted manually to a great extent. However, they predicted that competition will lead ports to adopt leading technologies to create a self-sufficient, real time monitoring and tracking system. Banks et al. (2007) stated that terminal operators develop better knowledge of the whole terminal through RFID technology, which improves the planning of terminal operations.

The Port of Singapore (PSA) Terminals handled approximately one-fifth of the world's total container transshipment throughput, with a total of 27.1 million twenty-foot equivalent units (TEUs) (PSA 2008). Due to the dynamic role played by the government of Singapore in promoting RFID technology. allocating US$ 5.8 million for RFID research and training, the port of Singapore became the first pilot port in Asia in 2005 under the U.S. Container Security Initiative by equipping all containers bound for U.S. seaports with RFID seals. A multi-dimensional grid in the port is made of thousands of transponders incorporated into the asphalt road of the shipyard (Zhou J. & Shi J., 2008). Thus, the positioning and location of containers can be accurately determined based on the coordinates of the unique RFID transponders and tags.

The Port of Rotterdam had the world's largest active RFID installation implemented in 2005 by 'WhereNet Corp.2' for the Broekman Group. The Group needed an RFID-based real-time locating system for its over 250,000 vehicles at the port. Each vehicle is assigned a unique identifier (Vehicle Identifier Number (VIN), which through its active RFID-tag allows the group to real-time monitor its assets. This resulted in an increased port throughput, saving time and cutting costs, leading to satisfied customers, but the cost per RFID tag is not specified (Perich, 2012)..

The port of Hong Kong was the busiest container port in the world in 12 out of the 13 year period from 1992-2004, with a throughput over 20 million TEUs in 2004 and 24 million TEUs in 2007. By late 2006 and the beginning of 2007, the port of Hong Kong engaged in a standardization project which included RFID and a Digital Trade and Transportation Network (DTTN). The goal was to improve the efficiency of exchanging data and business opportunities. DTTN advantages are its open architecture to all business parties, its operation neutrality, its compliance with most standards, and its high transparency. Being combined with RFID, the port's resource utilization is improved, and customs clearance can be performed upstream along the distribution, thus greatly reducing the shipment processing time at the border (Cheung and Lee, 2007).

In 2005, a joint venture by IBM and Maersk Logistics resulted in the development of a system for tracking shipping containers around the world. Instead of using 433 MHz RFID tags integrated with sensors and read by interrogators (readers) deployed at ports and other strategic points of the supply chain, this system goes beyond RFID technology and uses it as just a part of a collection of wireless technologies to transmit location and sensor data. This system, later called the Secure Trade Lane (STL) solution, uses tracking devices called TRECs (Tamper-Resistant Embedded Controllers) which are small intelligent wireless monitoring boxes mounted on containers which makes them smarter. TRECs perform an automatic container events data collection, including physical location, based on GPS and the state of the container (temperature, humidity, acceleration, and door status). TRECs communication can be achieved through communication over a satellite, a cellular system (GSM/GPRS), or a Wireless Personal Area Network (WPAN) based on ZigBee3 /IEEE 802.15.4 radio. A handheld device can also communicate with the TRECs over a WPAN for the automatic creation of the container manifest, invoices, and bills of lading, etc. The Shipment Information System (SIS) ensures that the information provided by TRECs is available to the supply chain's authorized actors with the appropriate information being sharing among them. This STL platform, a fully integrated SOA4-based distributed network, enables real-time access, tracking and monitoring of containers by each participant authorized to view, thus granting a full visibility of the supply chain from the manufacturer to the store. Furthermore, due to its versatility and the fact that it uses already existing infrastructure, STL is relatively cost effective. Due to its collected data, supply chain processes, such as container port operations, can add further security leading to more satisfied customers. The STL solution is at the focus of a large-scale international research project called Information Technology for Analysis and Intelligent Design for e-Government (ITAIDE). The aim of that project, sponsored by the EU, is to define and use the STL solution in order to make international trade safer while optimizing the administrative processes (Dolivo, October 2017).

CURRENT STATUS

Sokhna Port is located in the Gulf of Suez, southern Egypt. Sokhna Port's official name is 'Dubai Ports DP WORLD Sokhna', part of the international network called 'DP WORLD', which is the Emirati marine terminal operator. The company's base is in Dubai and is one of the largest marine terminal operators in the world. The company operates more than 60 terminals across six continents, with container handling generating around 80% of its revenue. In addition, the company has 11 new developments and major expansions underway in 10 countries. In a rapidly changing world, DP World Sokhna Port faces some problems, which are the basis for this research. The company controls mobile components inside its seaports (containers, cranes and trucks), but only in a semi-automatic manner which increases cost, time, mistakes, and decreased productivity.

The following section introduces the current procedures carried out in Sokhna port. The 'wastes' in these operations are then explored. Finally, there is a discussion of the use of RFID technology to deal with these resource-wasting problems, so as to save money and effort.

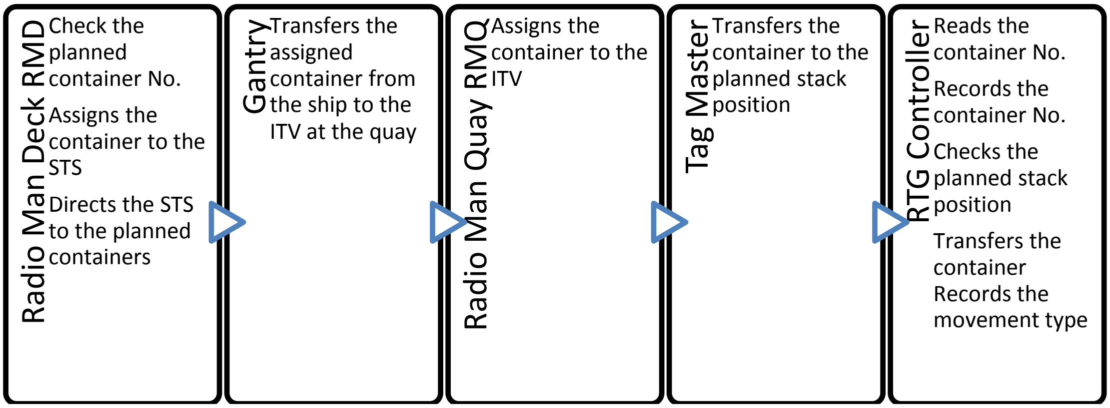
Current Procedures

In this section is an exploration into the actual various processes that take place: when the port receives containers, while transferring the container to a physical inspection area, while transferring the container to the stack after inspection, while transferring the container to the X-Ray inspection area, and when delivering the container out of the port. These five current processes are numbered 1 to 5.

1.Receiving Containers

At the Radio-man-deck, the container Number is reviewed, the container is assigned to the STS gantry, and the STS gantry is directed to the container. The STS gantry transfers the container from the ship to the shore. Radio-man-quay assigns the container to the Tag Master. The Tag Master transfers the container to the stacking area where the RTG Controller reads the container Number, records it, checks the planned stack position, transfers the container to the planned position, and records the movement type. The process is outlined in Figure 1 below.

Figure 1: The Processes for Receiving a Container

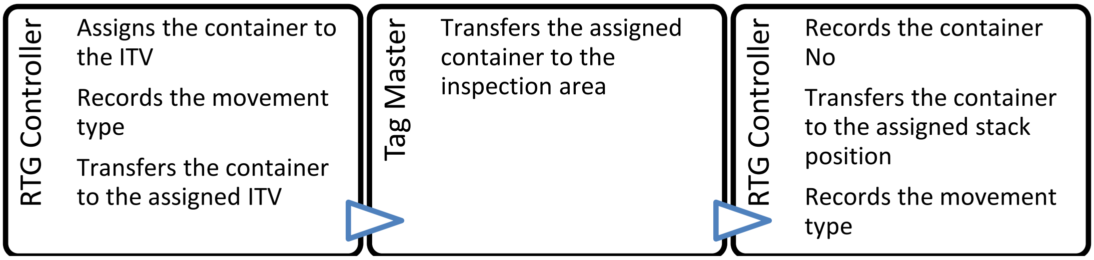


Source: Authors

2. Transferring a Container to the Physical Inspection Area

The RTG controller assigns the container to the tag master, records the movement type, and transfers the container to the tag master. Tag master transfers the container to the inspection area. The RTG Controller reads the container Number, records it, transfers the container to the planned position, and records the movement type. The process is outlined in Figure 2 below.

Figure 2: Transferring the Container to the Physical Inspection Area

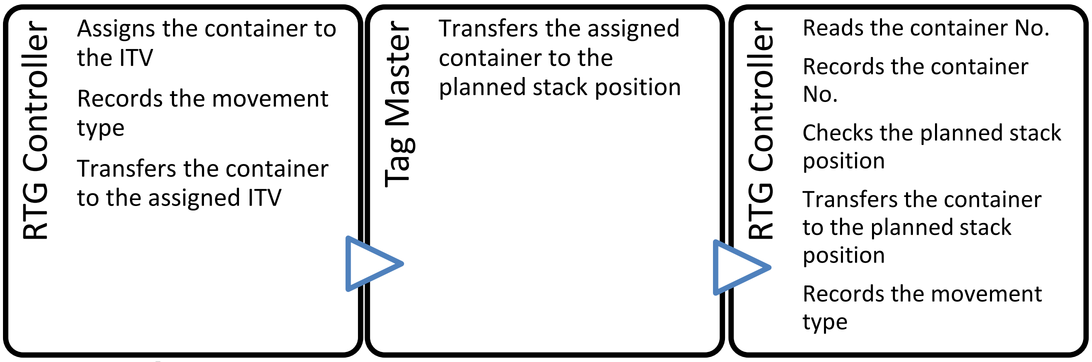


Source: Authors

3. Transferring a Container to the Stacking area after Inspection

The RTG Controller assigns the container to the tag master, records the movement type, and transfers the container to the tag master. Tag master transfers the container to the stacking area. The RTG controller reads the container Number, records it, checks the planned stack position, transfers the container to the planned position, and records the movement type. The process is outlined in Figure 3 below.

Figure 3: Transferring a Container to the Stacking Area

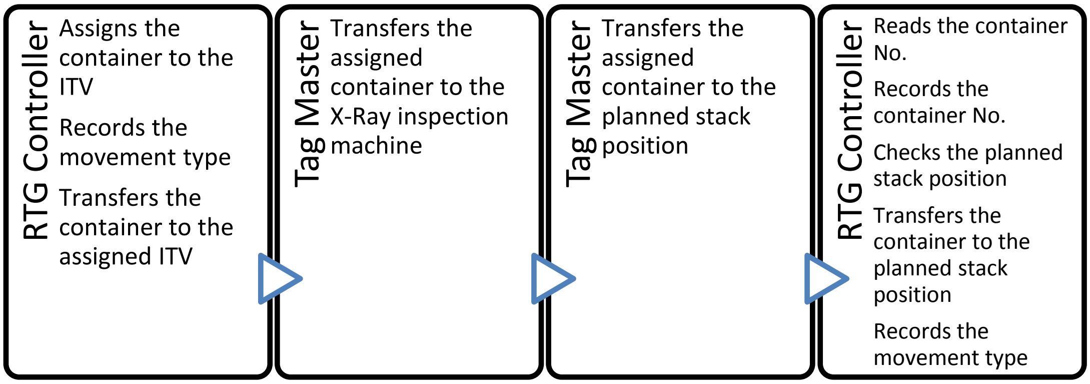


Source: Authors

4. Transferring a Container to the X-Ray Inspection Area

The RTG Controller assigns the container to the Tag Master, records the movement type, and transfers the container to the Tag Master. The Tag Master transfers the container to the X-Ray inspection machine then transfers it to the stacking area after inspection. The RTG Controller reads the container Number, records it, checks the planned stack position, transfers the container to the planned position, and records the movement type. The process is outlined in Figure 4 below.

Figure 4: Transferring a Container to the X-Ray Inspection Area

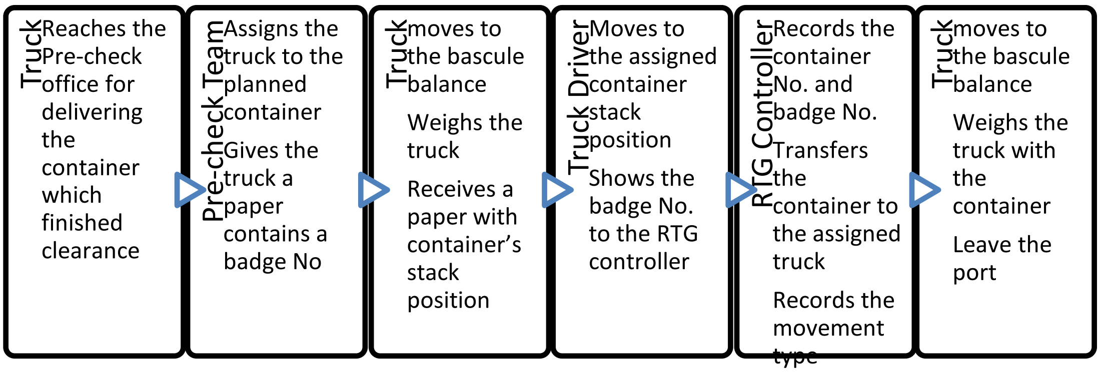


Source: Authors

5. Delivering Container Out of the Port

A truck reaches the Pre-check office waiting to be assigned to the container, which finishes clearance. The Pre-check Team assigns the truck to the planned container and gives the truck driver a paper that contains a Badge Number. The truck moves to the weighing balance machine, receives a paper with the assigned container's stack position, moves to the stack position, and shows the Badge Number. to the RTG Controller. The RTG Controller reads the Badge Number, records it, transfers the container to the assigned truck, and records the movement type. The truck moves to the weighing balance machine to be weighed again, loaded, and leaves the port. The process outline is shown in Figure 5 below.

Figure 5: Delivering the Container to a Truck to leave the Port



Source: Authors

Limitations of the current situation

The current situation suffers from

(i) high cost at the Radio-man-Deck ‘RMD’, Radio-Man-Quay ‘RMQ’, and Trucks’ operation of printed papers;

(ii) high wasted time at the Truck processing stage while waiting assignment by the Pre-check Team; and more importantly

(iii) a relatively high mistake rate in performing the RMD, RMQ, and RTG tasks.

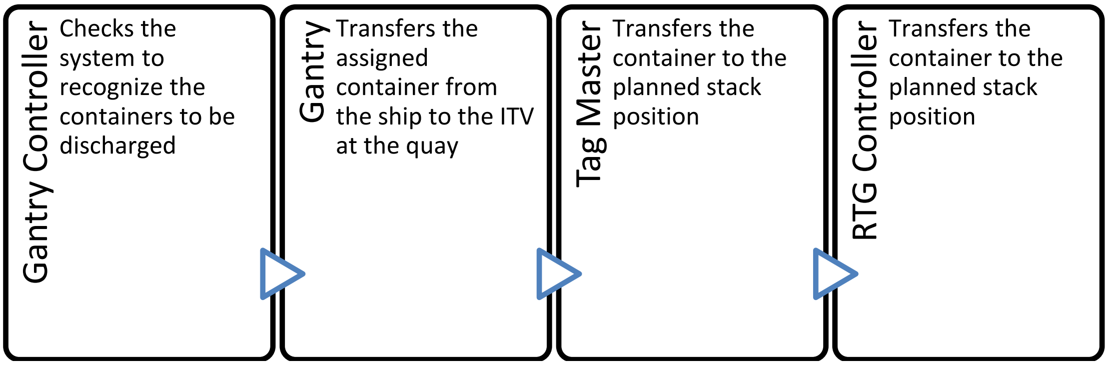
TOWARDS AN IMPROVED STATUS

In this section improved procedures are proposed that result in a better overall performance through the elimination of wastes. RFID tags would be used as the tool to achieve the intended objectives. These five proposed improved features are numbered 6 to 10.

6.Receiving Containers

The RFID system will be used for the tasks of RMD and RMQ, and for the recording tasks of the RTG controller. Operation costs are reduced after eliminating the RMD and RMQ jobs, in addition to reduction of the error rate due to the cancelation of the human factor interventions, leading to increased productivity. The proposed improved process in outlined in Figure 6 below.

Figure 6: Receiving Containers - Proposal

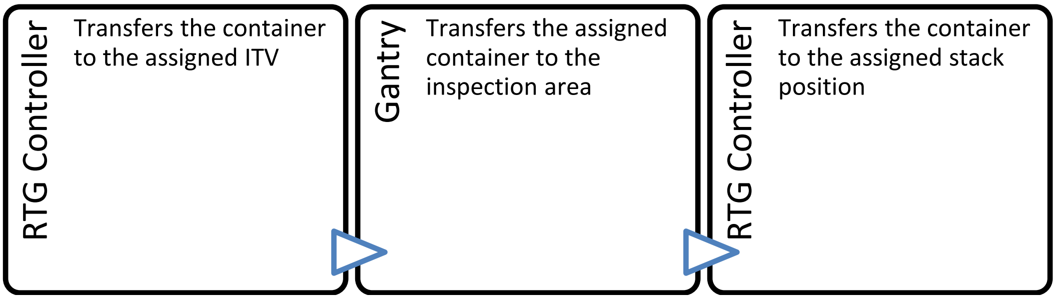


Source: Authors

7. Transferring a Container to the Physical Inspection Area

The RFID system will be used for the recording tasks of the RTG Controller, which will reduce the error rate by avoiding the human factor interventions. This will lead to increased productivity. The improved process is outlined in Figure 7 below.

Figure 7: Transferring a Container to the Physical Inspection Area – Proposal

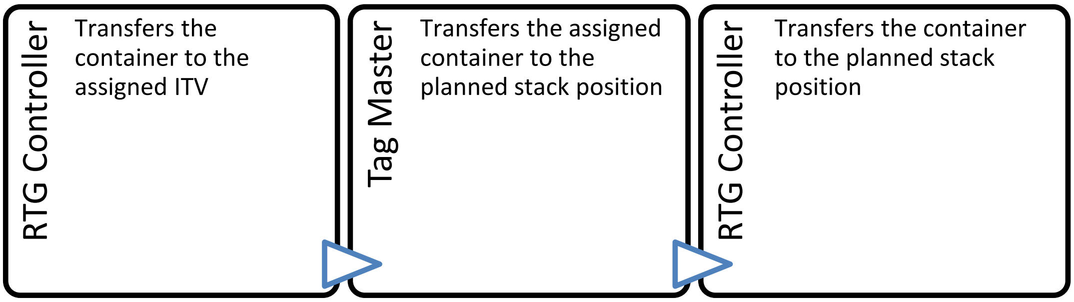


Source: Authors

8. Transferring a Container to the Stacking area after Inspection

The RFID system will perform the recording tasks of the RTG controller, resulting in a reduction of the error rate by avoidance of the human factor interventions, which will lead to increased productivity. The improved process is shown in Figure 8.

Figure 8: Transferring a Container to the Stacking Area - Proposal

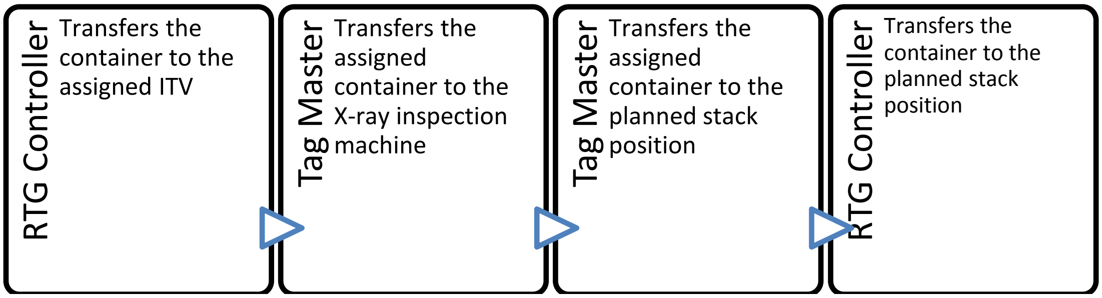


Source: Authors

9. Transferring a container to the X-Ray Inspection Area

The RFID system will perform the recording tasks of the RTG Controller, which will reduce mistakes by scrapping the human factor interventions, which will lead to increased productivity. The improved process is shown in Figure 9 below.

Figure 9: Transferring a Container to the X-Ray Inspection Area – Proposal

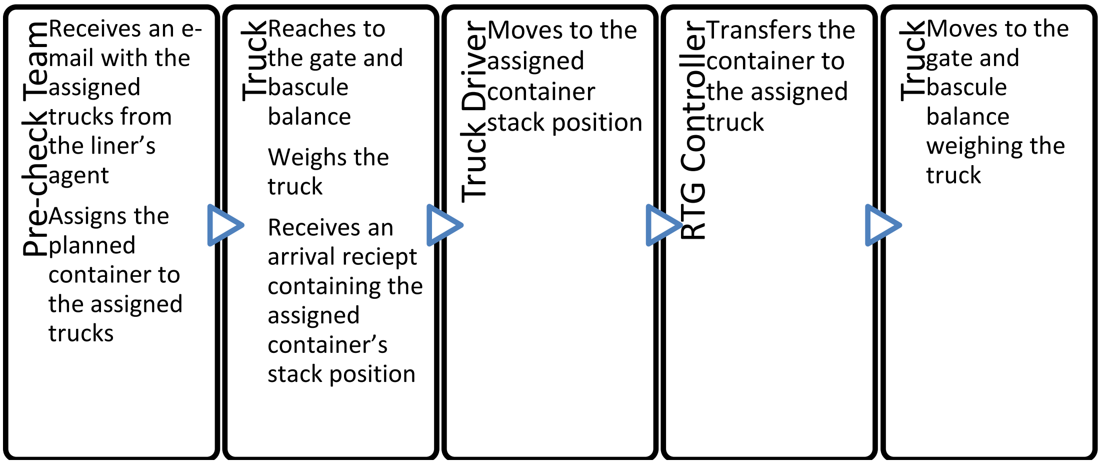


Source: Authors

10. Delivering a Container Out of the Port

The RFID system will reduce the trucks' operation time and the required supplies (e.g. printed papers), and will replace the system of recording tasks by the RTG Controller. This results in a reduction of the operation paper cost by an estimated US$11,000, a reduction of the operation time, and a reduction of the error rate. This also results in an increase in productivity as the trucks are pre-assigned before arrival. The improved operation is shown in Figure 10.

Figure 10: Delivering a Container Out of the Port - Proposal



Source: Authors

EVALUATING OPERATOR PERFORMANCE

Improved financial assessment

For the container operating procedures, the estimated annual cost of RMD and RMQ according to the market rates, is estimated as US$16,000, which is saved by replacing them as proposed above. The error rate is reduced and productivity is increased by terminating the jobs of RMD and RMQ, in addition to the system recording tasks of the RTG controller.

For truck operating procedures, the time consumed by the truck waiting for assignment is reduced by 60%, according to the authors' estimates (planned to be verified in future research). The estimated paper cost is reduced by an estimated US$11,000.

In the coming sections, key performance indicators are introduced, which are designed specifically for port operations when using RFID system. The introduced KPIs are a combination of already existing KPIs and some other proposed KPIs developed for the new operation model.

The Indicator of Basic Computation

The researchers built the needed KPIs one by one, based on two principles: the equipment utilization and the job service time. The equipment here includes Gantries, RTGs, Reach Stackers, Fork Lifts, and any other kind of cranes. The term of utilization is the 'handled TEUs' or the quantity of handled containers. The job service times are:

1. The job of the cranes
    a. Catching a container
    b. Moving a container
    c. Releasing a container
2. The job of the Tag Master
    a. Receiving a container
    b. Moving a container
    c. Delivering a container
3. The job of the container Truck
    a. Entry gate passing-in
    b. Weight measurement
    c. Receiving a container
    d. Entry gate passing-out

The researchers propose ten KPIs to be used in measuring the performance for the proposed business model. Three of them already exist, and the other seven KPIs are specially tailored for use in the proposed business model.

The old three KPIs, which are also mentioned by Literature Review authors, are:

1. Average TEUs per Vessel Day

2. TEUs per Crane Hour
3. Throughput per Linear Meter

The new seven KPIs are:

1. TEUs per Gantry Gang Hour
2. TEUs per Tag Master Hour
3. RTG Controller’s Errors Rate
4. Lost Containers Rate
5. Gantry’s Container Catching Time
6. Tag Master Waiting Time Rate
7. Truck Working Time for Container

Here below, are the details of these ten KPIs.

1. **Average TEUs per vessel day,** total tonnage of cargo handled divided by Total vessel spent (days) x Total working hours per day (hours)

$$\frac{Total\ TEUs\ handled}{Total\ No.of\ vessel\ days * Total\ working\ hours\ per\ day}$$

This KPI assesses the overall productivity of the gantry gang working on loading/dispatching cargo from or to the ship, from the point of view of the ship’s owners and the operation administration as it indicates to how far the gantry gang is time and cost effective.
(Note: in ‘DP World Sokhna’ terms, a Gantry Gang consists of one gantry crane, one Radio Man Deck, one Radio Man quay, a group of Tag Masters, and one RTG or more).

To measure this KPI we need to count three numbers (total handled TEUs, spent days or hours of vessels in loading and discharging, and employees working hours). The second and third numbers are already available in the port administration system, but for the first number we need to deploy some calculator to count the transferred containers from the ship’s deck to the shore or from the tag master to the ship’s deck. The consumed time is important as it is one of the most needed details for operation quality, referring to the productivity of the employee or the equipment itself, and to analyze their performance, as we have precise records for every movement.

The RFID reader attached at the gantry hook will carry the responsibility of counting and recording the transferred container's data from/to the ship, clarifying the following information:

a. The unique ID No. of used RFID reader during this task
b. The unique ID No. of each container (RFID tag) going through the RFID reader's read range, or in other words, every container is handled by the gantry, the tag master, or crane.
c. The catching time of every unique ID No. (container or RFID tag) by the gantry hook
d. The releasing time of every unique ID No. (container or RFID tag) by the gantry hook
e. The movement type of every unique ID No. (container or RFID tag) by the gantry hook "ship to shore or shore to ship".

To measure this KPI, we target the total recorded movements of every unique ID No. (Container or RFID tag) by the gantry hook, which is classified into two categories (ship to shore or shore to ship); it can also be counted by the TEU and the containers. As the available information is captured precisely every second, it is a good indicator for the operation performance analysis.

2. **TEUs Per Crane Hour,** Total No. of TEUs handled by the crane divided by total No. of the crane working hours (for any kind of crane, Gantry, RTG, or Reach Stacker)

$$\frac{Total\ TEUs\ handled\ by\ the\ crane}{Total\ crane\ working\ hours}$$

This KPI assesses the crane productivity regardless its type or usage. It measures the TEUs that could be handled by a crane during the working shift to monitor the crane operator and the machine, allowing the management to control and analyze the productivity in a very efficient way. To measure this KPI, the total TEUs handled by the crane and its working hours are needed to be counted.

The $Total\ crane\ working\ hours$ are measured via the port's Fleet Management System; but for $Total\ TEUs\ handled\ by\ the\ crane,$ we need to deploy some counter to count the containers handled by the crane. The RFID reader attached to the gantry hook will count and record the handled containers, clarifying some information such as:

a. The unique ID No. of used RFID reader during this task
b. The unique ID No. of each container (RFID tag) going through the RFID reader read range (handled by the crane)
c. The catching time of every unique ID No. (container or RFID tag) by the crane hook
d. The releasing time of every unique ID No. (container or RFID tag) by the crane hook
e. The movement type of every unique ID No. (container or RFID tag) by the crane hook

To measure this KPI, we target the total recorded movements of every unique ID No. (Container or RFID tag) by the crane hook (RFID reader); also it is counted by the TEU and the containers as well.

3. **Throughput Per Linear Meter,** Total TEUs handled at berths divided by Total square meter of berths

$$\frac{Total\ TEUs\ handled\ at\ berths}{Total\ square\ meter\ of\ berths}$$

This KPI assesses the linear meter productivity. To measure this KPI, we need to count the total TEUs handled by the entire berths. The $Total\ TEUs\ handled\ at\ berths$ is measured by deploying RFID readers at the gantries' hooks to count and record the containers handled by the gantries, clarifying some specific information, including:

a. The unique ID No. of used RFID readers during this task
b. The unique ID No. of each container (RFID tag) going through the RFID readers read range
c. The catching time of every unique ID No. (container or RFID tag) by the gantries hooks
d. The releasing time of every unique ID No. (container or RFID tag) by the gantries hooks
e. The movement type of every unique ID No. (container or RFID tag) by the gantries hooks (ship to shore or shore to ship)

To measure this KPI, we target the total recorded movements of every handled unique ID No. (Container or RFID tag) by the gantries hooks (RFID readers); it will be counted by the TEU and also the containers.

4. **TEUs per Gantry Gang Hour,** Total TEUs handled divided by Total No. of gantry gangs x total No. of working hours

$$\frac{Total\ TEUs\ handled}{Total\ No.of\ \ gantry\ gangs * Total\ working\ hours}$$

This KPI is similar to the Average TEUs per vessel day as it assesses the overall productivity of the gantry gang working on loading/dispatching cargo from or to the ship, but this KPI does not work only from the point of view of the ship's owners; it concentrates on the operation quality. The reason is that each gantry gang can use the same RTG, therefore the gang productivity cannot be measured separately from the other.

To measure this KPI we need to count three numbers (total handled TEUs, working gangs' number, and total working hours). These three numbers are measured as discussed above, as the second and third numbers are available at the port administration system: but for the first number we need some method to count the transferred containers from the ship deck to the shore or from the tag master to the ship deck. The RFID reader attached to the gantry hook will count and record the transferred container from/to the ship, clarifying the same information.

To measure this KPI, we target the total recorded movements of every unique ID No. (Container or RFID tag) by the gantry hook, which is classified into two categories (ship to shore or shore to ship); it is counted by TEU and also by containers.

5. **TEUs per Tag Master hour,** Total No. of TEUs handled by the Tag Master divided by Total No. of Tag Master working hours

$$\frac{Total\ TEUs\ handled\ by\ the\ Tag\ Master}{Total\ working\ hours\ of\ the\ Tag\ Master}$$

This KPI assesses the tag master productivity. It measures the TEUs that could be handled by the working hours of the tag master to control the tag master operator and the machine.

$Total\ working\ hours\ of\ the\ Tag\ Master$, are measured via the port's Fleet Management System, but for $Total\ TEUs\ handled\ by\ the\ Tag\ Master$, we need to count the containers handled by the tag master. This is done by attaching a RFID reader at the back of the tag master's truck, which will store data such as:

a. The unique ID No. of used RFID reader during this task
b. The unique ID No. of each container (RFID tag) go through the RFID reader read range
c. The receiving time of every unique ID No. (container or RFID tag) by the tag master
d. The delivering time of every unique ID No. (container or RFID tag) by the tag master
e. The movement type of every unique ID No. (container or RFID tag) by the tag master

To measure this KPI, we target the total recorded movements of every handled unique ID No. (Container or RFID tag) by the tag master (RFID reader); also it is counted by the TEU and the containers. In addition, we need to compute the container service time by the tag master (the transfer time from a certain point to another). For this, we need to compute the difference between the delivery time and the receiving time (the container service time by the tag master).

$$\begin{aligned}The\ Container\ Service\ Time\ by\ the\ tag\ master \\ &= The\ Container\ arrival\ Time\ to\ a\ certain\ point \\ &- The\ Container\ \ leaving\ Time\ from\ a\ certain\ point\end{aligned}$$

6. **RTG Controller's error rate (%),** Total No. of errors * 100 divided by Total No. of handled TEUs

$$\frac{Total\ No.of\ errors * 100}{Total\ No.of\ handled\ TEUs}$$

This KPI assesses the RTG Controller's error rate. Every container movement is planned over the operation system except some casual container shifting movements when needed by the yard supervisors. The RFID reader attached on the RTG will identify and report every movement regardless of planned movements, which allows the system to alert the operator to any error on time.

Here, the total TEUs handled by the crane can be counted by creating a counter that increases whenever the receiver at the hook of the crane receives a signal with a unique ID, during loading a container by the crane transferring it from some point to another. Every handled TEU will be compared over the system with the planned movement which will alert the RTG controller and the Planning Team simultaneously should mistakes happen.
But as casual movements are needed by the yard supervisors, these could be handled by creating requests over the system to the planning team for such movements.

7. **Lost containers rate (%),** Total No. of lost containers * 100 divided by Total No. of handled containers

$$\frac{Total\ No.of\ lost\ containers\ *100}{Total\ No.of\ handled\ containers}$$

This KPI assesses the chances of losing containers. To measure this KPI we need to count two numbers (registered cases of lost containers, and total handled TEUs). Lost containers are already registered by the port administration system. The total number of handled TEUs is counted over the spread of RFID reader devices at the port. The RFID reader attached at the gantry hook, tag master, reach stacker, and the RTG, all count and record the handled containers, storing information such as:

a. The unique ID No. of used RFID reader during this task
b. Every unique ID No. of each container (RFID tag) which goes through the RFID reader read range
c. The movement type of every unique ID No. (container or RFID tag) by the gantry hook (ship to shore or shore to ship).

To measure this KPI, we track the recorded movements of every unique ID No. (Container or RFID tag) by the gantry hook, tag master, reach stacker, and the RTG which are also counted by the TEU and the containers.

8. **Gantry catching container time,** Consumed time for catching the container * total No. of handled containers * 100 divided by Total working hours

$$\frac{Consumed\ time\ for\ catching\ the\ container*total\ \ No.of\ handled\ containers*100}{Total\ working\ hours}$$

This KPI assesses the overall productivity of the gantry gang working on loading/dispatching cargo from or to the ship. This KPI not only works from the point of view of the ships' owners, but it concentrates also on the operation quality.

To measure this KPI we need to count three numbers (total handled TEUs, working gantries number, and total working hours). These three needed numbers are measured as discussed above. The second and third numbers are already available in the port administration system, but for the first number, we need to count the transferred containers from the ship deck to the shore or from the tag master to the ship deck.

The RFID reader attached at the gantry hook will count and record the transferred container from/to the ship, storing information such as:

a. The unique ID No. of used RFID reader during this task
b. Every unique ID No. of each container (RFID tag) go through the RFID reader read range
c. The catching time of every unique ID No. (container or RFID tag) by the gantry hook
d. The releasing time of every unique ID No. (container or RFID tag) by the gantry hook
e. The movement type of every unique ID No. (container or RFID tag) by the gantry hook (ship to shore or shore to ship)

To measure this KPI, we need to track the total recorded movements of every unique ID No. (Container or RFID tag) by the gantry hook, which will be classified into two categories (ship to shore or shore to ship), and it will also be counted by the TEU and the containers.

9. **Tag Master waiting time rate,** Total waiting time for the containers * 100 divided by Total working hours

$$\frac{Total\ waiting\ time\ for\ the\ containers * 100}{Total\ working\ hours}$$

This KPI assesses the quality of the crane operators as it measures the waiting time of the tag master for the container that has already been handled by a gantry, reach stacker, or RTG. So, it is a good KPI to measure and control the labor performance (gantry operator, reach stacker operator, and RTG operator). To measure this KPI, we need to count the total waiting time of the tag master for the container.

First we will explain how the tag master will work when it receives or delivers a new container:

a. The tag master reaches the pickup point.
b. The tag master operator reports over the system that he is ready to receive a new container.
c. At the same moment, the crane operator acknowledges this and starts to transfer the container to the tag master.
d. The trailer sensors will report when the container is just steady over the trailer.
e. The tag master moves to the target.
f. The tag master operator reports over the system that the container is ready to be transferred.
g. The crane operator acknowledges this and starts to transfer the container to the targeted position.
h. The trailer sensors report when the container is transferred from the trailer

Now, the targeted number is the difference between the time when the tag master reports that it is ready to receive a new container and the time when the sensor reports that the transferred container is steady over the trailer.

$$\begin{aligned}&The\ Tag\ Master\ Time\\&=\ The\ Time\ of\ Sensor\ Report\ (the\ container\ is\ steady)\\&-The\ Time\ of\ Tag\ Master\ Report\ (ready\ to\ receive\ a\ container)\end{aligned}$$

This KPI is not measured only when the tag master receives a container, but also when it delivers a container.

10. **Truck working time for container,** Working time for the containers * 100 divided by Total working hours inside the port

$$\frac{Working\ time\ for\ the\ containers\ *100}{Total\ working\ hours\ inside\ the\ port}$$

This assesses performance enhancement after handling all the manual processes of the RTG controller and some of the weighing and the pre check team by the RFID devices. It will also clarify the time the trucks spend at every step. The RFID stores the truck arrival and departure time for each process such as departure and arrival time at the gate, weight, and the RTG lane side. The time between truck arrival and departure detected by the RFID reader is computed.

SUMMARY AND CONCLUSIONS

This research studied the processes performed in one of the major ports in Egypt, more specifically, the Sokhna port. Improved overall procedures have been proposed that eliminate some of the wastes in the operation, leading to an improvement in efficiency and a reduction in cost.

In the proposed procedures, a passive tag is attached to each container. Cranes and ITVs will be equipped with RFID readers. Each container's gathered information is sent to a central database. For each truck, Passive RFID tags are attached to the bodies of these container trucks. Tags on the truck are used solely to identify the truck, plus other information such as its load and plate number. RFID readers are mounted at the port entry gates to collect information from the tags. Confirmed trucks are permitted to pass through, and receive printed receipts containing the assigned container stack position. Data on trucks and arrival/departure times are recorded in the database, in addition to all of the container information. RFID readers will be mounted on the crane to ensure accurate container offloads or uploads to/from the right truck.

Mistakes could be discovered immediately by the control team using the proposed RFID system. Data is updated automatically and the operators will be allowed to report to the administration with any completed jobs or problems, on the spot. Each department expecting to receive additional jobs is updated through the entire operation system. Only an arrival receipt will be used regarding truck handling. RMD and RMQ jobs will be eliminated.

The major objective is to reduce operation cost, mistakes, and the operating time of containers and trucks; and increase port capacity and productivity. All this will enhance competitive advantage for the port and shippers. Regarding security, every container will be traced 24/7 even before it touches the port shore, then until it reaches the port gates. Sensors can be connected to the RFID tag to report the cargo temperature and humidity, and to discover any dangerous material such as nuclear materials. Gathering and recording data is concerned with every movement for each container with a precise time including the lift tools trucks.

This research also introduces suitable KPIs for the new business model to be used in controlling and measuring the performance of the most important and uncontrollable components in any seaport (Container, Crane, and Truck). The focus is on assessing the productivity of the crane, the tag master and the job service time. The productivity of Gantries, RTGs, Reach Stackers, and any other kind of containers is measured in terms of handled TEUs per hour. The job service time of handling the containers is also measured for tools studied, such as cranes and Tag Masters. Of the ten KPIs, three already exist, and the other seven are tailor-made for this model.

In future studies, these researchers are planning to extend this research by a work-in-progress development of key performance indicators designed specifically for port operations. The performance of the KPIs and the RFID system is validated through a simulation model.

REFERENCES

Ahsan, K., Shah, H., Kingston, P. (2009). Role of Enterprise Architecture in healthcare IT, *Proceeding ITNG 2009, IEEE*.

Ayyer, Shriniwas. (2012). Evaluation of a passive RFID system in a dynamic work environment. Retrieved from http://dx.doi.org/doi:10.7282/T32F7M7F.

Banks J., Pachano M., Thompson L., Hanny, D. (2007). *RFID Applied*. Wiley & Sons, Inc.

Cheung, F. (2006). Implementation of Nationwide Public Transport Smart Card in the Netherlands Cost-Benefit Analysis. *Journal of the Transportation Research Board, 1971:127- 132.*

Dolivo, F. (2007).The IBM Secure Trade Lane solution- A new, open approach to optimizing the global supply chain. http://www.zurich.ibm.com/csc/process/securetradelane.html; checked: May 2017.

Dulebenets, M., and Ozguven E.E. (2017). Vessel Scheduling in Liner Shipping: Modeling Transport of Perishable Assets. *International Journal of Production Economics, V(184), 141-56.*

Glover, B. and Bhaṭṭa, H. (2006). *RFID Essentials*. Sebastopol, CA: O'Reilly.

Haass, R., Dittmer, P., Veigt, M., Lutjen, M. (2015). Reducing food losses and carbon emission by using autonomous control – a simulation study of the intelligent container, *International Journal of Production Economics, 164, 400–408.*

Hakam, M. H., Solvang, W. D., and Pieskä, S. (2015), RFID Communication in Container Ports. *Journal of Intelligent Decision Technologies, 9(1), 3-16.*

Le-Griffin, H. D., & Murphy, M. (2006). Container Terminal Productivity: Experiences at the Ports of Los Angeles and Long Beach. *National Urban Freight Conference.*

Perich, R. (2012), WhereNet deploys world's largest active RFID system at Port of Rotterdam. www.theautochannel.com/news, accessed January 2018.
PSA (2008). http://www.singaporepsa.com checked: October 2012.
Sajid, M., & Ahsan, K. (2016). Role Of Enterprise Architecture In Healthcare Organizations And Knowledge-Based Medical Diagnosis System, *Journal of Information System Technology Management, 13(2).*
Shepard, S. (2005). *RFID Radio Frequency Identification*, McGraw-Hill Networking Professional, USA.
Wang, W., & Fan, S. (2009). RFID implementation in container transportation, *JCPC, 639-642, IEEE Xplore*.
Watfa, M.. K., Suleman, U., & Arafat, Z. (2013). RFID System Implementation in Jebel Ali Port. *Consumer Communications and Networking Conference (CCNC), 2013 IEEE, 950–55.*
Zhou, W., Piramuthu, S., Chu, F., & Chu, C., (2017). RFID-enabled Flexible Warehousing. *Decision Support Systems, 98: 99-112*.