Design and Implementation of a Port Simulator Using Formal Graphical Approach (FGA)

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Abstract: *The continuing growth of marine container transport, as well as, the complexity in the analysis of terminal port operations has created an ideal area for applying computer simulation. Simulators are able to generate considerable benefits and added value for the operational training. The traditional formal and on-the-job training of operational personnel is becoming inadequate, not only for providing proper skills and competencies regarding the operations to be performed, but also for addressing safety and efficiency standards in critical situations. Many ports and logistics structures have equipped themselves with simulation tools that allow an effective training activity without taking vehicles out of the normal operational cycle. This paper focuses on design and implementation of reusable, interactive, simulation-based training activities at the port and logistics sector using Formal Graphical Approach (FGA) and e-learning system, to deliver the learning objects to learners in an interactive, adaptive and flexible manner. We apply the simulator at Damietta port in Egypt as a real-world case study and developing effective web-based and computer-based learning contents in order to reach an optimal use of simulators in operational port training actions. We analyze the performance of the system and benefits of applying formal graphical approach on the training simulator. The results show the contribution of service routes, ports, container ships, and containers to the cost and performance of the system and a significant improvement is demonstrated in the operational and economic performance as a result of using the Training Simulator.*

Keywords: *Simulation, E-learning, Web-Based simulation, Port Container Terminal*

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1. Introduction

Not all learners learn in the same way and at the same rate. Learners' learning styles that reflect their cognitive abilities vary in known ways; some prefer the traditional text-based or oral presentation of content, while others learn more easily in a visual or kinetic instruction style. Simulation has been shown to be an effective way of teaching abstract concept, principle and process in many application domains.

Port can be viewed as a complex system containing several entities with interfering attributes. The whole image is very complex and special care should be considered to model such systems. Several works for investigating, analyzing evaluating and improving port activities are carried out, each of them is concerned with a specific area related to the port functions, and the key tool for most of these works is the simulation.
This paper discusses how simulation-based E-Learning can be used to improve Workforce performance, also as a process improvement tool for the achievement of better vessels turn around times and faster cargo flows by using Formal Graphical Approach (FGA).In handling of outgoing general cargo transported on trucks, all major processes are reproduced by the simulation model. The simulated system can be used as a process improvement tool.

This paper is organized as follows: Section 2 provides an overview of the operations performed at a Container Terminal (CT) and how different management issues are handled. Section 3 presents Simulation and the benefits of web-enabled simulation and Simulation-centric learning in Damietta port. Section 4 describes how Damietta Port Operations can be improved by using Port simulation system based on using Formal Graphical Approach (FGA). Section 5 discusses the performance results and the important contribution of the paper. Section 6 concludes the paper.

2. Operation Processes in a Port Container Terminal

A container port is a terminal where containers enter and leave by different means of transport, as trucks, trains, and ships (Input/output transport means) [9]. The discrete events associated to direct shipments operations of intermodal container operation are the following:

- Arrival: containers arrive to their originating ports.
- Storage: containers are stored before their departure.
- Transport: containers are transported on container ships to their destination.
- Exit: containers arrive to their destination. [2].

Containers arrive to terminal and are cleared within the provided truck and train operation areas, and then they are distributed to different stocks fulfilling the

requirements. Majority of containers are positioned in pre-reserved area from where they are shipped next. Container Terminal (CT) can be divided into four sub parts: Ship Arrival-Loading/Unloading-Horizontal Transport-Yard Stacking

2.1. Ship Arrival

The arrival of a ship requires the container terminal management to locate a berth position so that it can moor along the quay and a service time to schedule operations. This decision on choice of a berth policy has an impact on other decisions in the ship operations. The berth policy is formulated from choosing a sequence policy and a positioning policy.

Basic questions are when and where placing an arriving ship? In deciding the berth allocation to an arriving ship the following factors are considered:

- Length and draft of the ship.
- Berth Slot – based on ship line schedule Estimated Time of Arrival (ETA) and Estimated Time of Departure (ETD).
- Number of Containers to be handled, which infers to berth occupancy time.
- Berth availability.
- Try to keep to a high berth utilization rate
- The nearest available cranes to the assigned berth.
- Trade-off between the total time berthed and the customer service of ship owners caused by the sequence that ships are berthed. [6].

2.2. Loading and Unloading

Upon arrival of ship, Container Terminal (CT) manager has to decide which resources to be allocated to work on the ship. This is an important decision for Container Terminal (CT) manager as there are also other ships needed to be served as well, so the Container Terminal (CT) manager allocates resources in such a way that current ships on the berth are also serving. CT management involves allocating Quay Cranes (QC) and transport equipment such as Straddle Carriers (SC) or trucks and labor.

Some of the decision or problems that need to be answered in the loading and unloading of containers in a ship are:

- Number of containers that will be handled
- Crane Allocation (e.g. Number of Cranes to be assigned- Crane availability- Crane dimensions (can crane reach over the stacks of containers on the ship?)- Crane handling speed)
- Number of transporters to be assigned
- Traffic management of the transporters so that there are no bottlenecks or congestion in the yard.
- Number of gangs to be used for which ‘shifts’ and at which times.
- Minimize idle time of the cranes, transporters and labor [6].

2.3. Horizontal Transport

While serving a ship, CT manager try to avoid leaving any resource idle and allocate it to another job as soon as it’s free. CT manager avoid Quay Crane (QC) from interruption or being idle. For this purpose, terminal transport is made efficient and available so that Quay Crane (QC) can be more productive. However, there are still some problems related to the horizontal transport which are, routing, pickup sequencing and co-ordination with Quay Crane (QC) [11].

2.4. Yard Stack/Stack on Quay

The operations in container stacking in the yard and on the quay are influenced by the stacking policy used by the container terminal management. The containers are usually sorted using a stacking policy which may consider, for example; type (export or import), and size (i.e. 40’ foot or 20’ foot), destination, or by ship line that owns the container – there are many methods to organize a stack. In the situation of stack on quay, the containers that are to be loaded on to a ship are placed temporarily in a position near a Quay Crane (QC) to be loaded directly to another ship. This allows a faster service with less handling by avoiding stacking in a yard stack. The positioning stacking policies are viewed as either tactical or strategic, depending on how flexible the container terminal can configure the berths and stacks. Ideally, in transhipment operations, the ship unloading the containers to be loaded by another ship will be serviced at the same time with the other ship in order to avoid problems of stacking containers. This scenario offers a faster service. However, in reality the containers must often ‘dwell’ or be placed in a yard stack for a period of time, while waiting to be loaded onto another ship. Some problems or decisions affecting this process are: Stacking density- Yard configuration- Automatic container allocation- Dwell times [6].

3. Web Enabled Simulation

A simulation is a computer model that mimics the operation of a real or proposed system, such as the day-to-day operation of a port, the running of an assembly line in a factory, or the staff assignment of a hospital or call center [10].

Simulations can be better than experience because they compress time and remove extraneous details. Unlike life, simulations are optimized for learning. Indeed, the true beauty of simulation is that it provides an immersive learning experience, where skills, process, and knowledge can all be enhanced in a way that reality cannot. Also, the ability to explore, experiment, and repeatedly apply this knowledge to

unlimited model situations is what makes simulation the most versatile form of learning available.

We all know that adults usually learn best by doing. So why do we constantly ask them to learn by reading, or by listening? Simulation-centric learning solutions do not ask learners to sit through screen after screen of text. Instead, using proven simulation methodology, they challenge learners to manage a business, project or team and learn from their successes and failures.

Simulation-centric learning is one paradigm for creating the most value in online and in-class learning. Instead of using a simulation simply for testing or practice it makes simulation the key driver of the learning experience. Learning is delivered throughout the simulation, both as part of the storyline and on demand, through consulting, tutorials, reference-tools and supplemental information.

Since simulation-centric learning is based on discovery learning, you do not have to spend time focused on learning what you already know. As you face each new business challenge, the system recommends a rich array of resources to help make decisions: tutorials, best practice tips and tools. Get as much or as little help as needed to solve business problems and move ahead.

Since the simulation-centric experience utilizes goal-based scenarios, everything done focuses on how new skills and new behaviours help achieving real business goals. Success is not driven by how many test questions you get right, but how well you are able to optimize real business metrics, the same measures that businesses use every day.

3.1. The User Experience

Learners interact with real or simulated co-workers to make a series of decisions that are pertinent to their everyday jobs. Simulations recreate authentic business environments, where storylines and decisions are based on in-depth analysis and research of real companies.

The authenticity and personal relevance of the simulations provide learners with meaningful, memorable experiences that lead to real world success. Simulation-centric learning is designed for the user to have a challenging experience that is highly interactive, to maximize the retention and continuous application of knowledge.

Simulation-centric learning also enhances the sense of community within an organization by providing shared experiences and enabling learners to get support from peers.

3.2. The Benefits

The availability and interactive nature of web based simulation also provides a good medium for students to experience the complexity and dynamism of collaborative work and can be natural environments that combine distance education, group training and real-time interaction [7].

- **Learn by doing** -- simulated business environments provide business professionals with an engaging, interactive and realistic learning experience
- **Based on reality** -- the simulations used in this type of training are living case studies and emulate an appropriate business environment where teams compete as they would in real-life
- **Compelling and challenging** -- Simulations drive peak performance by creating a competitive environment where participants can exchange knowledge and combine skills from varying functions and expertise areas
- **Risk-free environment** -- Simulation allows decisions to be made and conclusions to be drawn with no risk to a business
- **Compression of time** -- Simulations provide an accelerated learning environment and decisions that may be made over a period of ten years in the work environment are condensed into several days
- **Quantitative and qualitative feedback** -- Simulations provide complex and accurate feedback in both behavioural and specific skill areas
- **Multi-dimensional learning** -- team, individual and group learning are all indicative of the simulation process
- **Specific** -- Many simulations are specific and directly tackle areas such as: Leadership, Project Management, Finance, Corporate Strategy, Insurance & Manufacturing to mention a few. In addition, simulations can be manipulated for independent clients depending on their needs.

The web can serve as an operating system and as a distribution channel for applications [7].

It is viewed by many that “distant learning combined with simulators makes a new and flexible training approach possible” [4].The benefits of web-enabled simulation are:

- Learners can run simulation exercises on their own machine in a self-study training mode. This provides flexibility with scheduling of training and the possibility of conducting training
- Compared to CBT, web-enabled simulation offers high fidelity interactive simulator training. The learners are engaged in an immersive environment.
- The built-in assessment and evaluation system provides feedback and guidance to the students. The assessment score is also available to the instructors.
- When connected to a Learning Management System (LMS), web-enabled simulation is presented in a managed learning environment where learners and instructor can interact
- The training adjusted to respond to the needs of the students.

We can list a number of features that supplement the characteristics of Games and simulations. When discussing games, he mentions six structural factors:

- Rules
- Goals and Objectives
- Outcomes and Feedback
- Conflict / Competition / Challenge / Opposition
- Interaction
- Representation or Story [1]

If e-learning is to be successful, the content must be appealing to the end-learner; learning is being forced into new directions such as computer games. Simulation meets that challenge [3].

4. Improving Port Operations Using Training Simulator

Most studies concerning port planning and simulation focus on the service of ships rather than trucks. The reason for this bias is that ship's downtime costs and customer demands are higher and more pressing than their terrestrial counterparts. This does not mean that optimizing truck servicing and equipment utilization is of no importance. Since a terminal's performance is judged on the overall performance of its individual components, this bias is not justified.

Simulation-based training places employees and customers in simulated environments that mimic real-life work situations. These learners can make mistakes and learn the consequence of their decisions. These "lessons" occur in a risk-free, hands-on training environment.

On the handling of outgoing general cargo transported on trucks, all major processes are reproduced by the simulation model.

Our Training Simulator model is a step-by-step education product; build up on a different methodology compared to similar existing Simulators. We use Formal Graphical Approach for design, performance and evaluation of simulation-based training activities in Damietta port (located 10 Km to the west of the Nile River and 23 mils west of Suez Canal. Total port area: 11.8 m. sqm. Water area: 3.9 m. sqm, Land area about 7.9 m. sqm. .Water area to Total port area is 1:3.no. of birth 16(4 for container and 12 for general cargo .birth depth 14.5 (13.5 safe) m.) We developed an effective web-based and Computer-based learning content for reaching an optimal use of simulators in operational port training actions. User can run this simulator via port web site (http://www.dam-port.com/training/mod/resource/view.php?id=155).

The first high level decision in the design process concerned whether the Training Simulator should be developed as a web or desktop based application. After exploring the advantages of both options, it was decided to develop as a web based application because of The Following reasons.

- Familiarity of the interface: The Internet provides a familiar interface for both interacting with and controlling a simulation [9].
- License and deployment models. The tool can be deployed locally, in an intranet setting or over the internet. The possibility exists to tailor the GUI allowing the use of the application on any device with a relevant web browser installed
- Cross-platform capability. The web allows for the ability to run an application on any Web browser on any operating system without compiling [5].This capability relieves the application developer from having to worry about a client's configuration.
- Controlled access. Access can be controlled to a web-based simulation application through the use of passwords, and limited time-span access
- can be allocated, users who access to specific or limited areas of an application need can be given access merely by being added to a password list, instead of having their client machines updated [9].
- Wide availability. A web-based simulation application can be used from anywhere in the world with an Internet connection and outside of normal business hours without having to transport hardware or software [5].
- Versioning, customization and maintenance. In using a web based system, maintenance is minimized [5]. All modifications can be made through the server, enabling frequent modifications, customizations and updates
- To be made and instantly distributed to the application, reducing error potential and
- Eliminating virtually all on-site maintenance.
- Integration and interoperability. A web based tool can integrate and inter-operate with both existing and future web based applications, as well as web enabled
- Desktop applications [5].

By clicking the run button in a simulation model we see the work done move around the organization. The symbols in the corner of the screen tell where the Channels, Terminal, gates (in /out), berth, Scales, warehouses, customs and Roads are located in real system.

Our Training Simulator is animated. This enables visualization of a new facility and a greater ability to visualize the impact of experiments in an existing facility.

5. Result and Discussion

Number of trainees who are trained on our Training Simulator is 60 employees and customers, in the period from January 1, 2009 to January 31, 2009; also the

Figure1. The Whole Virtual World with Channels, Terminal, gates, berth and Roads.

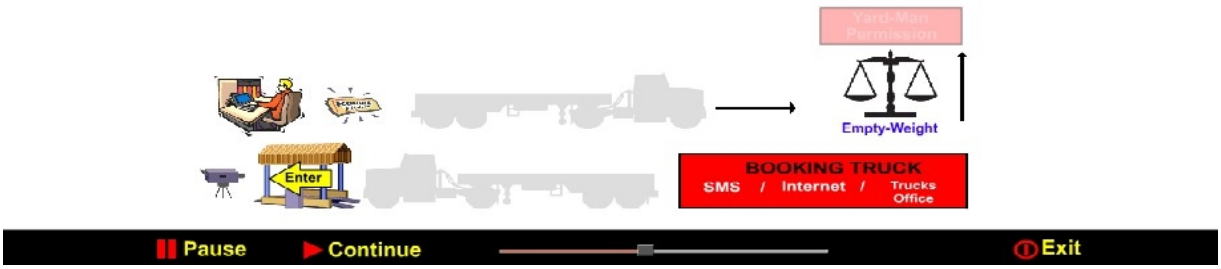

Figure 2. The port training simulation system at Scale state.

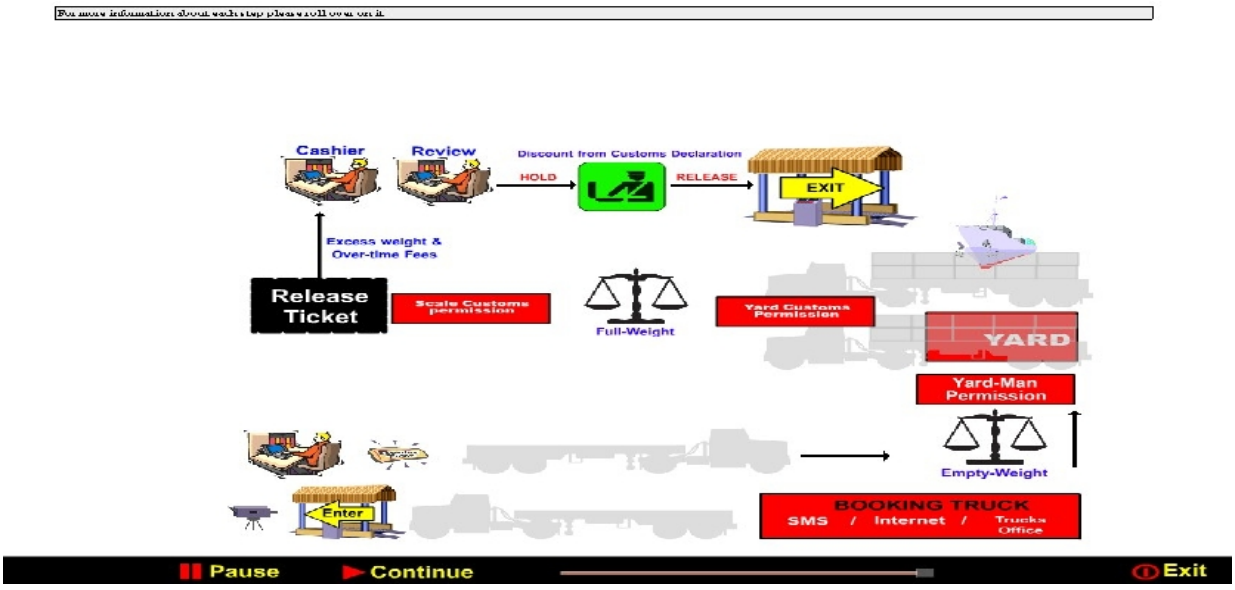

Figure 3. port training simulation system.

simulator is available on a public access Web site(http://www.damport.com/training/mod/resource/view.php?id=155), and is therefore accessible to any one with a PC, Internet connection and Web browser with Macromedia Flash plug-in.

The purpose of this study is to provide an alternative exercise for trainees, in which they practice in a virtual environment before tackling the real operation. In figure 1, we reported a typical screen-shot of the terminal during the simulation.

Figure 2 and 3 show the Web based training simulation system. The interface is provided by a web browser, where port training simulation system is embedded into a HTML page. The symbols in the corner of the screen tell where the Channels, Terminal, gates (in /out), berth, Scales, warehouses, Customs and Roads located in real system. In figure 3; a histogram reports the average rate of Trucks waiting times in customs in Damietta port to complete its Cycle .in Table1, we show the time taken (in minutes) to complete trucks cycle. As shown in figure 4 the Trucks Cycle Time is reduced from 150 min to 50 min after implementation of the Training Simulator in Damietta port at Egypt. From Table 1, it can be observed that the use of training simulator has significant impact on the number of hours spent waiting by trucks in Damietta port at Egypt to complete its cycle in customs. The users now have a good knowledge about what he must do to complete the truck cycle because we use Formal Graphical Approach (FGA) in the Training Simulator to teach the customers and employee the formal rules about every step in trucks cycles.

We use e-learning system to deliver the Web-Based Training Simulator e-learning system based on the PHP + Database (MYSQL) installed on server with the following configurations:**Hard ware**(Dell Power Edge 2800with Intel(R) Pentium(R) 2 x 3.2GHz Xeon / 2MB Cache / 800FSB-4GB of PC-3200 ECC RAM (at 333MHz)-3 x 146GB 10K U320 Hot Swap SCSI Hard Disk) and **Software** (Oracle Enterprise Linux operating system- Apache Web Server-My SQL server-java jdk1.5.qas vfv0_08-php my admin -Linux High Availability (Heart Beat). We used the flash and action script to built The Training Simulator.

Table 1.Rate of trucks waiting time at the customs only in 2009 at Damietta port

Months 2009	Jan	Feb	March	April	may	June	July	Aug	Sep	Oct
Truck Cycle Time (min	150	140	120	105	90	80	60	60	60	50

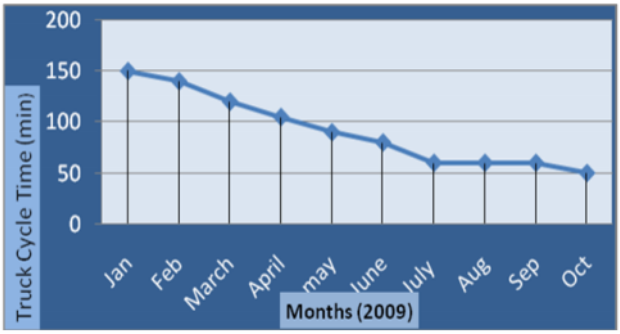

Figure 4. A Histogram representing the average rate of Trucks waiting times in customs only in Damietta port.

Here we compare between three systems:

- There is no training for users (no system). The users dealing with the system in the port but with no knowledge about the system. N=13.4
- Using training simulator to teach the users how to deal with the system in the port (old system), but we don't use formal graphical approach (FGA) or e-learning. N= 8.7

- Using formal graphical approach (FGA) to design the training simulator and e-learning system, to deliver the learning objects to learners in an interactive, adaptive and flexible manner. N= 5.7

From Table 2 and Figure 5, it can be observed that the use of current training simulator has significant impact on the number of hours spent waiting by trucks in Damietta port at Egypt to complete its full cycle compared with other systems. The mean waiting time is reduced from 13.4 to 5.7.

Table 2. Comparison of the mean waiting time for trucks before using simulator in training and after. For full truck Cycle in Damietta port.

Systems	no system	Old system	Current system
The mean waiting time(hour)	13.4	8.7	5.7

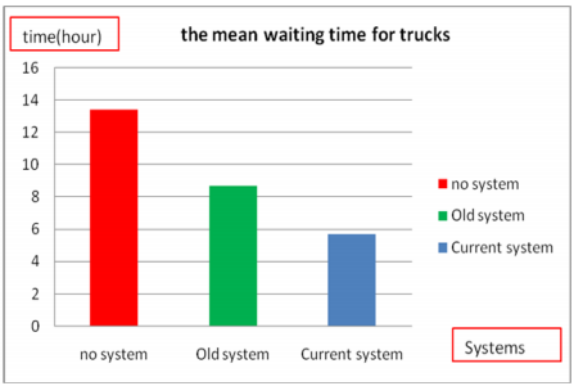

Figure 5. A Histogram representing the mean waiting time of Trucks in Damietta port .

The important contributions of this paper are:

- We have designed and implemented a successful Training Simulator of the port operations in Damietta port at Egypt.
- The Training Simulator is a step-by-step education product; build up on a different methodology compared to similar existing products.
- The Training Simulator is web based, Independent of the user's platform. A user has access to the Simulator from anywhere in the world using the Internet, breaking the limits of distance and the number of participants on site.
- We use Formal Graphical Approach (FGA) in the Training Simulator to teach the customers and employee the formal rules about every step in trucks cycles.
- The efficient way to help employees and customers that dealing with ports to work smarter and operate more efficiently is through training.
- Simulation training places employees in simulated environments that mimic real-life work situations, where learners can make mistakes, learn the consequence of their decisions in a risk-free, hands-on training environment.
- Reduce the trucks waiting time and faster cargo flows by optimally utilizing the port resources. Reduced waiting time encourages trade and improves the competitiveness of the port to provide efficient and effective services at a low cost.
- Simulations can spark interest for learning and make a boring topic fun.

6. Conclusion

This paper represents a part of our research work, aiming at improving management practices of a container terminal and operation cycles in Damietta port at Egypt. In this paper we have proposed Training Simulator for container terminal system. Simulation tools, such as the one described above contributes to the improvement of internal operations of container terminals, and operation cycles. Simulators are able to generate considerable benefits and added value for the operational training, they also provide a safe environment for testing problem-solving techniques, without the risks that we encounter in the real world.
Case study based on real world port systems has been presented; a significant improvement is demonstrated in the operational and economic performance as a result of using the Training Simulator. This paper presents an example simulation decision based application. It is found to be beneficial to develop the tool as a web based application, rather than a desktop based application due to the nature users of the tool, the ability to control access to the tool, the wide availability of the tool to users, the advantages in versioning, customization and maintenance, increased integration and interoperability, familiarity of the interface to users and cross-platform capability.

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