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Simulation of container operations in the marshaling yard – case study: Aprin station

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In this project, an attempt has been made to investigate the loading/unloading operations for container loads on a at the Aprin station with a simulation approach. Simulation is an approximate imitation of the operation of a process or system whose performance is examined over time. In this study, Aprin station was selected as the largest railway station for container transport in Iran. To find out the detailed operation in this station, a field visit was performed and the details of the operation and the probability function of activity times were obtained. Based on the field visit, a discrete event simulation model was developed and Python language was used to implement it. The results of comparing the actual data and the output of the simulation model show that with a probability of more than 99%, the simulation model describes the reality.

1. Introduction

The complexity of transportation systems often makes it difficult to study and analyze them. In such situations, computer simulation is a powerful way to analyze and design transportation systems. The availability of special simulation programming languages, extensive computing capabilities at a decreasing cost per calculation, and significant recent advances in simulation methods make this topic one of the most common and widely accepted analysis tools. Simulation examines the interrelationships of any complex system, and in fact attempts to find the best solution by creating and testing all possible scenarios and modes.

In the field of modeling simulation of unloading and loading operations in the railway, a lot of research has been done and many articles are available. In these studies, different modeling and simulation tools have been developed for this purpose, which will be mentioned.

In this article, the focus is on container transportation because the container allows intermodal transport, i.e. the container from origin to destination using various methods of transportation such as road, rail, sea and air. In the pre-container period, the goods had to be loaded slowly in the truck during time and then transported to the station and unloaded again and reloaded in the wagon. This process was a tedious process and took a long time. It was necessary for the wagons to be present at the

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rail station a few days ago to complete the unloading and loading process. When the container arrives at the station, the container is loaded and the station traffic control is notified that the container is ready to be dispatched. Trains arriving at the station could, depending on the number of containers they carried, unload and load the containers in a shorter period of time and continue their journey.

This article consists of six sections: The second section reviews the literature. In the third part, a report of the visit of the Aprin station is presented. In the fourth section, the analysis of the data obtained from the visit is presented. In the fifth section, a discrete event simulation model is presented and compared with reality results for validation purposes. In the last section, we will summarize and present the results obtained from this article.

2. Literature Review

In the world where the gap between initial developments and the introduction of the final product to the customer is constantly narrowing, the need for a fast shipping system is a basic need. Due to the increase in traffic, the terminals are under a lot of pressure to move the increasing volume with good quality. Therefore, terminals and marshaling stations have a key role in the field of railways, and the goal is to carry out operations in the best possible time and cost. Computer simulation is one of the suitable tools for analyzing and investigating operations in railway stations. Extensive studies in this field have been conducted with a simulation approach, which is reviewed below.

Klima and Kavicka [1] present a new tool for simulating the classification operations in the railway called RBSim (The Recreation Behavior Simulator). The output of this simulation program is presented in the form of live monitoring of key parameters and station performance criteria and time-dependent statistics related to locomotives and wagons. One of the problems of this research is that it is not possible to change the simulation process according to the characteristics of the desired rail system.

Cenek [2] describes the model including routing and moving of rail wagon in the yard, and sorting problems. For easier understanding, the author first use the node and arc method (nodes represent paths and arcs indicate the relationship of a possible motion from one direction to another) that wagons are not placed in nodes and the wagons move through the arcs of the network. The disadvantage of this model is that it does not take into account the length of the train and the occupation of the rails when searching for a route in the area. This model was programmed in Turbo PASCAL and graphical output was used to show the current state of a simulation system.

The previous two papers focused on simulation of moving the train between stations and did not focus on in-station operations. In the following, we will review articles that focus on in-station operations. Among the factors that exist in the process of unloading and loading operations in-station, we can mention two categories of human factors (the same as operational labor) and infrastructure factors. In infrastructure factors; cranes, platforms, lines, wagons, warehouses and vehicles are discussed. Due to the fact that crane operation is more important than other cases, the articles carried out in the basin of improvement and optimization of gate cranes have been more than other cases mentioned. In the following, the related articles have reviewed.

A paper is entitled "Designing a Simulation Process for Scheduling Rail Container Terminals Based on Flexsim" improves the efficiency of rail gantry cranes and reduce the waiting time of trains and container trucks by finding the optimal schedule for crane operation. For this purpose, a three-dimensional simulation platform, called Flexsim, has been used to simulate different operating modes of rail gate cranes at the central railway container station. Also, this software can provide real-time graphic animation and full performance report; and compare the advantages and disadvantages of different designs in a relatively short time and select the best schedule [3].

In paper entitled "Simulation-Based Optimization for Railway Container Terminal Unloading Strategies", Li and Wang [4] simultaneously use the simulation and genetic algorithms have led to the optimal location of equipment and also loading and unloading strategies at the railway container terminal. In this paper, the methods adopted are based on

SBO (Simulation Based Optimization) because SBO is an approach consisting of simulation techniques and optimization algorithms, i.e. the simulation model is used to evaluate the performance of solutions. Under the guidance of such evaluations, optimization algorithms search for better new solutions in the feasible region and constantly new solutions is provided by genetic algorithm and re-evaluated with the simulation model. This process is repeated until a termination condition met.

The paper [5] uses "Internet +" technology to build the logistics information platform of the container terminal, which allows trucks to share information to obtain the allowable amount and exact time of arrival at the station. Given that optimizing the dispatch system of a container center is an NP-hard problem, a multi-layered genetic algorithm is designed to achieve the optimal arrival moment for flexible scheduling to the container terminal. This paper aims to minimize total equipment working time. Finally, according to the model introduced in the paper, the Takoradi container terminal proposes medium- and long-term planning ideas for port development in Ghana.

The article [6] explains that gate cranes in railway container terminals use the indirect mode of "transfer of container from truck to yard and from yard to train". This article allows the implementation of "direct transfer" mode and analyzes the container from truck to train and explains the importance of this model for railway container terminals. The three assumption mentioned in this article include the uncertainty of both the operation time of the trucks and the intervals arrival time of trucks, and the limitation of the operating area. It also introduces three achievements, which include improving the performance of gate cranes, helping to preserve the green environment (by reducing the operation and container space required in the yard) and saving the time of container trucks. The paper refers to the use of the Internet of Vehicle (IOV) and states that IOV can transmit information such as the speed, position and load information of container trucks through devices. The accurate times obtained by IOV are used for doing the simulation process inside the container terminal.

In another article entitled "Modeling and Simulation Methods for Managing the Container Terminal of Riga Port", port of Riga that unloads and loads ships, trains and trucks is examined. It should be noted that the port of Riga is the largest container terminal in the Baltic Sea. This paper aims at improving logistics processes in the container terminal with a simulation approach. Logistic processes include the duration of trucks stay in the terminal, and bring containers to/from the terminal. For this purpose, GPSS and Proof Animation have been used [7].

The paper written by Jan Klaws and et al [8] is the simulation study of two commons loading/unloading solution (DRMG and TRMG) with lateral loading and no overtaking each other. The question is: Is adding cranes to existing systems lead to higher productivity? And if so, what is the rate of productivity? In addition, it should be tested whether the addition of cranes due to the interference of cranes with each other during operation, may reduce efficiency or not? The simulation conclusions showed that there was a significant discrepancy between the mean DRMG and TRMG operation time, and this difference was evident in all simulations performed. In general it can be found that the efficiency of a TRMG system was better than that of a DRMG system.

The issue of optimizing and simulating in loading/unloading operations at railway terminals has also been looked at from other side. For example, the article "Optimization of container loading in rail-truck terminals according to energy consumption" tried to investigate the issue of container loading/unloading in rail-truck terminals with respect to energy consumption and an optimization model was developed to minimize the total displacement time of the containers inside the yard. For this purpose, a genetic algorithm has been developed. This article classifies the containers into two categories. The first is the output containers that are brought to the terminal by trucks but do not enter the yard and are loaded directly on the train. The second is the output containers that are waiting in the yard for loading on the train. Finally, by the use of this approach, there is the ability to reduce the total energy consumption by 22% [9].

From the review of the above articles, we find three points. First, we conclude that the design of an accurate simulation, in addition to being able to express the real situation, can help us in choosing the optimal strategy along with the optimization methods. Second, due to the conditions of container stations in Iran, the stacker is one of the most important machines in moving containers, which has been ignored in the reviewed articles, and we will discuss in this article. Third, in all previous articles, simulation has been performed in the real world. In this article, we also select the Aprin station as the case study.

3. Site visit

Aprin yard located in Islamshahr, Tehran is the largest dry port in Iran. This station was opened in 1998 with a capacity of one line and the more lines were built and prepared for operation by 2002. The area of the Aprin yard is 700 hectares, of which about 86,000 square meters is allocated to facilities such as warehouses, locomotive and wagon repair shops, fuel storage facilities, lubrication and sanding of locomotives, office buildings, and dormitories (Figure 1).

To develop a simulation model of activity inside the dry port of Aprin, a site visit should be made to extract the relevant processes and times. Due to the lack of information in this regard, this visit was necessary. Site visit was conducted in two days. Since this project has targeted the loading/unloading of container loads, it should be noted that only all loading/unloading operations for loaded containers were visited in these two days. According to the rider of stacker, the maximum speed of this vehicle is 40 km / h, and in the best case, it can perform 2 operations of unloading the container from the wagon to the yard and lifting the third container from the wagon in 1 minute (Figure 2).

A visit of Aprin yard resulted in more than three hours of filming the details of the operation at the station. The purpose of filming in the first place was to obtain the loading and unloading operation times for the various components involved in the system. The advantage of this method is that whenever we need to extract more data (for example, timing of separated movements of the stacker, including unloaded movement, lift the container, carry container to the desired destination, putting and lifting container on the rail wagon). This can be done by referring to the videos and the measurement error is greatly reduced.

4. Data analysis

The videos taken from the area loading and unloading operation of the Aprin station were examined one by one, and the times related to the following six operations were obtained:

1. Carrying the container from the truck to the yard

2. Carrying the container from the truck to the train car

3. Carrying the container from the yard to the truck

4. Carrying the container from the yard to the train car

5. Carrying the container from the train car to the yard

6. Carrying the container from the train car to the truck

Figure 3 shows the time distribution function of operations 2, 3, 4 and 5, which is a normal distribution function.

5. Development of simulation model

5.1. Introduction

After visiting and extracting the detailed process and obtaining the relevant time distribution function, the simulation model can be developed. The process of modeling is as following. This paper uses a discrete event simulation approach. According to the observations in the station of Aprin, the assumption of the simulation model was extracted. Important parameters were considered as input to the simulation model. The simulation process was extracted by watching the recorded videos from the station and it is the basis of the programming of the simulation model. Python is used for implementation. To validate the simulation model, the results obtained from the simulation model are compared with the data collected from the station of Aprin.

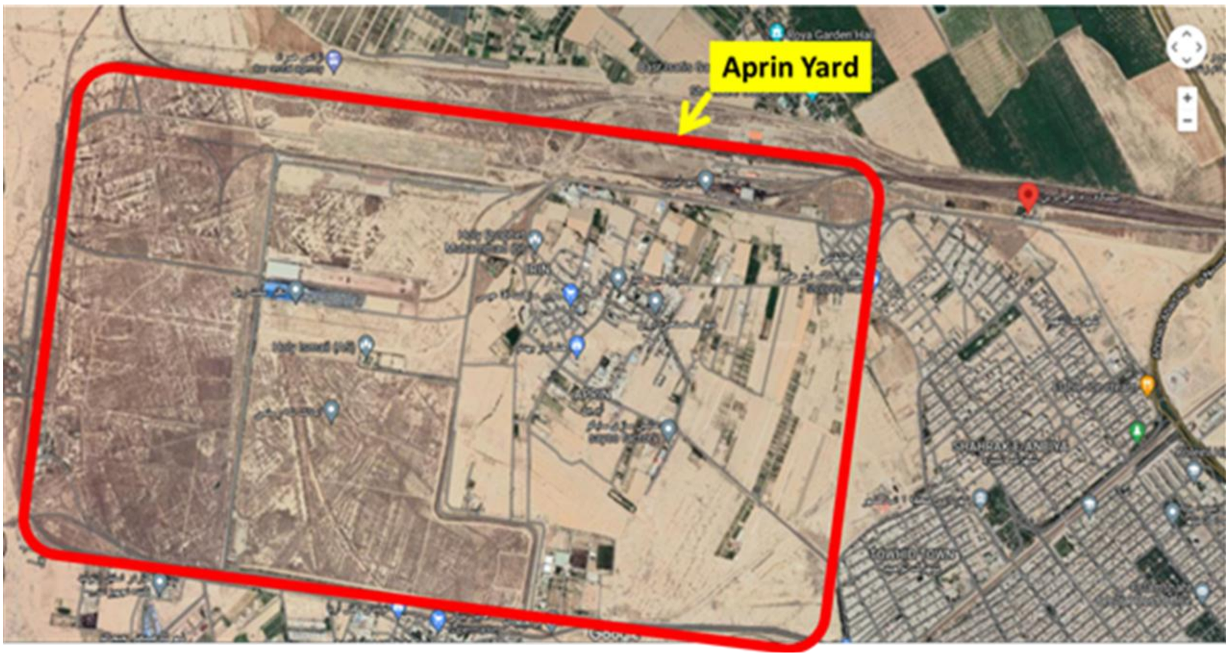


Figure 1. Top view of the entire area of Aperin station

Figure 2. View of the transport equipment of Aprin station

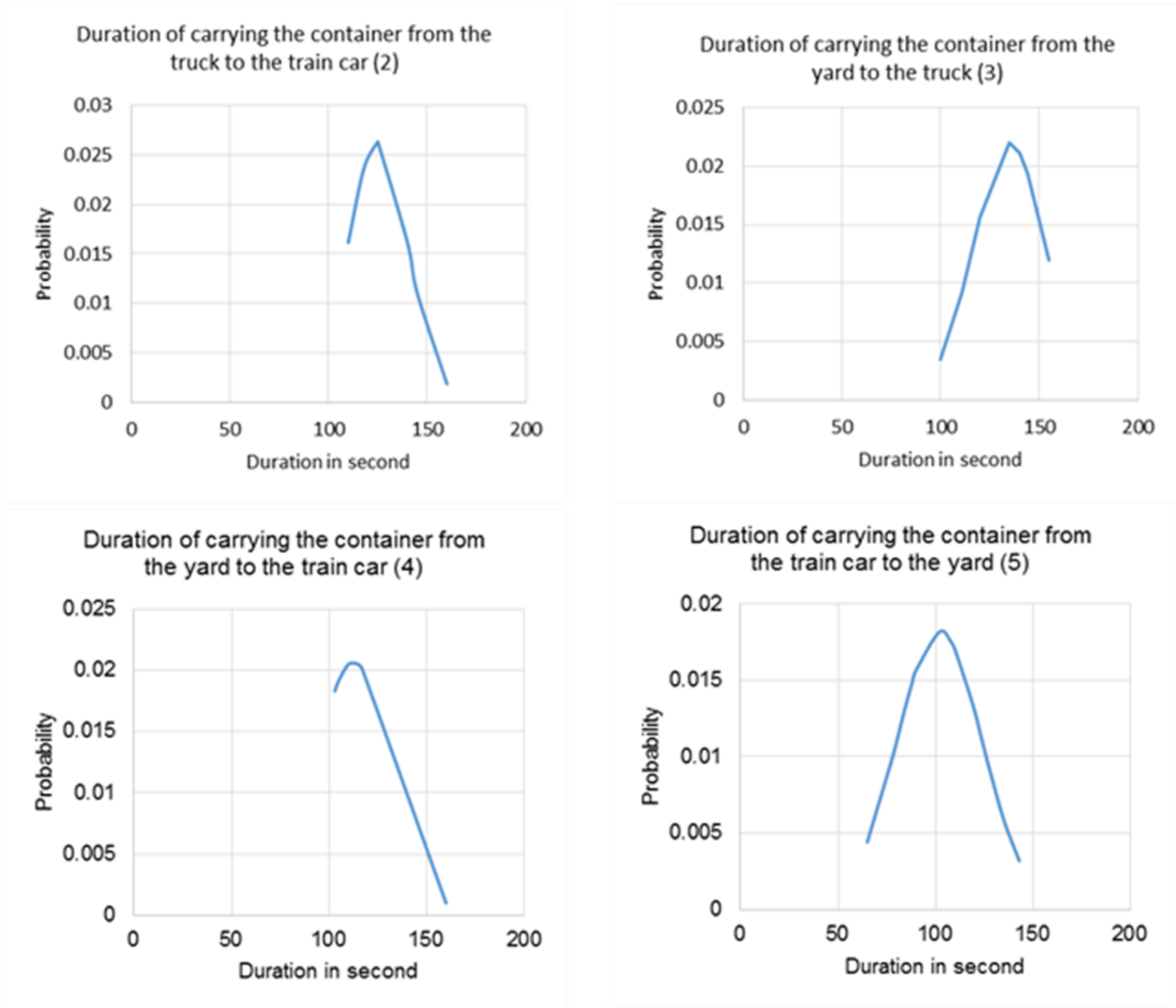


Figure 3. View of the transport equipment of Aprin station

5.2. Implementation

The programming of this simulation is written by Python language. To start the simulation, it is needed to have assumptions, initialization of data and random number generator. Among the assumption used in this simulation are the following.

•All containers are considered 20 feet

•Each wagon has the capacity to carry two twenty-foot container

•Each incoming/leaving truck carries one container

•The yard area has enough space to perform all operations

•The number and arrival time of containers (by rail or road) is predetermined.

•The stacker is located in the warehouse or yard at the beginning of the simulation. Not in the path of between yard and warehouse.

These assumptions are derived from the observation of the Aprin station. It is clear that if the other station is simulated, the above assumptions can be changed and the simulation model is capable of other assumptions as well.

The initialization of the data includes the following:

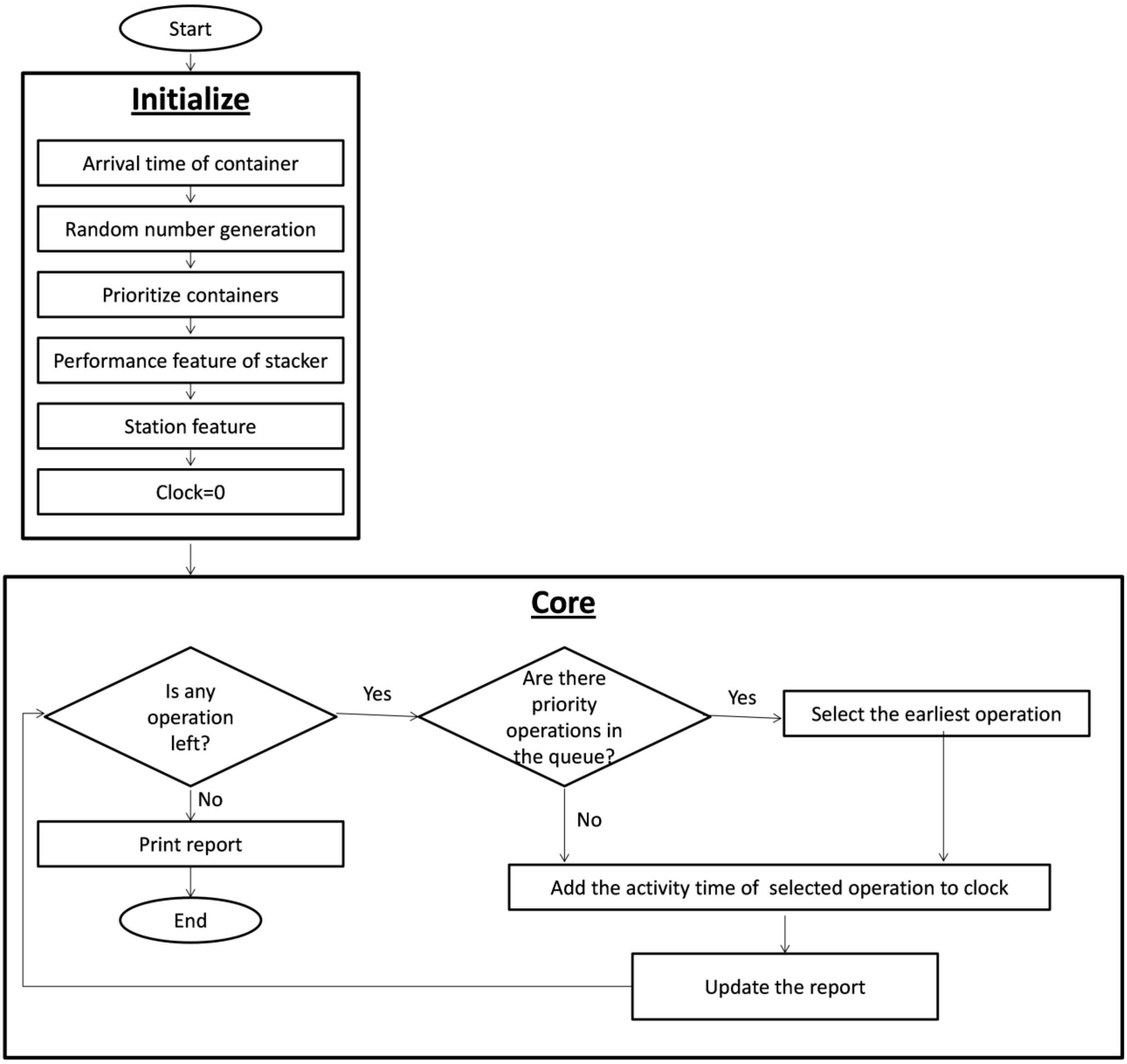


Figure 4. Flow chart of simulation

•The time of arrival of the stacker from the warehouse to the area was assumed to be 3 minutes.

•The number of containers is divided into three sections of yard: containers are inside the yard, containers enter to the yard by truck and containers enter to the yard by train.

•Getting number of replications for the simulation

•Getting the arrival time of trucks and trains at the yard

•Generating random numbers base on the probability function using the Python programming language.

•Getting priority of container inside the yard

•Getting the feature of yard such as the distance between the loading/unloading platform of rail and truck by container storage.

5.3. Simulation Process

The flow chart of this simulation is described in Figure 4. The flowchart consists of two parts. In the first part (initialize), the model inputs are entered and in the second part (core), which is the main core of the program, the operation of moving the stacker and moving the container is performed.

After the relevant inputs from the user, the core of the program is created, which continues until the containers are finished. To start the simulation, The stacker does one of the following six operations on each container.

1. Selecting the container in the yard
2. Selecting the incoming container by the truck
3. Selecting the incoming container by train
4. Selecting the yard to unload the container lifted by the stacker
5. Selecting a trailer to unload the container lifted by the stacker
6. Selecting the train to empty the container lifted by the stacker

It should be noted that the simulation of Aprin station, due to the presence of one stacker, only one of the above activities is performed and a stacker can select one of the containers for the operation. If more than one stacker is active at the station, more than one activity can occur simultaneously. Obviously, if the container is unloaded from the truck, it will not be reloaded on the truck again, and the same happens for the selected container of the train and the yard. This fact considers in the program.

Regarding the prioritization of stacker operations, if the truck and train are ready to unload at the same time, it will always be a priority with the truck, and if the truck is not in the yard, the next priority is on the train. Regarding prioritization for unloading and loading, priority is with unloading and then with loading. That is, if a truck is ready to be unloaded and a truck is ready to be loaded at the same time, first the truck is unloaded by a stacker and then the truck is loaded. A queue is created for each priority and the stacker will not serve on lower priority containers unless the higher priority queue is empty. Of course, there may be other priorities for moving containers, which can be the transport of dangerous or perishable goods that are given as input to the simulation model.

Once the activity has been assigned to the stacker, the duration of that activity must be determined. The list of activities that can be assigned to the stacker is as follows:

•Transporting the container from the truck to the yard

•Carrying the container from the truck to the train car

•Transporting the container from the yard to the truck

•Carrying containers from the yard to the train car

•Carrying containers from the train car to the yard

•Carrying the container from the train car to the trailer

When one of the above activities is selected, according to the distribution extracted in Figure 1, a random value is generated for that activity.

5.4. Validation

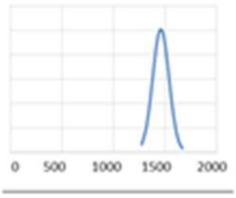
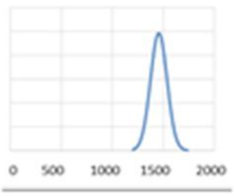
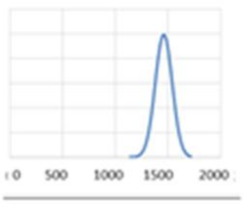
In order to validate the outputs of the simulation model, the best solution is to statistically compare the output of the application with the actual data collected. That is why we referred to the recorded videos. For example, the total duration of the operation was compared by the stacker in the simulation and reality. This time was 24 minutes and 9 seconds by referring to the videos at the Aprin station. The simulations were repeated for 100, 1000 and 10000 times and the results were given in the table.

As shown in table 1, in the simulation program, the total operating time after 10000 simulations is an average of 1459 seconds, which is equivalent to 24 minutes and 19 seconds. With a probability of more than 99%, the total operating time of the simulated operation is statistically identical to the total operating time which is observed. Therefore, validity of the simulation model is confirmed.

6. Summary and conclusion

In this paper, an attempt was made to make a simulation program for loading/unloading the container of the station based on reality. In order to obtain the required data, a site visit to the station Aprin was performed on two days and real-time data could be extracted by filming the operations of the site to find the probability distribution function. The simulation mode was written in the Python programming language. The proposed simulation model has the ability to test the effect of different scenarios on the performance of the station. These scenarios are:

Table 1. Results of running the simulation program

Number of simulation repetitions	100	1000	10000
Average total operating time (seconds)	1460.13	1455.81	1459.25
Standard deviation of operation time (seconds)	79.14	80.95	80.42
Function of distribution of total operation time			

design the new layout of the station, the use of autonomous vehicles and gantry cranes, the impact of truck and stacker failures. Capacity calculation is another application of the simulation model that plays an important role in the development of the station to meet the new demand.

In this simulation model, it is assumed that the operation is performed by one stacker. Because the volume of operations at Aprin station was less than the capacity, the operation of a stacker is sufficient to perform the entire loading/unloading operation of the Aprin station. If the volume of operations in this station increases, more stackers will be required, in which case, the simulation model presented in this paper has the ability to perform simulations for more than one stacker.

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