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A SIMULATION BASED APPROACH FOR DOCK ALLOCATION IN A FOOD DISTRIBUTION CENTER

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ABSTRACT

This research endeavor focused on the warehouse receiving process at a large food distribution center, which comprises of trucks with goods reaching the destination warehouse, unloading and finally putting away the contents to the specific aisles. Discrete event simulation was used to model the current system's functioning and to identify operational inefficiencies which were quantified through a detailed value stream mapping exercise. Inspired by 'lean' philosophy, a dock allocation algorithm was designed to take into account the relationship between the dock location and the destination aisle to 'optimally' assign the trucks to the docks. After validating the baseline, new scenarios incorporating the allocation algorithm were tested. Two of the scenarios showed an average reduction of 30% in daily travel distance for the 'put-away' personnel. The simulation model also helped visualize the benefits that would accrue through the use of lean principles to reduce the non-value added time in warehouse operations.

1 INTRODUCTION

'Lean' philosophy has been widely applied in the manufacturing sector. Recently, the food distribution industry has started adopting 'lean' concepts to reduce and eliminate the process wastes. Due to the short life cycle of the perishable and non-perishable items, the food distribution industry has to strive to maintain a minimal turnaround time for the goods. Applying 'lean' concepts for identifying and eliminating the wastes is one of the methods which can be implemented to maintain a low turn around time for the goods while increasing the utilization of the warehouse resources such as put-away personnel, fork-lifts, and storage aisles. As pointed recently by Gagliardi et al. (2007), significant amount of research has been focused on the determining the pickup slots and pickup routes in the warehouse, along with the use of a combination of simulation and optimization techniques. It was also well documented by Trebilcock (2004) that optimization software can be used to schedule the arrival of trucks at the warehouse to improve the inbound process.

This research endeavour primarily focuses on reducing the 'motion' waste identified in the receiving process of a food distribution warehouse's inbound activity. The inbound department in the warehouse performs the tasks of receiving and storing the products. Delivery trucks arrive with one or more advanced shipping notices, which list the type and quantity of products to be delivered. At the concerned warehouse, the trucks from the suppliers are provided a time slot at which they are supposed to arrive for the receiving/unloading process. Inbound activity of the warehouse can be broken down into sub-activities such as, scheduling of trucks, dock allocation, paper work, lumping, receiving, and put-away. Detailed process mapping followed by value stream mapping was performed to identify and quantify the wastes due to non-value adding activities within the aforementioned sub-activities. Based on the results of the value stream mapping effort, the distance travelled in the put-away activity was found to be very high. This was principally due to the sub-optimal methods employed for dock allocation.

With the goal of reducing the dock turnaround time, a dock allocation algorithm, with the inputs of product mix, volume and pre-defined storage aisle locations, was designed. This algorithm focused on reducing the excessive distance traveled from the receiving dock to the storage aisles. A discrete event simulation model of the operations within the entire warehouse was developed to study the impact of the dock allocation algorithms and test a few 'what-if' scenarios. For practical implementation purposes, a C++ program was also developed to demonstrate the applicability of the algorithm for real time dock allocation.

This paper has been organized as follows. Section 2 is devoted to the methodology followed by Section 3 which describes the simulation model's baseline and validation results. Improvements and alternative scenarios are described in Section 4. Finally, the findings and conclusions of the study are discussed in Section 5 of the paper.

2 METHODOLOGY

As the first step in 'lean' thinking, a Value Stream Map (VSM) was developed. This VSM covered all the sub-activities of the inbound process of the warehouse. The results obtained through VSM helped identify the areas contributing to the non-value adding activities. However, to gain more insight into the micro level processes of the sub-activities covered in the VSM, a detailed process map was developed. The details of the process map were used in developing the conceptual model for the discrete event simulation model. Data for the simulation model was partially collected through time studies and the rest through the system database. After the verification and validation of the baseline model, the alternative scenarios were developed.

The alternative scenarios were developed with the objective of reducing the distance traveled by the palletized products which need to be put-away to the corresponding storage aisles. The distance traveled by these products in the put-away process was dependant on the position of the dock gate where the products were unloaded and the position of the pre-defined storage aisles for the particular type of goods. Since the location of the goods in the storage aisle was pre-defined as per the pickup activity of the outbound process, the preeminent option was to allocate a dock which was closest to the storage aisles. However, this was not an easy task, since in a large food distribution warehouse, the trucks can carry multiple goods which were stored in different storage aisles of the warehouse.

Subsequently, a dock allocation algorithm was developed. This algorithm took into consideration different types of products which the truck would be delivering to the warehouse. The algorithm took into account the number of boxes and the height of boxes to calculate the number of pallets. Based on the number of pallets, the distance traveled was calculated for the total goods delivered by each truck for each available dock. The best dock would have the minimum travel distance for the products. In this study, two approaches have been taken to demonstrate the use of the dock allocation algorithm. The first approach was to use the algorithm for scheduling the trucks as per the best dock for any given combination of loads that the truck would be carrying. Benefits of this approach have been illustrated using the simulation model (details in Section 3). The second approach was to use the algorithm for ad-hoc dock allocation of any truck at any given point of time, where the best available dock would be assigned to the truck. The implementation of this approach was done using a C++ program. The results were simulated and compared with baseline performance.

2.1 Value Stream Mapping

To apply 'lean' philosophy in any organization, the first step is to identify and quantify the wastes in its processes (Hines, Rich, and Esain 1999). One of the tools used to identify waste is VSM. There are two categories of time in a VSM called 'value added time', a.k.a VA, and the 'non-value added time', a.k.a NVA. For the food distribution warehouse inbound process, the VA time accounts for the time where the product is moving through the inbound process of the warehouse, while the NVA time is the time when the product is sitting idle in the warehouse waiting to be unloaded from the truck, received by the receiver, etc.

Time and motion studies were performed to study the performance of the inbound activity. The data collection was done over a period of ten days for each of the intermediate steps in the inbound activity such as lumping, receiving and put-away. From the VSM shown in Figure 1, it can be seen that the non-value added time accounted for more than an hour and nineteen minutes on an average as compared to the value added time of an hour and thirty three minutes.

2.2 Process Mapping

A detailed process map of all the sub-activities of the inbound process was developed. This included processes such as the advance scheduling of the trucks, paper work which needed to be completed once the truck had arrived, lumping of the goods, receiving the goods, putting away the palletized goods to the corresponding storage aisles, and the payment process. In the interest of brevity, only one of the aforementioned process maps has been shown in this paper. The logic for the simulation model was developed from the details of these process maps.

Figure 2 shows the process map for the advance scheduling of the trucks. It can be observed from the process map that the current scheduling and dock allocation were done based on the personnel's skill and experience. The time slots were assigned to the trucks based on the type of the load and the number cases (volume) the truck was carrying. The dock allocation was also done so as to differentiate the trucks carrying perishable and non-perishable food items. However, the actual dock allocation took place when the truck arrived on the scheduled date and was given any particular available dock based on visual inspection.

3 SIMULATION MODEL

The simulation model was developed using ARENA® 10.0 process simulation.

3.1 Model Objective

The simulation model was utilized as a tool to analyze the existing warehouse inbound receiving operations. Specifically, the model was meant to evaluate methods to allocate

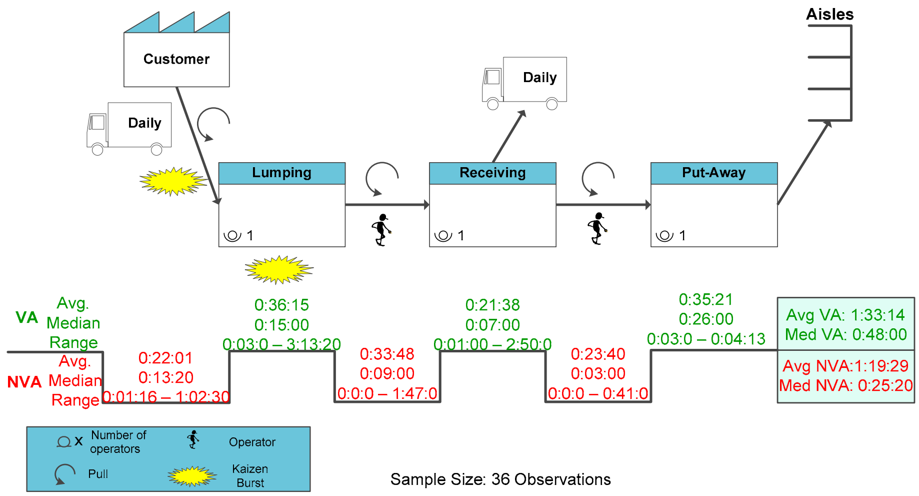

Figure 1: Value stream map for the inbound activity

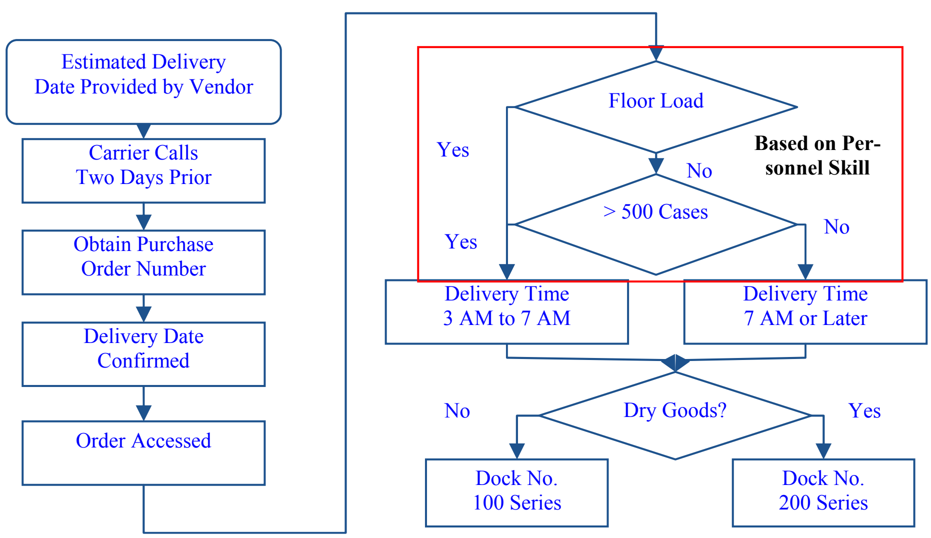

Figure 2: Process map for scheduling of trucks arriving from the suppliers

docks to the incoming trucks in a systematic and efficient manner.

3.2 Model Logic

The model was built to capture the actual functioning of the warehouse inbound operations. Trucks were scheduled to arrive between 3am and 10am on a daily basis. From data analysis, it was apparent that a large percentage of trucks arrived late. The truck arrival pattern was modeled based on the scheduled time of the trucks, taken along with the probability distributions of the amount of delay experienced by trucks throughout the different times during the day. To capture the occasional trucks which arrived earlier than their scheduled times, probability of such arrivals were computed and included in the model. The time spent at the guard shack, lumping, receiving and put-away was also captured using probability distributions. The distance by the warehouse operators for transporting the goods to the designated aisles was calculated as another input to the simulation model.

3.3 Required Data

The model and analysis were based on a significant amount of data. Portions of the data were collected by direct observations and time studies. Other data were made available from the system database.

Observational Data

- Duration for unloading the goods
- Duration for receiving (book entry process)
- Duration of put-away process
- Delay observed in intermediate stages

System Database

- Product codes and put-away aisles
- Pallet capacity for different products
- Historical data regarding previous trucks volumes

Table 1 summarizes the probability distributions used to fit the processing times for various inbound activities. Table 2 presents the best fitted probability distributions for the time delays for truck arrivals with respect to the scheduled time slots.

Table 1: Inbound Activity Distributions

Inbound Activities	Probability Distributions (in minutes)
Lumping	3 + WEIB(27.8,0.743)
Receiving	0.99+ WEIB(15.6, 0.681)
Put Away	3 + WEIB(29.4, 0.827)
Guard Shack	1 + LOGN(5.18, 6.92)

Table 2: Delay Distributions for Truck Arrivals

Delay Distributions (in minutes)		
Time Slot	**Dry Docks**	**Cold Docks**
3 AM	EXPO(19.1) + 4.5	5 + WEIB(9.86, 0.298)
4 AM	WEIB(26.9, 0.489) - 0.001	EXPO(76.9) - 0.001
5 AM	5 + ERLA(44.6, 1)	EXPO(76.8) - 0.001
6 AM	WEIB(60.5, 0.725) - 0.001	EXPO(71.4) - 0.001
7 AM	EXPO(52) - 0.001	5 + 220 * BETA(0.713, 1.08)
8 AM	135 * BETA(1.05, 1.38) - 0.001	195 * BETA(0, 0) - 0.001
9 AM	EXPO(50.6) - 0.001	UNIF(5, 145)
10 AM	4.5 + GAMM(19.1, .899)	BETA(0.596,0.557) - 0.5

3.4 Model Design

An ARENA simulation consists of several modules, which when brought together can create a replica of the real time system. The conceptual model is presented in Figure 3.

3.5 Verification and Validation

The model's logic was verified by observing the animation and reviewing it with the experts at the facility. Model validation is defined as "substantiation that a computerized model, within its domain of applicability, possesses a satisfactory range of accuracy consistent with the intended application of the model" (Schlesinger et al. 1979). Statistical tests (2 sample t tests) were carried out to check the validity of the model's performance parameters. Utilization and queue time were validated against system performance (Tables 3-4). Distance traveled for put-away was also validated (Table 5), as minimization of this parameter was the goal of the study.

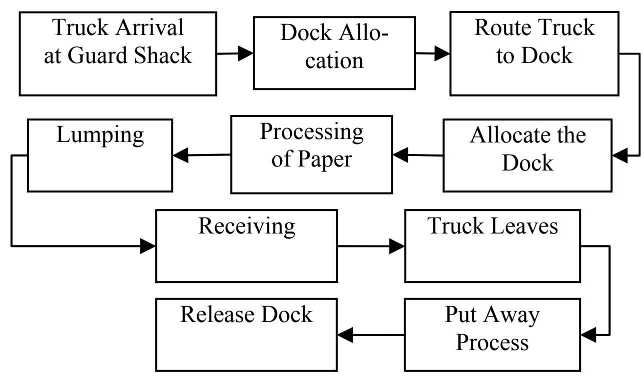

Figure 3: Simulation model logic

Table 3: Utilization of Docks

Docks	System	Simulation	% Difference	P-Value
Cold Docks	34.96%	34.92%	-0.18	0.185
Dry Docks	25.92%	21.34%	-17.67	0.309

Table 4: Wait Time for Docks (Average Queue Length)

Process	System (Hours)	Simulation (Hours)	% Difference	P-Value
Lumping	0.106	0.138	29.32	0.706
Receiving	0.338	0.397	17.47	0.602
Put-Away	0.126	0.224	78.24	0.167

Table 5: Validation of Put-away Distance Traveled

Docks	System (Feet)	Simulation (Feet)	% Difference	P-Value
Cold Docks	2911	3071	36.83%	0.693
Dry Docks	3782	3348	28.64%	0.831

4 IMPROVEMENT SOLUTIONS

4.1 Dock Allocation Based on Aisle

As mentioned earlier, three alternative solutions were proposed, each with the goal of reducing the travel distance for the put-away personal. The first solution was based on the type of goods a truck was carrying. In the scenario, where a truck was carrying a majority of goods which were to be placed in the VNA's (Very Narrow Aisle), it was recommended that those trucks be allocated docks closer to those VNA aisles. The converse was also true (if the truck was carrying goods mainly consisting of broad aisle based goods). Hence, this solution pointed towards blocking off certain docks for trucks carrying VNA based products and the remaining aisles for the broad aisle based products. Analysis of the data pointed out that only 3% of the trucks would fall under this category. The small volume of trucks was not conducive to the central aim of the research endeavor. Therefore, this alternative was not explored further.

4.2 Dock Allocation Based on Distance Traveled

This alternative scenario exploited the fact that the system database already knew the products coming in the particular truck along with the volume of the products. The exact locations (aisles) where these products were to be stocked were also present in the system database. By combining both these sets of information, it was possible to come up with a good approximation of the distance the put-away personnel had to travel when the truck was allocated to a particular dock.

The simulation model exploited this information to the maximum extent. In this scenario, the best suitable dock was allocated to the incoming truck based on the put-away distance calculated. If the incoming truck was not able to obtain the best suitable dock, the next best dock was allocated to it, and so on. The results of this scenario are presented in Table 6.

Table 6: Results for Alternative Scenario II

Dock	Baseline	Scenario II	% Difference
Dry Docks	3071	1940	36.83
Cold Docks	3348	2389	28.64

4.3 Dock Allocation Based on Schedule

In this alternative, scheduling of docks based on least put-away distance was attempted. The idea was aimed at global 'optimization' of dock allocation, while the previous alternative could be regarded as a local 'optimization' (or greedy) algorithm. Based on the arrival schedule for each time slot, the docks would be allocated. Therefore, theoretically, for every time slot, each truck would be allocated the best possible slot in advance (unlike first come first serve system in the earlier scenario). From a practical perspective there were two roadblocks which may hinder the smooth functioning of this algorithm:

- Delays in truck arrival
- Docks not being available on time (excessive delay in the unloading and receiving process)

The results for this scenario are presented in Table 7. Even with the prospective bottlenecks, this scenario is shown to provide better solutions than the existing method of dock allocation.

Table 7: Results for Alternative Scenario III

Dock	Baseline	Scenario III	% Difference
Dry Docks	3071	2081	32.23
Cold Docks	3348	2569	23.27

4.4 Result

Table 8 presents the comparison of the two alternative solutions proposed. It was seen that both the proposed methods perform better than the model that is currently being used. However, it was noted that scenario III, which was built with the aim of attaining a global optimal solution, did not perform as expected (compared to scenario II - greedy approach).

Table 8: Comparison of Solutions

Dock	Baseline	Alternative II	Alternative III
Dry Docks	3071	1940	2081
Cold Docks	3348	2389	2569

Some of the reasons for the results that were observed were due to the facts mentioned earlier (delays, variance in unloading time, etc). Despite these issues, scenario III is still a very useful option from a planning perspective, if the delays in truck arrivals and other process variances can be controlled and minimized. It provides the management with a systematic approach to allocate trucks to the docks. Scenario II was mainly introduced with a practical implementation in mind. In the current real life setting, delays in the arrival of trucks are inevitable. Similarly, the variance seen in unloading trucks during the receiving process can not be controlled in an acceptable range, thus causing some of the docks not available on time and delays propagating throughout the rest of the day.

4.5 Practical Implementation

Once the proposed solutions were validated, it was decided to demonstrate the capability of the model using a real time implementation. For this purpose, a computer program was developed in C++. The program used real time inputs regarding the goods present in the trucks. It then performed calculations to determine the best available dock for that truck. In a subsequent version of the program, the user was provided with the distance values for a truck associated with all currently available docks. The user was then allowed to choose the dock that he/she felt was best for the truck under consideration.

5 CONCLUSIONS

The dock allocation process was shown to have an impact on the travel time required for putting away goods in the warehouse inbound process. When viewed from a systems perspective, the impact was reflected on the overall turn-around time of the dock. Thus, a faster put-away process would reduce the turn around time of the dock. From the customer's perspective, the wait time for their trucks (wait for dock allocation) would be reduced. Similarly, goods kept on the warehouse floor waiting put-away were considered as a waste from a 'lean' point of view. Using an approach which combined the application of 'lean' principles and computer simulation, recommendations were proposed with the goal of reducing the put-away distance. A decrease of up to 30% in the total travel distance for put-away can be achieved by utilizing the information already available in the system and 'optimally' allocating the docks to the incoming trucks. Practical application was demonstrated by developing a computer program in C++.

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