IDENTIFYING THE OPERATIONAL PROCESS OF A RO-RO TERMINAL USING SYSTEM DYNAMICS MODELLING

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ABSTRACT -The growth of Roll on Roll off (Ro-Ro) shipping operations have become significant in global maritime operations with the continued growth of the global automobile distribution. To optimize Ro-Ro terminal operations, it is required to identify the major processes that takes place within a Ro-Ro terminal. This study identifies the major operational flows within the Ro-Ro terminal using Systems Dynamics (SD) modelling. Five causal loops are identified and discussed in the study which are tested under the actual operations of a well-reputed Ro-Ro terminal. First loop refers to basic assignment between berths and storage yards, while loops 2 and 3 describe variables in discharging and loading vehicles consecutively. Loop 4 describes the procedure of allocating drivers to loading and discharging processes while loop 5 focuses on its impact towards loading and discharging times of vehicles. This study demonstrates the major actors that impact the rate of transferring an incoming set of vehicles to a yard location in the Ro-Ro terminal. Location and layout of the yard and berthing areas, operational restrictions within the Ro-Ro terminal, terminal specific operational procedures and impact of the human factors have been identified.

Keywords: Ro-Ro operation, System Dynamics, Operations management, Maritime terminal operations

1. INTRODUCTION

Sea freight volumes through deep-sea vessels is approximately 70% by value and 80% by volume [1]. Global vehicle manufacturing is expected to reach 111.2 million units by 2022[2]. Since global vehicle distribution grew by 4% annually for the last decade, Ro-Ro terminal operations have also grown. However, academic studies in the area is scarce compared to container operations [3], [4]. In Ro-Ro transportation, additional handling equipment is not required. Automobile units are moved by drivers. However, being high-valued cargo, terminal operators minimize the relocations of automobiles within the terminal. According to Iannone et al. [4] accepted levels of damages to vehicles in transshipment yards lies between 0.5%- 1%. This results in higher transport costs in moving automobiles [2]. In addition, transportation and waiting of vehicles results in emission costs which result towards environmental degradation [5]. This study focuses on addressing the question of the major actors of Ro-Ro operation and determining major processes that impact overall terminal efficiency.

2. MATERIALS AND METHODS

System Dynamics modelling(SD) is capable of capturing multiple interdependent ,dynamic variables in a system [5],[6],[7]. Hence SD is considered as a suitable technique to achieve the objectives of the study. Modelling of any system using the SD approach can be presented under 5 major steps according to Bayer [7]: 1. Articulating the problem to be addressed, 2. Formulating a dynamic hypothesis concerning the causes of the problem, 3. Formulating a simulation model to test the dynamic hypothesis, 4. Testing the model until it is suitable for the purpose, and 5. Designing and evaluating policies for improvement. Required quantitative and qualitative data points were identified through rom the available literature and expert interviews from Ro-Ro terminal operation [4],[5],[10],[11].Data collection was done in a major Ro-Ro terminal in the Asian region for a period of one week. Altogether 06 Ro-Ro vessels called the terminal during this week There are 3 main berths and 13 storage blocks assigned for Ro-Ro operation.

3. RESULTS AND DISCUSSION

The causal loop diagram represents the conceptual flow of vehcile units within a Ro-Ro terminal (Figure 1). The relationship among 49 varibales are depicted. Five main casual loops are identified.

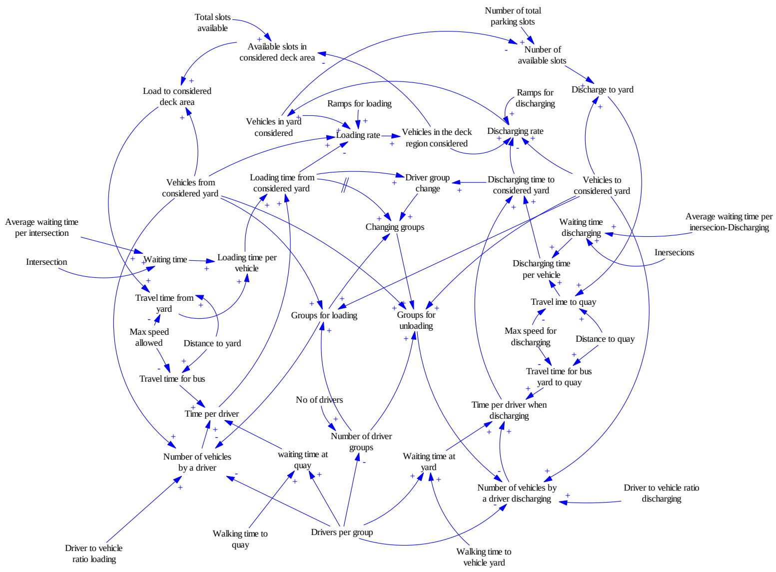

Figure 12. Causal loop diagram operation at a Ro-Ro terminal

First loop explains the basic loading and unloading process that takes place in a Ro-Ro terminal. When the Ro-Ro vessel arrives at the berthing area, the unloading and unloading processes begin. The vehicles in considered region of the vessel are assigned to the yard considered. Second loop is based on the discharging process from the considered region in the deck, to the yard. Availability of empty slots, location of the storage slots and speed allowed for discharging are affecting the discharging process. Third loop includes variables regarding the loading process. Following a similar procedure to the discharging operation, loading is also performed directly from the yard to quay as a common practice. The next loop demonstrates the role of the deployed drivers. The available drivers for an 8-hour shift are taken as constant, since human capital is limited. These drivers are assigned to loading or discharging classified as groups. In this causal loop, the driver groups from loading function are directed to discharging once the loading process is completed. This ensures the optimal use of drivers which also optimizes the discharging time. The final loop encompasses method of driver allocation. For loading process, a driver of a particular group moves a vehicle from the yard to the vessel and positions the vehicle. Then he reaches an assigned spot in the quay area until the entire group of drivers have completed the process. Once the entire group has assembled, they are transported back to the yard using a shuttle. This is similar for the discharging operation. Where the shuttle waits in yard area for drivers. The above relationships have been defined within the endogenous focus of the study. The existing processes within terminal operations are described. Therefore, this study does not focus on creating alternate causal loops to existing ones. Stock and flow diagram was created based on the above causal loops. The model was formalized by describing the relationship among the variables using equations. The equations of each relationship is not provided due to limitations of the paper. The model was used to simulate the handling efficiency of the selected terminal. The results of the simulation according to different scenarios are given below.

1. Identifying the impact of changing driver availability for each shift

The drivers allocated are working as groups. When the overall number of drivers available for each shift increase the number of groups of drivers increase. Here the number of drivers for each group is kept constant at 10 per group.

Table 1. Impact of driver availability

Drivers per shift-50		Drivers per shift-60		20% increase	
Loading rate (Vehicles/hour)	Discharging rate (Vehicles/hour)	Loading rate (Vehicles/hour)	Discharging rate (Vehicles/hour)	% Change in loading rate	% Change in discharging rate
45.38	1758.49	50.89	2098	12.1%	19.3%

2. Identifying the impact of increased travel distance per each vehicle unit

The model considers the impact that travelling distance has towards handling. When the travelling distance increase, it is expected to increase the handling time for each vessel because the vehicles are transferred to yards directly in the discharging process. This is practiced in loading operation as well.

Table 2. Impact of vehicle travelling distance

Average distance travelled in the terminal 0.5Km		Average distance travelled in the terminal- 1 Km			
Loading rate (Vehicles/hour)	Discharging rate (Vehicles/hour)	Loading rate (Vehicles/hour)	Discharging rate (Vehicles/hour)	% Change in loading rate	% Change in discharging rate
46.7	1347.42	36.3	950.6	-22.2%	-29.4%

Based on the above causal loops handling efficiency of the terminal depends on 1. handling volume;2. Crew availability; 3. Terminal layout; 4. Vehicle routes used; 5. Average speed maintained; 6. Terminal practices. In this study giving priority for discharging the terminal practices and retaining vehicles temporarily in the wharf for loading are evaluated under terminal practices.

4. CONCLUSION

This study focused on identifying the major processes that are affecting efficient operations in a Ro-Ro terminal. System Dynamics was used to represent the operation. A causal loop diagram was developed, and the major feedback loops relating to terminal efficiency were identified. The identified feedback loops of the operation were validated through a data collection to create stock and flow diagrams of the operation. Further improvements can be made by considering the landside operation which includes assigning the export vehicle assignments.

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ISSN: 2513-2504

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