PERFORMANCE ANALYSIS OF TRANSSHIPMENT PROCESSES IN CROSS DOCK TERMINALS

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dedication

Abstract: A cross dock terminal is a distribution center that receives, sorts and dispatches goods, usually paletised, without storing, or with minimum storage time, in accordance with the needs of various participants in a supply chain. The organization of internal transport during transshipment from inbound to outbound vehicles is a very complex problem. This paper gives a simulation model of transport-transshipment process that enables comparison of different strategies of transshipment and dispatching rules.

Keywords: Cross Dock, Dispatching rules, Simulation Model, Performance Indicators, TOPSIS.

1. INTRODUCTION

A cross dock terminal is a distribution center that receives goods from suppliers and carries out sorting and shipment of these goods. The cross dock system reduces the need for storage of goods and level of stocks. The organization of internal transport during transshipment from inbound to outbound vehicles is a very complex problem. The aim of this paper is to develop a simulation model which enables comparison of different operative work strategies by chosen performance indicators.

The paper comprises of seven parts. The second part describes a cross dock terminal, the basic functions, transshipment strategies and problems to be solved. The operative strategy description is given in the third part. The fourth part describes the simulation model developed in this paper and the fifth part describes the method of valuing simulation models by applying TOPSIS method. The sixth part gives the example on which the developed model was tested and gives the output results. A conclusion is given in the seventh part.

2. CROSS DOCKING

A cross dock terminal is a distribution center in a supply chain that receives, sorts and dispatches goods without storage or with minimum storage time (up to 24 hours), in conformity with the requirements of different participants. The basic goal is to directly transfer goods from inbound vehicles to outbound vehicles, whereby the two most expensive operations in classic distribution centers are eliminated: storing and order picking (Van Belle et al., 2011).

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The functions of a cross dock terminal are: receiving of goods, sorting of goods and dispatch of goods. Reception of goods is carried out in inbound unloading docks. Vehicles with goods wait on the parking lot and are assigned to inbound docks where unloading and reception of goods is carried out. If temporary storing is necessary, the goods are placed on the cross-dock next to inbound or outbound doors or in zones between them. The goods are sorted according to users’ locations thereby prepared for dispatch. The shipment vehicles are assigned to outbound doors, the goods are loaded and vehicles effect shipment. Most of the cross dock terminals are rectangular facilities (I, L, T, X, U and E shapes) with several doors. The terminal doors may be intended only for loading or unloading, or a combination.

In contrast to traditional warehousing, the cross dock system enables the following (Van Belle et al., 2011): reduction of costs, consolidation of deliveries, shorter delivery terms, less space necessary for warehousing, less risk of damage during warehousing, better service to users, faster capital turnover, etc.

A large number of studies have been published recently that deal with the problems of cross dock systems on various levels of management: operative, tactic and strategic. The most frequently analyzed problems were (Van Belle et al., 2011; Sheikholeslam and Emamian, 2016): Location of cross-docks, Layout design, Cross-docking networks, Vehicle routing, Dock door assignment, Truck scheduling, Temporary storage, Internal traffic, etc.

3. OPERATIONAL STRATEGIES

Managing a transshipment process in a cross dock terminal may be viewed as making managing decisions on distribution of resources and objects with the objective of meeting transshipment requirements. Transshipment demand is defined by arrival times of vehicles and volume of transport between inbound and outbound dock doors. On the basis of transshipment requirement and available resources (cross-dock facility characteristics, handling devices, space, people), an adequate transshipment strategy is necessary to be applied. There are various strategies of cross dock terminal operation in literature (Van Belle et al., 2011):

- One-touch transshipment strategy means the goods are unloaded from inbound vehicles and directly loaded on outbound vehicles.
- Two-touch transshipment strategy or single-stage storage means the goods are unloaded from vehicle, transported to temporary warehouse, and later loaded on vehicles.
- Multi-touch transshipment strategy or two-stage storage means the goods are temporarily stored at inbound door. There it is sorted, transported to warehouse zone at outbound door, stored and then loaded on vehicles.

There are operation strategies where loading or unloading is possible in order to serve vehicle with priority. Some types of goods always require one-touch transshipment without additional storage and detention. Furthermore, there are strategies when goods are prepared for buyers at the suppliers, which significantly speeds up operation of cross dock terminals. In practice, one cross dock terminal may apply different strategies of operation in conformity with additional requirements of goods, vehicles and users. The management decisions on the choice of operative transshipment strategies directly affect productivity and efficiency of cross dock terminal operation.

Managing transshipment vehicle means defining an assignments of the handling equipment into a set of requests for transshipment by applying corresponding dispatching rules. There are numerous dispatching rules in literature which can be applied in cross dock terminals (Le-Anh and De Koster, 2004). Dispatching rules can be based on single-attributes or multi-attribute rules on the basis which managing decisions are made (travel distance, travel time, waiting time, queue length etc.).
This paper observes a cross dock terminal where centralized dispatching is applied on the basis of current state by applying two dispatching rules:

- Shortest travel distance first (STDF) and
- Modified multi-attribute dispatching rule (Multi-mod)

The STDF rule minimizes empty vehicle travel time. When a handling equipment completes a task, it is assigned the next one, which is closest to its current location. If there is no task, the equipment is returned to the depot.

Multi-mod rule is based on two criteria: length of empty travel and service waiting time. The objective function is (Le-Anh and De Koster, 2004):

$$f_{vi}(D_{vi}, W_{vi}) = \alpha \times D_{vi} + \beta \times (W_{vi})^p; \alpha + \beta = 1$$

where $D_{vi}$ is length of empty travel, $W_{vi}$ is vehicle waiting time $v$ for request $i$ and $p$ is integer value.

4. SIMULATION MODEL

A simulation model of cross dock terminal operation has been developed in this paper for the purpose of analyzing various operation strategies and dispatching rules. The basic idea was to test different strategies for the same scope of transshipment tasks – internal traffic between inbound and outbound doors. In the model, the known data are the type and quantity of inbound and outbound flows, arrival time of vehicles to terminal and distribution of vehicles at inbound and outbound doors. The simulation model has been based on the following assumptions:

- All delivered goods to the terminal must also be shipped from the terminal.
- Terminal parking lot has unlimited number of parking spaces.
- The order of servicing vehicles at one door corresponds to the order of their arrival at terminal.
- The vehicle at the inbound/outbound doors is served by only one handling device at the same time.
- The size and weight of goods do not affect time of loading, unloading, transport or storage.
- Loading/unloading operations cannot be interrupted and vehicle replaced.
- All available handling equipment may be used in realization of any of tasks.

The Model includes:

- Two transshipment strategies – one-touch and two-touch cross dock,
- Two dispatching rules – STDF and Multi-mod,
- Three data sets – different arrival times of vehicles, and
- Availability of needed number of handling devices.

A set of performance indicators which enable analysis of different strategies is obtained for all stated variants. The simulation model was developed in Microsoft Visual Studio 2010, C#, Net Framework 4.0. Model classes and objects were defined in C#CrossDockLib.

5. EVALUATION OF OPERATIONAL STRATEGIES

An evaluation of transshipment strategies is a complex problem which should provide the decision makers an insight into the quality of applied strategies. The choice of the best operational decisions in this paper was made according to the following criteria:

- number of engaged handling devices ($b$),
- total distance travelled by handling devices ($s$),
- handling devices usage rate ($p$),
order of vehicles waiting for service \((r)\),  
service time of inbound and outbound vehicles \((k)\),  
usage of inbound and outbound doors \((v)\), and  
total service time in terminal \((t)\).

Multi-criteria ranking of operative strategies is done by applying TOPSIS method (Chen, 2000). This method values all alternatives based on their weighted coefficients and distance to positive-ideal and negative-ideal solutions. The best alternative is the one which has the smallest distance to positive-ideal solution and greatest distance to negative-ideal solution (Lai et al., 1994). The aim is to choose a strategy which, at the same time, maximizes use of handling equipment and minimizes all other criteria.

6. EXAMPLE

In this paper, a simulation of a cross dock terminal, l-shaped, 58m in length and 26m wide, with 8 inbound and 8 outbound doors was done (figure 1). Locations for every handling unit were previously determined, in order to provide direct loading from inbound to outbound vehicles. Temporary storage space was organized in front of outbound doors (3 rows, 17 places each). There are 16 forklifts in the terminal. Forklift travel speed, loading and unloading time of cargo are stochastic variables with the normal distribution.

![Figure 1. Schematic view cross dock terminal](image)

The simulation covered one working day. Delivery was carried out by 80 vehicles that delivered 28 units of cargo each (total 2240). Shipment was carried out by 84 vehicles. Three sets of inbound data that consist of various vehicle arrival times in the observed period for transshipment strategies were defined as it is shown in figure 2. For each set of data, two transshipment strategies were applied, two dispatching rules (parameters were \(\alpha=0.8\), and \(p=3\)) and different number of transshipment vehicles varying from 12 to 16. Table 1 shows the results of simulation for Data Set 1. The results for Data Set 2 and Data Set 3 were obtained in the same way.
Multi-criteria ranking of operative strategies was carried out by applying TOPSIS method. In this example it was assumed that all criteria have the same weighted factors. The ranking results are shown in Table 2.
Table 2. TOPSIS Ranking

<table>
<thead>
<tr>
<th>Data Set</th>
<th>The Best Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Set 1</td>
<td>One-touch cross-docking + STDF 12 transshipment vehicles</td>
</tr>
<tr>
<td>Data Set 2</td>
<td>Two-touch cross-docking + Multi-mod 16 transshipment vehicles</td>
</tr>
<tr>
<td>Data Set 3</td>
<td>Two-touch cross-docking + Multi-mod 16 transshipment vehicles</td>
</tr>
</tbody>
</table>

Data Set 1 includes with uniform arrival of vehicles to the terminal. The best strategy for this set is one-touch cross-docking, STDF rule while the process realization requires fleet of 12 handling devices. Data Set 2 and Data Set 3 include non-uniform arrivals of vehicles to terminal. In these cases, 16 handling devices are needed, while the best strategies are two-touch cross-docking and Multi-mod rule.

7. CONCLUSION

The goal of this paper was the development of a simulation model for analyzing performances and comparing operational strategies of managing transshipment processes in a cross dock terminal. The model presents an approximation of the real system, considering predefined set of the performance indicators. The TOPSIS method was used in this paper for ranking different operative strategies.

Improvement and further development of the simulation model may be in following directions:

- evaluating multiple strategies and dispatching rules,
- applying handling equipment of different characteristics,
- respecting additional vehicle requirements, freight units and users,
- limiting the number of parking spaces in terminal,
- possibility of longer storing of goods, etc.

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REFERENCES


