PERFORMANCE ANALYSIS OF TRANSSHIPMENT PROCESSES IN CROSS DOCK TERMINALS

Bratislav Lazić[a,*], Gordana Radivojević[b], Gorana Šormaz[a]

[a] University of Belgrade, Mihajlo Pupin Institute

[b] University of Belgrade, Faculty of Transport and Traffic Engineering, Serbia

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).

* Bratislav.Lazic@pupin.rs

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):

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

where D_{vi} *i*s 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, I-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.

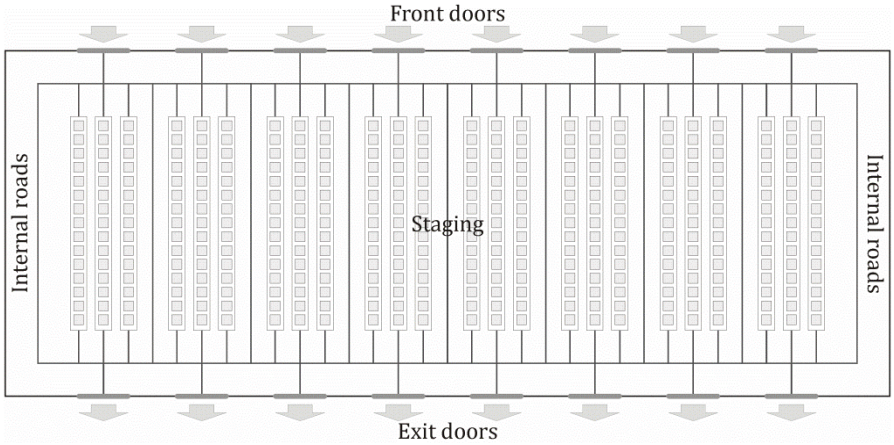

Figure 1. Schematic view cross dock terminal

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 α=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.

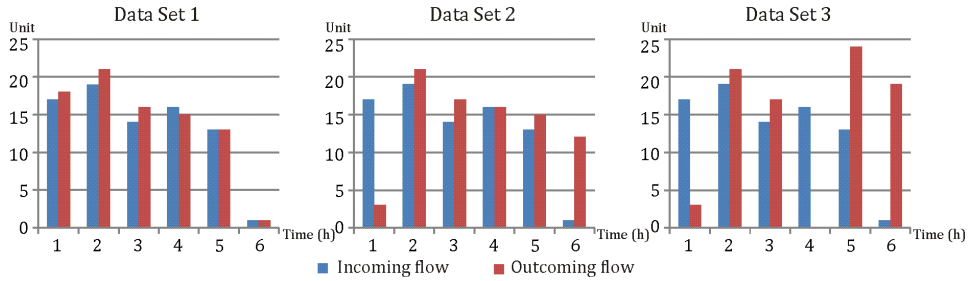

Figure 2. Distribution of vehicle's arrivals

Table 1. Performance Indicators for Data Set 1

OS	Tr (s)	Forklifts			Doors		Vehicles			Cargo (s)
		b	*s* (m)	*p* (%)	In (s)	Out (s)	In (s)	Out (s)	Max *r*	
Pn	19300	12	195038	94.51	117955	139149	135103	153624	7	1997191
Pm	19309	12	194950	94.43	115138	137763	122696	146903	6	2065735
Pn	19315	13	202351	91.26	106863	130158	109973	132206	5	1805085
Pm	19314	13	200090	90.27	107049	129433	109331	131389	5	1837449
Pn	19309	14	206897	86.97	103859	124608	105446	125061	5	1724840
Pm	19331	14	205989	86.9	103920	124947	104945	125224	5	1753870
Pn	19319	15	210730	83.51	101939	121645	102745	121753	5	1696491
Pm	19309	15	210188	83.54	101926	122162	102533	122387	5	1714002
Pn	19321	16	214977	80.8	100883	119851	101531	119962	5	1677676
Pm	19310	16	214096	80.57	100922	120095	101156	120212	5	1691662
Jn	21369	12	185445	99.44	128612	158690	197858	295734	20	3991610
Jm	21848	12	187302	98.63	134245	163616	211758	316355	21	4150858
Jn	20077	13	184490	98.18	110841	150976	150402	239615	15	3312734
Jm	20113	13	185485	98.76	112911	151441	145667	235662	14	3335587
Jn	19300	14	187922	97.14	89839	138387	97950	170743	9	2710569
Jm	19299	14	189031	97.81	92526	141960	101431	175812	8	2695297
Jn	19292	15	201865	95.81	67711	122597	67997	126656	5	1998363
Jm	19291	15	204059	95.95	71283	126444	72035	130751	5	1961214
Jn	19288	16	215058	94.57	61798	116515	61763	118042	5	1807962
Jm	19305	16	217874	94.43	63005	120871	63371	123359	5	1756443
Pn – one-touch cross-docking + STDF						Jn – two-touch cross-docking + STDF				
Pm – one-touch cross-docking + Multi-mod						Jm – two-touch cross-docking + Multi-mod				

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

Data	The Best Strategy
Data Set 1	One-touch cross-docking + STDF 12 transshipment vehicles
Data Set 2	Two-touch cross-docking + Multi-mod 16 transshipment vehicles
Data Set 3	Two-touch cross-docking + Multi-mod 16 transshipment vehicles

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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