

January 01, 2003

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Recommended Citation

Gupta, Surendra M.; Jarupan, Lerpong; and Kamarthi, Sagar V., "Simulation based approach for return packaging systems" (2003). . Paper 103. <http://hdl.handle.net/2047/d10013830>



Laboratory for Responsible Manufacturing

Bibliographic Information

Jarupan, L., Gupta S. M. and Kamarthi, S. V., "Simulation Based Approach For Return Packaging Systems", *Proceedings of the 2003 Northeast Decision Sciences Institute Conference*, Providence, Rhode Island, pp. 175-177, March 27-29, 2003.

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SIMULATION BASED APPROACH FOR RETURN PACKAGING SYSTEMS

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ABSTRACT

In this paper, we investigate the effect of different dispatching rules and the vehicle assignment schemes applied to a returnable packaging system in order to provide superior customer satisfaction. The investigation is conducted by a simulation approach, using a commercial software ARENA[®]. The simulation results show that different combinations of dispatching rules and the vehicle assignment schemes affect the customer satisfaction levels differently.

OVERVIEW

Concerns over packaging and containers contributing towards the solid waste stream have been heightened in the past decades. According to the Environmental Protection Agency, the increasing fraction of packaging and containers in the total solid waste is raising disposal costs and depleting landfills. Therefore, the practice of recycling and reusing packaging and containers have been gaining support as it helps to reduce the natural resource usage and toxicity of the discarded materials in the landfills.

Reuse of packaging and containers is the most favorable and simplest practice. In industries, packagings such as pallets are used to facilitate handling and transfer of large volumes of goods from one place to another. Such packages are expected to return to where they originated from and thus can be addressed as returnable packages. However, it has been acknowledged that some returnable packages can require a high initial investment. But such investment can be offset by multi-utilization, resulting in cost savings together with environmental benefits [7].

Although many papers report the use of returnable packages, there are only a few studies that address the implementation of returnable packaging systems. Several studies have appeared involving the concept of reverse (closed-looped) logistics [3]. Crainic *et al.* [2] proposed dynamic and stochastic formulations for the allocation of empty containers in a land distribution and transportation system. Kroon and Vrijens [8] considered the design of facility locations in a reusable transport packaging system. Del Castillo and Cochran [4] developed mathematical models for the production, distribution and collection planning of reusable containers, and applied to a soft

drink manufacturer in Mexico. Duhaime *et al.* [6] presented a model used by Canada Post to determine the number of empty containers distributed, returned and stored each month.

Dethloff [5] constructed a heuristic procedure of vehicle routing problem (VRP) with simultaneous delivery and pick-up services into the return distribution mechanism. Cheong *et al.* [1] approached the column generation methodology for VRP models of a soft drink distribution company in Singapore, solving for the assignment of a fixed fleet of heterogeneous vehicles to various routes.

The existing studies concentrate on the determination of production and/or logistic performance (e.g. transportation costs). However, none of them considers customer satisfaction. In this study, we investigate the effect of different dispatching rules and the vehicle assignment schemes on customer satisfaction using a simulation approach.

DESCRIPTION OF A RETURNABLE PACKAGING MODEL

A returnable packaging model involves four parties namely, a *container agency (CA)* who owns a set of containers being stored at a *container depot (D)*, a group of *product dispatchers (PD)*, and a group of *product recipients (PR)*. Figure 1 illustrates an example of a simple returnable packaging model that involves one *PD*, one *PR*, and two different *D*.

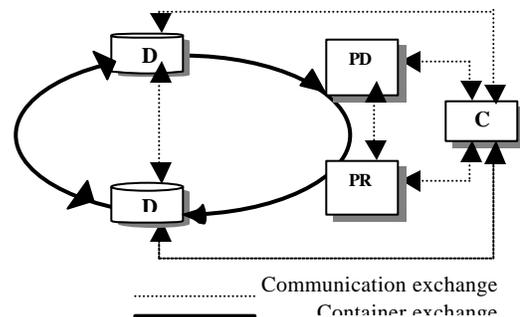


Figure 1: A returnable packaging model

The *PD* notifies the *CA* of a desired number of containers. The containers go through inspection and cleaning at the nearest *D* (to the *PD*) before delivery with

the help of a vehicle. When the *PD* receives the empty containers, the products are packed and transferred to the *PR*. The products are unpacked at the *PR*, and the empty containers are returned to the nearest *D* (to the *PR*), which is not necessarily the same *D* from where the containers originate. When the empty containers arrive at *D*, they are again put through maintenance process and stored. However, an appropriate stock level of empty containers is maintained at both *D*. If, at any *D*, the available inventory level falls below the designated level, it will be replenished from another *D* that has excess containers.

The notations used in the model are as follows:

- T*: length of observation time; $T = \{1, 2, \dots, t\}$
PD: set of product dispatchers; $PD = \{1, 2, \dots, s\}$
PR: set of product recipients; $PR = \{1, 2, \dots, r\}$
D: set of container depots; $D = \{1, 2, \dots, d\}$
V: set of vehicles; $V = \{1, 2, \dots, v\}$
NC: number of containers in an order (order size)
VC_v: vehicle capacity; $v \hat{I} V$ and $VC_1 = VC_2 \dots = VC_v$
K'_d: stock level of depot *d* at period *t*; $d \in D, t \in T$
c'_{sd}: random request by product dispatcher to container depot at period *t*; $s \hat{I} PD, d \in D, t \in T$
j'_{rd}: random returned containers from product recipient to container depot at period *t*; $r \hat{I} PR, d \in D, t \in T$
w'_{dd}: stock of empty containers available at depot over period *t*; $d \in D, t \in T$
w'_{dk}: balancing of empty containers transferred from depot *d* to depot *k* at period *t*; $d, k \in D, t \in T$
t_{hm}: transit times of various movements, where the origin η and the destination μ may represent a depot, a product dispatcher, or a product recipient. Thus this delay includes the time required for loading at the origin, waiting time for vehicle to pickup, journey time between two locations, and unloading time at the destination.
J'_{ds}: empty containers transferred from depot at period *t*, and arrives at product dispatcher at period $t' = t + t_{ds}, d \in D, s \in PD, t \in T$
J'_{sr}: containerized products departs from dispatcher at period *t* and arrives at recipient at period $t' = t + t_{sr}, s \in PD, r \in PR, t \in T$
J'_{rd}: empty containers returned from recipient at period *t*, and arrives at depot at period $t' = t + t_{rd}, r \in PR, d \in D, t \in T$

The constraints included in this returnable packaging model can be expressed as:

$$\sum_{d \in D^t} \mathbf{J}'_{ds} = \mathbf{c}'_{sd}; \forall s \in S^t, \text{ for all } v \quad (1)$$

$$\sum_{r \in R} \mathbf{J}'_{sr} = \mathbf{c}'_{sd}; \forall s \in S^t, \text{ for all } v \quad (2)$$

$$\sum_{d \in D} \mathbf{J}'_{rd} = \mathbf{j}'_{rd}; \forall r \in R^t, \text{ for all } v \quad (3)$$

$$\sum_{d \in D^t} \mathbf{J}'_{ds} \leq \mathbf{K}'_d; \forall d \in D^t, \text{ for all } v \quad (4)$$

$$\mathbf{w}'_d^{(t-1)} - \mathbf{c}'_{sd} + \mathbf{j}'_{rd} + \mathbf{w}'_{dk} \leq \mathbf{K}'_d; \forall d, k \in D \quad (5)$$

$$\sum \mathbf{w}'_k = \sum \mathbf{w}'_d; \forall d, k \in D \quad (6)$$

$$\sum_{d \in D} \mathbf{J}'_{dv} = \sum_{s \in S} \mathbf{J}'_{sv}; v \in V \quad (7)$$

$$\sum_{r \in R} \mathbf{J}'_{rv} = \sum_{d \in D} \mathbf{J}'_{dv}; v \in V \quad (8)$$

$$M \sum_{d \in D, s \in S} \mathbf{J}'_{ds} \leq VC_v^t; \forall v \in V, M \text{ is large number} \quad (9)$$

$$M \sum_{r \in R, d \in D} \mathbf{J}'_{rd} \leq VC_v^t; \forall v \in V, M \text{ is large number} \quad (10)$$

Constraints (1)-(3) ensure that the disappearance of containers during transfer never occurs. Constraint (4) ensures that there are enough empty containers available at *D* for each request by a *PD*. Constraint (5) ensures that the stock level is maintained at each *D*. Constraint (6) indicates the replenishment of empty containers when the stock level at any *D* is not satisfied. Constraint (7) and (8) ensure that the containers are transferred from one place to another by the same vehicle, while constraint (9) and (10) ensure the *VC* is not violated by *NC*.

EXPERIMENTAL FRAMEWORK & ASSUMPTION

In this study, we limit ourselves to a single type and size of container. Different locations of *PD*, *PR* and *D* are independent to each other and uniformly distributed over the square region, thus distances among them are measured using the Euclidean metric.

Order size (*NC*) of empty containers from each *PD* is uniformly distributed. Orders arrive at *CA* with an arrival rate λ , and the interarrival time between orders is exponentially distributed. We assume that a modern communication technology is utilized between *CA* and *D* so that the communication time is negligible. Activity times for sorting, cleaning, inspecting, packing/unpacking, and loading/unloading containers behave according to a triangular distribution. None of containers are lost in the process of the study. We further assume that *CA* is responsible for all transfers (i.e. from *D* to *PD*, *PD* to *PR*, and *PR* to *D*) of containers by a fleet of homogeneous vehicles with a fixed capacity (*VC*). Vehicles travel with a constant velocity, and *VC* is assumed to be large enough to handle each order size, i.e. $VC \gg NC$.

Vehicle assignment schemes

All vehicles originate from the same *D*. We assume that each vehicle will service, at a time, one request of

transferring containers from one point to another. After the vehicle completes the request, one of the two vehicle assignment schemes is applied: (1) *RETURN*—the vehicle first returns and waits at the original *D* for another request from any other nearest location (of *PD*, *PR*, or *D*); (2) *PROCEED*—the vehicle proceeds to the nearest location without returning to the original *D*.

Dispatching rules

We consider four dispatching rules to determine the sequence of order fulfillment: (1) the *First-Come-First-Out (FCFO)* rule which organizes awaiting containers in order of arrival; (2) the *Earliest-Due-Date (EDD)* rule which organizes awaiting containers by their assigned due date of fulfillment; (3) the *Large-Size-First-Out (LSFO)* rule and (4) the *Small-Size-First-Out (SSFO)* rule which organize awaiting containers by the order size.

Performance measures

We analyze the returnable packaging model by monitoring the average waiting times which comprises three components: (1) WT_D , the average waiting time that containers spend at *D* to be transferred to *PD*; (2) WT_{PD} , the average waiting time that containers spend at *PD* to be delivered to *PR*; (3) WT_{PR} , the average waiting time that containers spend at *PR* to be returned to *D*. In addition, other measures including the average cycle time (\bar{F}) from the time an order is placed and containers depart from a *D* until returning back to the same or different *D*, and the percentage and the average time of orders that are fulfilled early (*EF*) are also considered.

SIMULATION RESULTS

Relevant performance measures obtained from the simulation run (with 1200 replications) are shown in Table 1. From the product dispatcher’s perspective, we thought that it was suitable to consider WT_D , WT_{PD} , and *EF*(%). In that case, five solutions in the Pareto efficient set are obtained. The *RETURN_LSFO* combination provides the lowest WT_D , while the *PROCEED_SSFO* combination gives the lowest WT_{PD} . The *RETURN_EDD* combination gives the highest *EF*(%). Two other combinations, *RETURN_FCFO*, and *RETURN_SSFO* provide alternative efficient solutions.

Effects of dispatching rules and vehicle assignment schemes on the three components of average waiting times (WT_D , WT_{PD} , and WT_{PR}) result differently. First, WT_D is minimized by the *LSFO* rule in the *RETURN* option but is minimized by the *SSFO* rule in the *PROCEED* scheme. Second, the values of WT_{PD} and WT_{PR} are reduced dramatically in the *PROCEED* scheme compared to the

RETURN scheme. We also note that the *SSFO* rule minimizes WT_{PD} in both vehicle assignment schemes. Third, *RETURN* scheme tends to provide better results in terms of the percentage of and the average time of early-fulfilled orders (higher *EF*(%) and lower *EF*(hour)). Finally, the *EDD* dispatching rule gives interesting results for *EF*(hour) and *EF*(%).

Table 1: Summary of results

RETURN		FCFO	EDD	LSFO	SSFO
	\bar{F} (hour)	293.28	293.33	295.00	291.67
	WT_D (hour)	64.74	65.42	63.24	66.62
	WT_{PD} (hour)	106.33	102.72	108.17	98.89
	WT_{PR} (hour)	98.28	41.17	97.33	99.33
	<i>EF</i> (hour)	13.95	5.08	13.78	14.17
	<i>EF</i> (%)	24.31	33.15	24.1	24.46

PROCEED		FCFO	EDD	LSFO	SSFO
	\bar{F} (hour)	104.33	103.83	110.17	97.17
	WT_D (hour)	82.00	82.25	85.67	78.75
	WT_{PD} (hour)	4.03	2.68	2.77	2.32
	WT_{PR} (hour)	2.41	2.37	2.34	2.14
	<i>EF</i> (hour)	15.38	14.85	16.27	14.23
<i>EF</i> (%)	12.43	3.13	11.56	13.6	

In conclusion, different combinations of dispatching rules and vehicle assignment schemes affect customer satisfaction levels differently. This enables a decision-maker to choose the best trade-off solution among several alternatives.

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