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SIMULATION AND ANALYSIS OF NON-AUTOMATED DISTRIBUTION WAREHOUSES

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ABSTRACT

The distribution warehouse is located between manufacturers and customers. Storage facilities are designed around four primary functions: holding, consolidation, break-bulk, and mixing. In addition, materials handling within a storage-handling system reduces to three primary activities: loading and unloading, movement to and from storage, and order filling. Generally, it is more difficult to build a simulation model for a non-automated warehouse than for AS/RS, because materials handling is much more complicated. In this study, a procedure to build simulation models for move-store activities of complicated and non-automated distribution warehouses is proposed. The simulation model here is designed to execute together with the program for generating parameters of materials handling. Then, simulation analysis is performed, using a simulation model built by the proposed procedure.

1 INTRODUCTION

Warehouses serve as processing or materials handling stations in the logistics system, and hold the inventories that perform the buffering or decoupling functions. The distribution warehouse is located between manufacturers and customers. The distribution warehouse has most space allocated to temporary storage and more attention is given to speed and ease of product flow (Ballou 1992).

By the way, the modern warehouse must play the role not only of storage for raw materials, parts, and end products, but also of a dynamic inventory control for a smooth logistic system, such as procurement, production, inventory, sales, and distribution, by establishing the information system to update kinds and quantities of stored items. Recently, the automated storage and retrieval system (AS/RS) has been utilized together with conveyors and/or AGVs in the above-mentioned fields.

With regard to modeling AS/RS, the degree of preciseness of modeling depends on the purpose of analysis. There are some reports on applications of simulation to model an AS/RS (Harmonosky and Sadowski 1984, Medeiros, Enscore, and Smith 1986, Muller 1989, Gunal, Grajo, and Blanck 1993). In the previous studies, the AS/RS is modeled precisely and realistically to behave as the real system does (Takakuwa 1994, Takakuwa 1995, Takakuwa 1996).

The distribution warehouse is different from a holding warehouse, and it is not usually automated inside the warehouse. Hence, it is much more difficult to build simulation models for the distribution warehouse. In this study, both the program for generating parameters of materials handling and the corresponding simulation program are developed for a real distribution warehouse. In addition, simulation analysis is performed, based on a real performance.

2 A DISTRIBUTION WAREHOUSE

A general view of the distribution warehouse is shown in Figure 1. There are two major areas inside the distribution warehouse. Storage and retrievals of the racks at the left-hand side inside the distribution warehouse can be performed to/from the racks on either side of an aisle up to level five. At the right-hand side of the warehouse, pallets are put directly on the floor by one of forklift trucks.

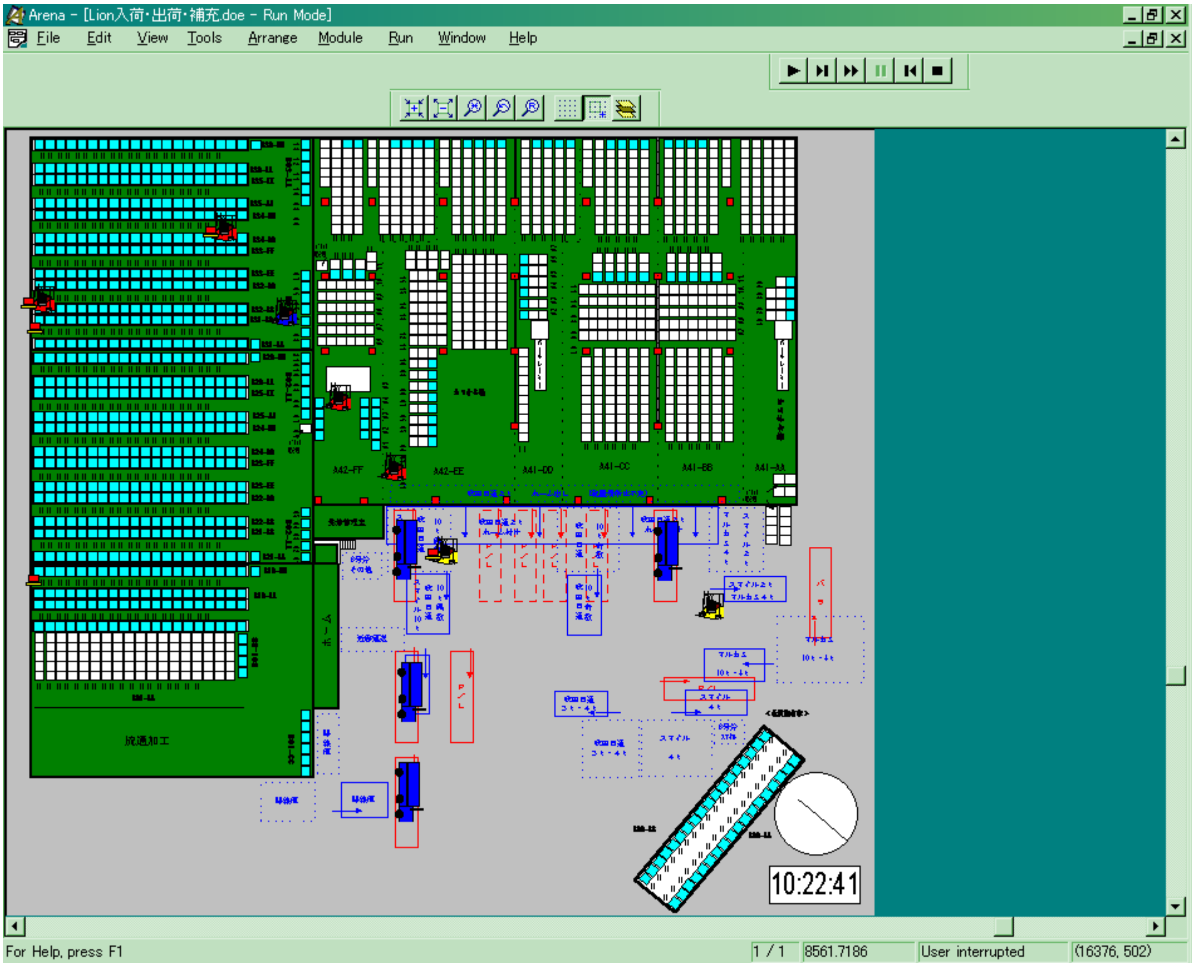

Figure 1: Layout of a Distribution Warehouse

2.1 Overall Characteristics

The overall characteristics of the distribution center examined in this study are summarized as follows:

(1) Plottage: 12,418 square meter
(2) Floor space: 7,656 square meter
(3) Actual floor space for holding: 6,666 square meter
(4) Number of incoming cases per month: approximately 345,000 cases
(5) Number of outgoing cases per month: approximately 342,000 cases
(6) Number of forklift trucks
  1) Indoor (not reach-lift type): 13 units
  2) Indoor (reach-lift type): 2 units
  3) Outdoor (not reach-lift type): 3units

The reach-lift type of forklift trucks located indoors can store and retrieve pallets at all levels (tiers) in the rack.

2.2 Daily Operations

The major operations at the distribution warehouse comprise receiving/putaway, order picking/truck loading, and replenishment operations.

2.2.1 Receiving/Putaway Operation

A truck carrying items arrives at the distribution warehouse, and stops at the designated position inside the distribution center. Then, the items on the bed of the truck are unloaded by either an outdoor forklift truck or an indoor forklift truck, depending on the location where the truck has stopped. There are three cases for handling incoming items.

(1) A Zone (Putting on the floor.)
(2) B Zone (Putting on the rack.)
(3) Second floor

After all items have been unloaded completely, the truck departs for its destination.

2.2.2 Order Picking/Truck Loading Operations

Once the direction for outgoing items is sent to the host computer, the list of picking is generated. An operator of an indoor forklift truck will pick up the corresponding items from the designated addresses, based on the list. After he picks up the items which are enough to be put on one pallet, he transports them to the tentative position for shipping. If the tentative position is outside the warehouse, the items put on the pallet is delivered to an operator of an outdoor forklift truck. After the predetermined amount of items put on pallets is gathered for one truck to transport, an operator checks the items whether all are gathered correctly.

Then, a truck arrives at the distribution center, and stops at the assigned position, all items are to be loaded on the bed of the truck. After that, the truck departs for its destination.

2.2.3 Replenishment Operations

In the distribution warehouse, items, which are put either on level one (the grand level) of the racks (shown in the left-hand side in Figure 1) or on the floor inside the warehouse, can be picked up for shipping. Replenishment operations are ones to transport some amount of items from the current addresses to the designated addresses for performing incoming and outgoing operations smoothly. Hence, depending on the picking/shipping schedule, items on pallets should be moved from level (tier) two or higher to level one (ground level) to facilitate order picking. Replenishment operations are performed in some separate fashions. Operators perform replenishment operations daily for the items located at level one and on the floor. In addition, operators have to replenish items to meet picking requirements; this operation is called urgent picking.

Once the directions of replenishing items are released, an operator picks up the designated items, and puts them on a pallet. Then, he transports them to the destination address. In this case, transportation from the rack to the tentative position (and vice versa) cannot be performed by a single forklift truck, so both one reach lift and the other type of forklift truck must cooperate to work together to perform these consecutive operations.

3 SYSTEMATIC APPROACH FOR SIMULATION

A series of the approaches for performing simulation are developed to evaluate the performance of the distribution warehouse. In this section, three major issues are described especially for stressing the characteristics of the proposed procedure.

3.1 System for Generating Parameters

At the first stage, a series of input data should be generated for performing simulation. An overall procedure of the system for generating parameters is developed to do this, as shown in Figure 2.

This system adopts Microsoft Access and DAO (Data Access Object) to handle data of addresses, items, and inventory. Data tables and queries are generated with Access, and the associated logic is specified with DAO. In addition, Excel files are generated to use them as an input of simulation experiments from the data tables of Access.

Six parameters should be inputted to perform the system:

(1) Inventory level at picking addresses (%)
(2) Inventory level at storing addresses (%)
(3) No. of pallets at free addresses (pallets)
(4) No. of units of incoming trucks (trucks)
(5) No. of units of outgoing trucks (trucks)
(6) No. of days of creating data (days)

Furthermore, data tables are used to perform the system for generating data. There are three types of data tables from the functional standpoint; that is, the parameter data tables, the variable data table, and the output data tables. These data tables have been prepared by examining the past observations. Various means of transportation are used at the distribution centers. The list of transportation is shown in Table 1.

Table 1: List of Transportation

Code No.	Transportation
16	Truck 2 tons
17	Truck 3 tons
19	Truck 4 tons P.
20	Truck -freight
25	Truck 10 tons
32	Truck 10 tons P.
39	Truck 13 tons PR.
53	Freight 10 tons
72	Container 5 tons
74	Container 5 tons R.
82	Trailer 20 tons
88	Truck 13 tons
99	Others

After performing this system, all necessary input data are generated automatically on all operations at the distribution warehouse.

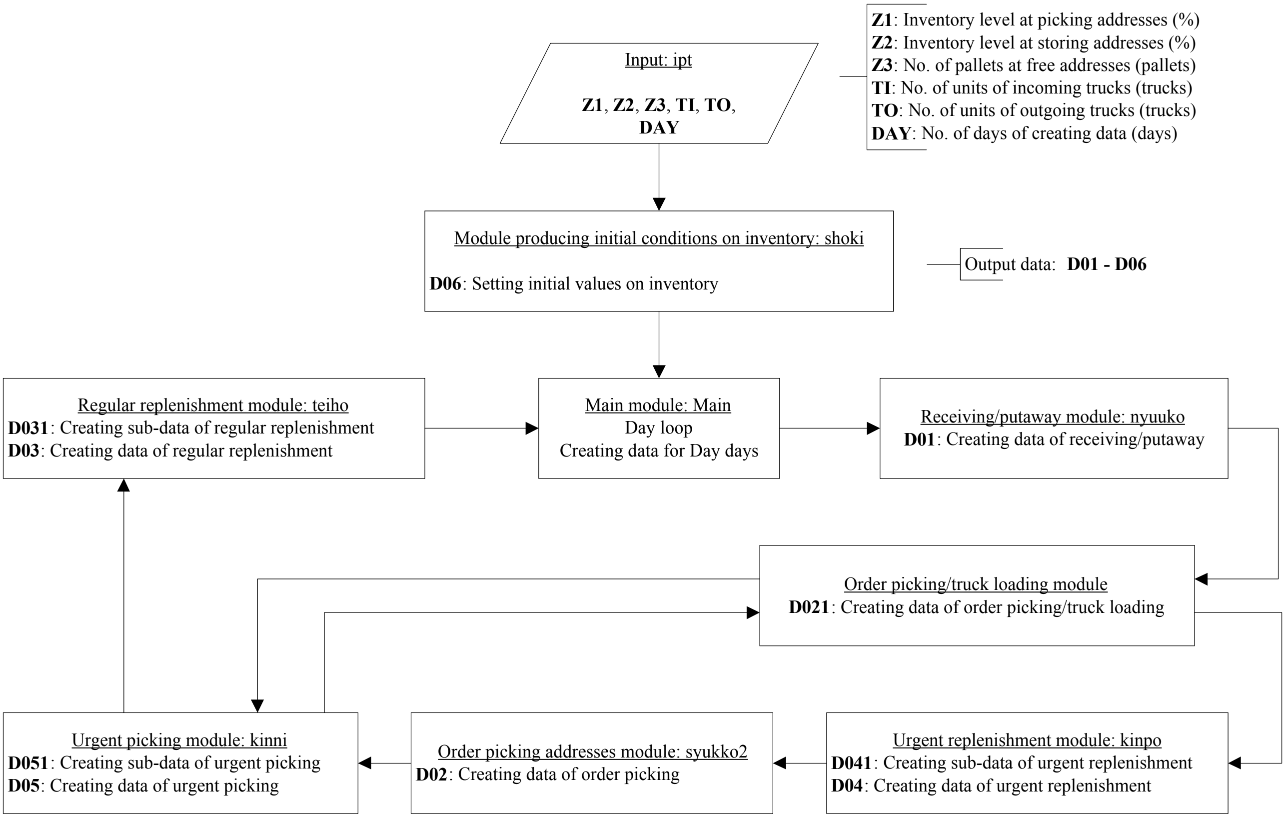

Figure 2: Overall Procedure for Generating Data

3.2 Input Data for Simulation

There are three major groups of input data, by performing this data-generating system. This system has been developed, by observing actual activities of receiving/ putaway, order picking/truck loading and replenishment operations.

3.2.1 Data Related to Receiving/ Putaway Operations

Data on incoming operations comprise two lists, i.e., the incoming pallet list and the incoming truck list.

(1) The incoming pallet list
Incoming items on each pallet are listed in the incoming pallet list, the contents of all pallets are indicated in one sheet, as shown in Table 2 (a).

(2) The incoming truck list
Any information on the truck is summarized from the incoming pallet list. The number of data is the same as the number of trucks for one day as shown in Table 2 (b).

3.2.2 Data Related to Order Picking/Truck Loading Operations

Data on order picking/truck loading operations comprise three lists, i.e., the outgoing item list, the outgoing pallet list, and outgoing truck list.

(1) The outgoing item list
Outgoing items and trucks for shipping are listed in the outgoing item list. The number of data is the same as the number of outgoing items for one day, as shown in Table 2 (c).

(2) The outgoing pallet list
Any information on the outgoing items is summarized for one pallet. The number of data is the same as the number of outgoing pallets for one day, as shown in Table 2 (d).

(3) The outgoing truck list
Any information on the truck is summarized for one truck for shipping. The number of data is the same as the number of trucks for one day as shown in Table 2 (e).

Table 2: Data to be Generated

(a) The Incoming Pallet List

Item	Type	Zone	Brank	Bay	Level	No. of outgoing items	No. of pallets	No. of remaining	Company code	Transportation	Picking No.	Destination Code	Date
JNCST*E	1	B21	AA	12	2	48	1	0	3302	32	622	6741339	990901
PTKL*M	2	A41	BB	05	1	2	0	2	3302	32	622	6741339	990901
PTKL*M	2	A41	BB	05	1	2	0	2	3302	32	622	6741339	990901
WSEDT	2	A42	FF	16	1	8	0	8	3302	32	622	6741339	990901
SYGCT*L	2	A41	CC	06	1	10	0	10	3302	32	622	6741339	990901
BSMA*J	2	A42	FF	08	1	12	0	12	3302	32	622	6741339	990901
WSEDS	2	A42	FF	17	1	12	0	12	3302	32	622	6741339	990901
TSNT*L	2	A41	CC	17	1	24	0	24	3302	32	622	6741339	990901
HHTT	2	A41	DD	09	1	24	0	24	3302	32	622	6741339	990901

(b) The Incoming Truck List

Item	Zone	Brank	Bay	Level	No. of incoming items	No. of pallets	No. of remaining	Transportation	Transportation No.	Palet flag	Beginning row of one track
HSTM*J	A41	CC	15	1	3	0	3	32	4889	1	2
HSTT*K	A41	CC	18	1	45	1	0	32	9049	1	3
HSTT*K	A41	CC	18	1	45	1	0	32	9049	1	3
HSTT*K	A41	CC	18	1	45	1	0	32	9049	1	3
HSTT*K	A41	CC	18	1	45	1	0	32	9049	1	3
HSTT*K	A41	CC	18	1	45	1	0	32	9049	1	3

(c) The Outgoing Item List

Transportation	Transportation No.	Pallet flag	Beginning row of one truck	No. of lines of data	Positon	Time
32	4889	1	2	1	1	1800
32	9049	1	3	16	1	1800
20	9210	1	19	1	0	1800
53	9253	1	20	16	0	1800
32	9301	1	36	23	1	1800
39	9369	1	59	17	0	1800

(d) The Outgoing Pallet List

Company code	Transportation	Picking No.	Destination Code	Date	Picking list	Pallet code	Beginning row of one pallet	No. of rows of one pallet
3302	32	622	6741339	990901	1	1	2	1
3302	32	622	6741339	990901	2	1	3	5
3302	32	622	6741339	990901	2	2	8	2
3302	32	622	6741339	990901	2	3	10	1
3302	32	622	6741339	990901	2	4	11	1
3302	32	622	6741339	990901	2	5	12	1

(e) The Outgoing Truck List

Company code	Transportation	Picking No.	Picking list	Beginning row of one truck	No. of pallets	Beginning row of one pallet
3302	32	622	3	2	22	2
3302	32	623	8	35	26	24
6052	32	624	13	117	33	50
615	32	625	1	258	20	83
615	32	626	7	278	27	103
3302	32	630	6	347	22	130

(f) The Replenishment Pallet List

Item	(To) Type	Zone	Bank	Bay	Level	(From) Type	Zone	Bank	Bay	Level	No. of completed	No. of pallets	No. of remaining	Date
SGS-8	1	B16	LL	10	3	2	B01	AA	14	1	20	1	0	990901
SGS-8	1	B16	LL	10	4	2	B01	AA	14	1	20	1	0	990901
SGS-8	1	B16	LL	10	5	2	B01	AA	14	1	20	1	0	990901
SGS-8	1	B16	MM	04	4	2	B01	AA	14	1	20	1	0	990901
SGS-8	1	B16	MM	06	3	2	B01	AA	14	1	20	1	0	990901
SGS-15	1	B16	MM	02	2	2	B01	AA	16	1	20	1	0	990901

3.2.3 Data Related to Replenishment Operations

Data on replenishment operations comprise three lists. These three lists are generated with the same format. Hence, only the replenishment pallet list is described here.

(1) The replenishment pallet list
Items to be replenished are listed for one-pallet bases. The number of data is the same as the number of pallets for replenishment, as shown in Table 2 (f).

3.3 Simulation Model

In this study, the simulation is performed by SIMAN/ Arena (Pegden et al. 1994, Kelton et al. 1998). Animation on the monitor is shown in Figure 1.

3.3.1 Entities of the Simulation Model

Pallets and trucks are modeled, by using entities. They have various attributes for the corresponding purposes.

(1) Incoming truck entity
Incoming truck entities are generated with VBA (Visual Basic for Application) in the logic of generating incoming trucks, by using incoming truck list. Their attributes are summarized in Table 3 (a).

(2) Incoming pallet entity
Incoming pallet entities are generated with VBA, by using incoming pallet list. Their attributes are summarized in Table 3 (b).

(3) Outgoing truck entity
Outgoing truck entities are generated with VBA in the logic of generating outgoing trucks, by using outgoing truck list.

(4) Outgoing pallet entity
Outgoing pallet entities are generated with VBA, by using outgoing pallet list.

(5) Replenishment pallet entity
Replenishment pallet entities are generated with VBA in the logic of generating replenishment pallets, by using replenishment pallet list.

3.3.2 The Logic of the Simulation Program

The logic of the simulation program comprises three major parts:

(1) The logic for receiving/putaway operations
Generating incoming trucks.
Arrivals of trucks – Awaiting forklift trucks for unloading.
Unloading – Generating incoming pallets – Departure of trucks.

(2) The logic for order picking/truck loading operations
Generating outgoing trucks – Generating outgoing pallets.
Picking operations – Awaiting forklift trucks for loading.
Arrivals of trucks – Awaiting forklift trucks for loading.
Loading – Departure of trucks.

(3) The logic for replenishment operations
Generating replenishment pallets.
Replenishment operations.

Table 3: Attributes of Entities

(a) Incoming Truck Entity

Attribute	Description
Picture	Animation symbol
A_EntType	Entity type
A_Data#	Index of incoming truck list
A_Trk#	No. of truck
A_TrkType	Type of truck
A_PltQty	No. of incoming pallets
A_PltIdx	Index of incoming pallets list
A_PltCnt	Pallet counter
A_TimeEnter	Time
A_TrkPark#	No. of unloading lot

(b) Incoming Pallet Entity

Attribute	Description
Picture	Animation symbol
A_EntType	Entity type
A_NowX	Current position of network
A_NextX	Next position of nextwork
A_TmpX	Tentative position of netwok
A_DstX	Destination of network
A_DstLv	Destination level
A_DstType	Destination type
A_DstBlk#	Block No. of destination
A_Data#	Index of incoming pallet list
A_Fork#	Fork No.
A_NextS	Next station

4 SIMULATION EXPERIMENT

As the first step of the procedure, six parameters should be inputted to perform the system, as follows:

(1) Inventory level at picking addresses: 34 (%)
(2) Inventory level at storing addresses: 94 (%)
(3) No. of pallets at free addresses: 143 (pallets)

(4) No. of units of incoming trucks: 20 (trucks)
(5) No. of units of outgoing trucks: 30 (trucks)
(6) No. of days of creating data: 1 (days)

Regarding the number of reach-lift forklift trucks, two alternatives are examined, by performing simulation experiment; one truck and two trucks. The numbers of other types of forklift trucks are same for the two alternatives. The results are summarized in Figure 3 (a) and (b), respectively. The beginning time and the ending time for the three particular types of operations are especially shown at these two figures. By increasing the number of reach-lift forklift trucks (, i.e. from one truck to two trucks), the ending time of replenishment operations could be drastically earlier.

5 SUMMARY

(1) A practical modeling method is presented for performing simulation of complicated and non-automated distribution warehouses. The method consists of two phases: the program for generating parameters of materials handling, and the simulation program.
(2) It is found that it is much more difficult to build simulation models for large-scale and non-automated distribution warehouses than for AS/RS, because there are usually replenishment operations at the non-automated distribution warehouses.
(3) The proposed modeling method is presented using an actual case to demonstrate the applicability to the actual large-scale and non-automated distribution warehouses.

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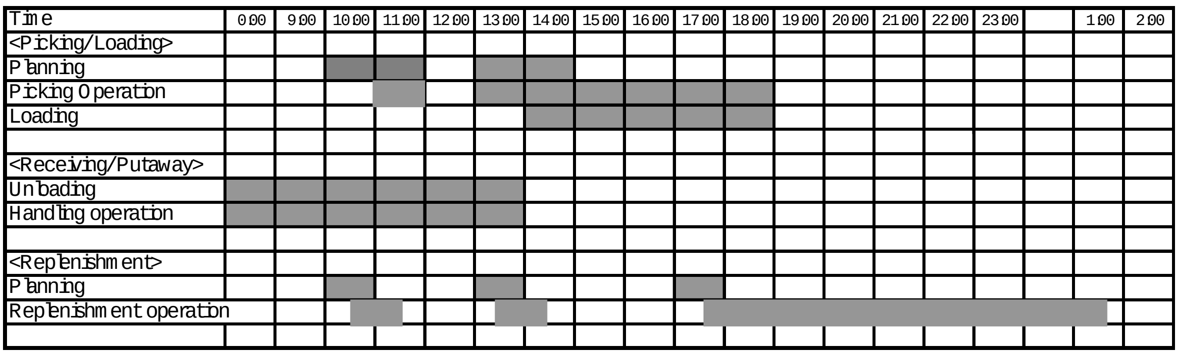
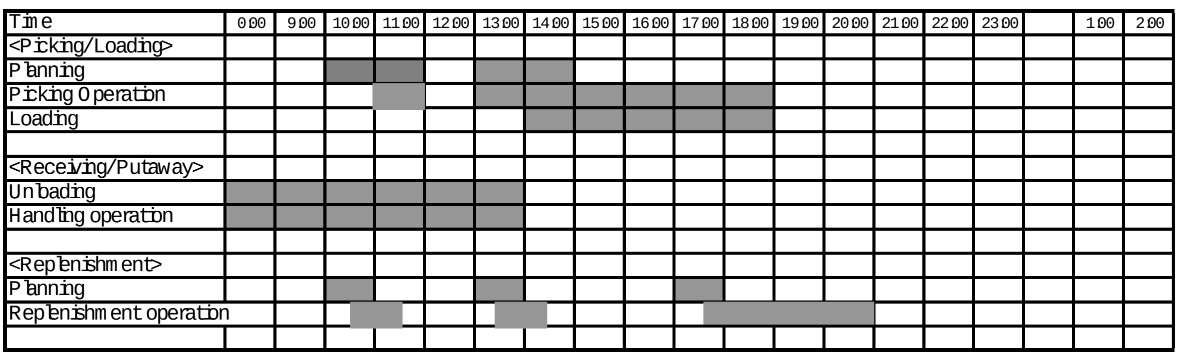


(a) One Reach-Lift Truck



(b) Two Reach-Lift Trucks

Figure 3: Simulation Results

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