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A Generic Hierarchical Simulation Model to Improve Distribution Center Operations

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Abstract

Distribution Center is one of the most significant parts of a supply chain and thus it is essential for distribution center managers to understand their facility well in order to maximize their profit. It takes a lot of time for distribution center managers to figure out how many resources they need in storage locations where they need to store and pick a particular item in order to increase the throughput. For this purpose, redesigning a facility through simulation has attracted many distribution center managers. Through simulation, managers can easily forecast their throughput.The main operations of a distribution center are picking, storing and shipping of orders. Picking is the most important operation of a distribution center. Most of the distribution centers operate in the similar fashion and thus it is more logical to build a model which can be used for any distribution center.In this research, we have built a hierachical simulation model of picking and shipping operations of a distribution center. The hierahcial model is made up of small submodels. The submodels were used to build a complete simulation model of a distribution center.The hierahcial simulation model was run for twenty four hours and the results are verifed with the single simulaiton model of the same distribution center.

Key words: *simulation, distribution centres*, *hierarchical simulation model, order picking, zone picking strategy*

1. Introduction

In recent times there has been an increase in the wage of workers; meaning a manifold increase in the distribution center rent of the industrial property [1]. The most important decision for any distribution center is how to increase their throughput with the number of workers in their hand or to know how many extra workers they need to achieve their goals. Therefore, it has become a challenge for distribution center managers to optimize their worker configuration in order to increase their throughput.

This has driven their attention to making a simulation model of their facility which can help them to forecast their throughput with the working population. In the past, various researchers have used simulation as a tool to solve the problem of a distribution center, but those models are single models where the focus of solving a problem is limited to just one distribution center.

Thus making any change within that model is difficult for someone who is not familiar with the simulation tools [2]. Also, creating a hierarchy model is found to be less time consuming compared to a single model [2]. It is being observed that showing all the objects in a single model has caused distraction among the users towards the actual problem making it difficult to understand the actual logic of the model. Also, the validation and verification of single model are difficult [2], [3].

It is better to have a hierarchy of models where each model is focusing on one section, making it more user friendly. So, if there is any change to be made the user knows where to make that change and can easily test the model at a submodel level.

Besides, in a single model, the user does a lot of repetitive work which can be easily discarded in hierarchy model as in a hierarchy the submodels are created as objects which can be easily extended. This paper aims to construct an hierachical simulation model of picking operations in distribution center

The paper is organised as follows the section two presents the literature review, section three presents problem description, section four presents a hierarchical model, section five presents case study and section six conclusion.

2. Literature Review

Simulation has been widely used to understand and improve warehouse/distribution centre operations. Simulation is "Experimentation with a simplified imitation (on a computer) of an operations system as it progresses through time, for better understanding and/ or improving that system" [3].

According to Chang and Makatsoris [4], simulation can help the warehouse personnel to understand their system well, to see the effect of an unexpected event and minimize the risk of loss.

Macro and Salmi [5] used simulation to identify the storage capacity and rack efficiency of of medium volume, low stock keeping unit warehouse and medium volume large stock keeping unit warehouse.

Petersen etl.al [6] has found through simulation that storing items based on class based storage policy (divides storage into different classes based on their demand) improves the picking operatins of a warehouse.

Roy et. al [7] used simulation to identify the blocking effects on the transaction cycle time which is caused by the AVS/RS in an automatic warehouse.They found through simulaiton that blocking delays 2%-20% of the transactions times.Faria and Reis[8] used a simulation model to minimise the picking cost by re arranging the storage locations and by re applying different routing policy.The authors found through simulaiton that s-shape and return routing as the best routing policy. The authors also found in their simulation study that if the items with high sales are located at the most acessible positon then it reduces the picking time. In the past, most of the simulation, models that were built were limited to a single distribution center/warehouse problem.

A typical supply chain has suppliers and customers at the two ends of the chain. Multiple operations and processes happen between these two ends of a supply chain such as manufacturing, warehousing, distribution etc. In the past, the simulation models that were built solely focused on one distribution centre problem. However, a single model can be overwhelming and confusing for a nonprofessional [2],[3].

Having a hierarchical model will present a better picture of these integrated aspects of a supply chain. „Hierarchical simulation means simulating a design at different levels of abstraction in terms of both the structure and the behavior of the underlying component" [9]. The focus of this research is to build a hierarchical model that would help the warehouse personnel to increase their throughput by optimizing the worker utilization.

3. Problem Description

To make the model generic the following properties were considered in the layout design of the hierachical model:

- A typical distribution center consists of multiple zones where zone picking strategy is used. In zone picking strategy a worker is responsible for picking items in his/her zone. An order may have items in multiple zones. The reason for considersing zone picking strategy in this research is that it minimises the walk time, helps in balancing the worker load and subsequently increases the throughput [10],[11].
- The distribution center has levels and each level has multiple zones.
- There are few towers that are made up of multiple levels.
- The distribution center uses conveyors to transport items from one zone to another.The conveyor is in between the zones of each level.
- There is a mezzanine which is made of multiple zones. The number of zones in the mezzanine is compartively smaller than in a level as it occupies less space of the property.

Figure 1 shows a layout of a tower which is made up of three levels and twelve zones, and conveyor on each side of the level. There are two zones on the right side of the level and two on left side

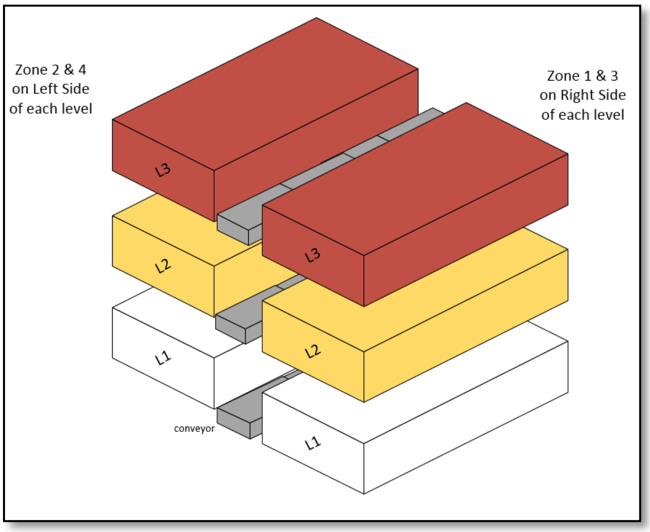

Figure 1 A tower with three levels and twelve zones

Figure 2 describes the picking operation of a distribution center.The process of picking in a distribution center generally starts with a computer aided management system generating the orders to be picked on a given day. An empty tote with a labelled bar code is scannned and placed on to the conveyor belt that takes it to the right tower.

At the begining of each tower, there is a scanner that takes the tote to the right level. A tote passes through all the zones in a level. There is scanner at the beginning and middle of each level that determines if a tote has items to be picked in any of the zones of that level, if there are items to be picked then tote is diverted to a gravity conveyor where a zone worker scans it to identify the type and number of items to be picked from that zone.The zone worker then places the items into the tote and re scan to confirm the picking. The tote is then placed back to the powered conveyor by the worker.

At the end of each level of a tower, there is another scanner that determines the number of orders left for that tote if a tote has fulfilled all its orders it will be diverted to the main conveyor which takes it to the sorting and shipping section. The following assumptions were made to understand the picking operations of the distribuiton center.

- A tote passes through levels in a tower in serial order, that means it will first go to level1, then level 2 and so on.
- A tote can only go to another tower through the last level of a tower, that means if a tote has items to be picked from another tower, then it will pass through all the levels of that tower and is diverted to next tower through its last level.
- A tote can go to mezzanine through any of the levels of a tower, that means it does not have to go through all the levels if it has to go to the mezzanine.
- The tote will go to the mezzanine at the end of its picking cycle.
- A tote may contain multiple orders.
- The sorting of orders is done during the shipping.

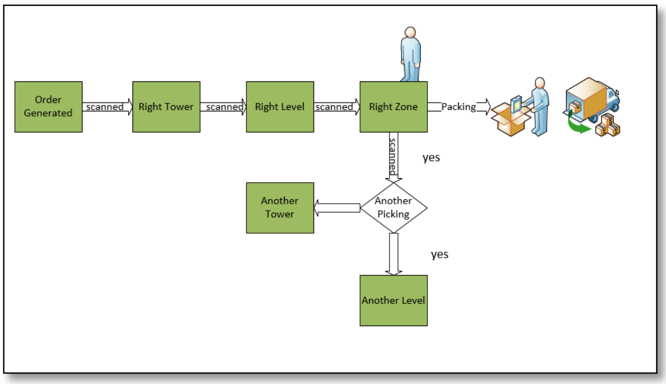

Figure 2. Order process

The objective of this paper is to build a hierachical simulation model of a distribution center. The hierachcial simulation model is built by using several small submodels. Thus making it more simple and easy to understand for someone who is not from a simulation background.

Futhermore, it also saves time if a distribution center personnel want to make changes in the zone picking strategy. The personnel do not have to make changes in all the zones but need to make a change to the zone submodel. The change would be pushed to all the zones. Also, the model can be easily re-used for any other distribution center with little modifications and the distribution center layout can easily be modified to any shape like circular, rectangular etc.

4. Hierarchical Model

After understanding the layout design and flow of items a hierarchical model was constructed using Simio[12]. The small submodels were created and used as objects to make a complete model. Each submodel was made separately. The models were created based on their hierarchy and properties that will be defined in each model.Figure 3 describes the submodels hierachy diagram that was made to build a complete simulation model.The properties of each model are given in table 1. Submodels are described below:

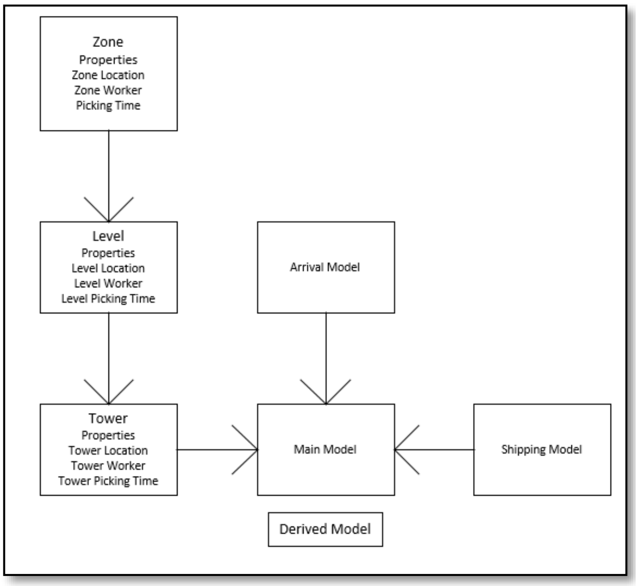

Figure 3. The hierachical diagram of the submodels

Zone Submodel: A zone submodel was built first because every level and tower has zones. In other words, zone submodel is the model which every other submodel would inherit properties from.

The zone model is made by using two servers. The units/totes come to a zone if there is an order to be picked up from that zone by a worker. The zone submodels properties are created which are defined later in other submodels. The zone properties are described in table1.

Level Submodel: The level submodel is built by combining several zone submodels. A level submodel has multiple zones and inherits all the properties of zone submodel. The zone location is defined in this model. The level properties are described in table 1.

Tower Level Model: The tower level model was built by combing several level submodels. The level submodels were used as objects to create a tower. The level location property is defined in this submodel. When an order enters a tower there is a branching of three paths and there is condition defined on each path that takes it to the right level. Figure 4 shows the steps that were taken to build a tower.The properties defined in tower level model is described in table 1.

Table 1. Properties of submodels

Properties	**Description**
Case Study Model	
Workers	Workers are the resources that are responsible for picking operations. Each tower has its workers. A property called workers is created at the zone model and is pushed down to all the models that extend it.
Picking Time	Picking time is the time a worker needs to pick an item. It is described in the server of the zone model and is inherited by the models that extend it.
Packing Time	This is the time that is needed to pack an item
Zone Submodel	
Zone Location	It is a property that gives a name to a zone. This property is later defined in the level submodel.
Level Submodel	
Level Location	It is a property that gives a name to a level. It is defined later in the tower model
Tower Submodel	
Tower Location	This is a property that gives a name to a tower. It is defined later in the four tower model
Mezzanine Submodel	
Mezzanine Location	This is a property that gives a name to a tower. It is defined later in the four tower model
Shipping Submodel	
Ship Index	This is a property that is used to define the probablity that an order would go to particular station for packing

Mezzanine Submodel: The mezzanine model was built by combining several zone submodels. This model is same as a level model and inherits all the properties from the zone model.

Picking Station Submodel: The picking station submodel was built using three tower submodels as objects and a mezzanine submodel.

Shipping Submodel: The shipping submodel was built by using a server. The properties that are created in this submodel is described in table 1.

Shipping Tower: The shipping tower was built using multiple shipping submodels as objects.

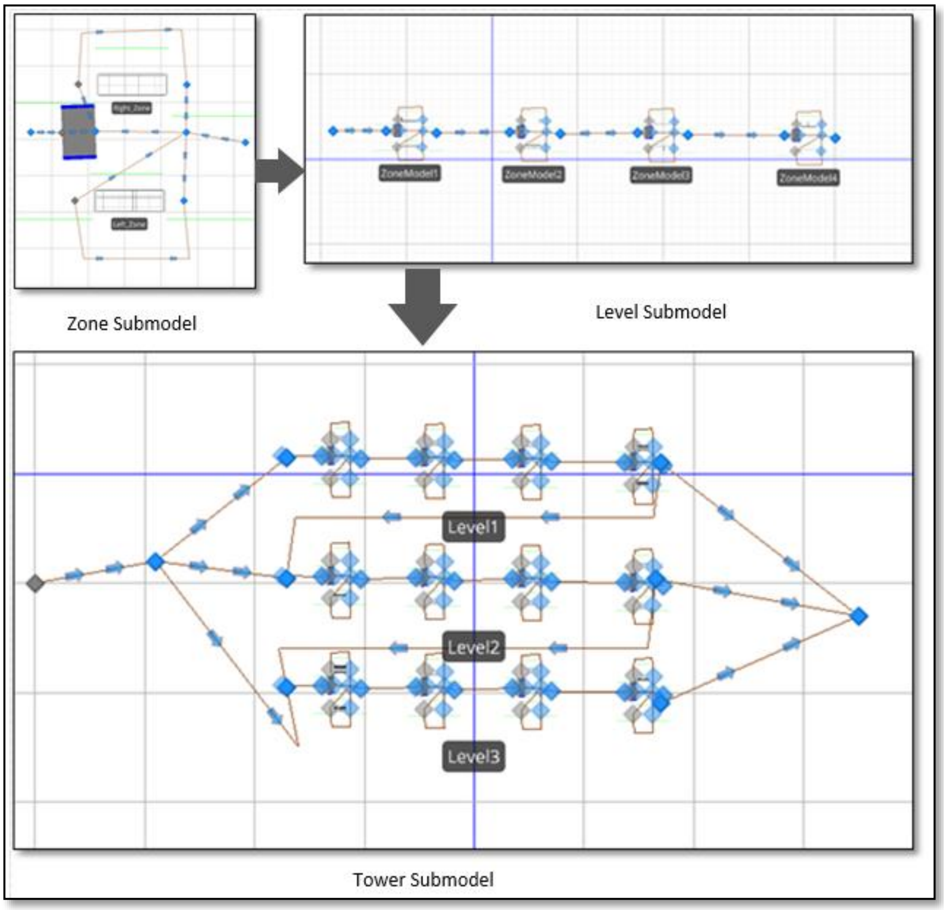

Figure 4: Steps to build tower submodel

5. Case Study

The submodels were used to make a complete simulation model of a Columbus, Ohio distribution centre. A single simulation model of the same distribution centre was built by Sormaz et. al [13]. The distribution centre processes online orders of toys and stores 21,000 sku's of different product types. The distribution centre has three towers in which they store their picking items, each tower has three levels one over the other. Each level has eight zones and a conveyor that runs in between the level. This means there are four zones one on each side of the level.There is also a mezzanine and it has six zones. The complete model was built by combining three tower submodels , a mezzanine sub model and shipping tower.This model defines all the properties that were pushed to its submodels. The number of workers, picking a time and packing time is defined in this model. The orders arrive and are combined with the totes based on random discrete distribution. The totes are directed to their respective tower and then to level and zone where they are supposed to pick items. The tote exits the tower when all its orders are complete.The complete simulation model is shown in figure 5.

In order to validate the model the proposed hierahcial simulation model was run for 24 hours with the same data and the number of workers that were used in the single simulation model[13]. Table 2 presents the results of hierachical simulation modela and single simulation model.

Table 2: Results comparison between Single simulation model and hierarchical model (hm)

Experiment	Tower Workers	Mezzanine Workers	Average Throughput [13]	Average Throughput(HM)
1	48	15	151,026	151,863
2	30	10	150,915	151,874
3	35	11	150,802	150,191
4	40	12	151,173	151,079
5	55	18	150,515	150,749

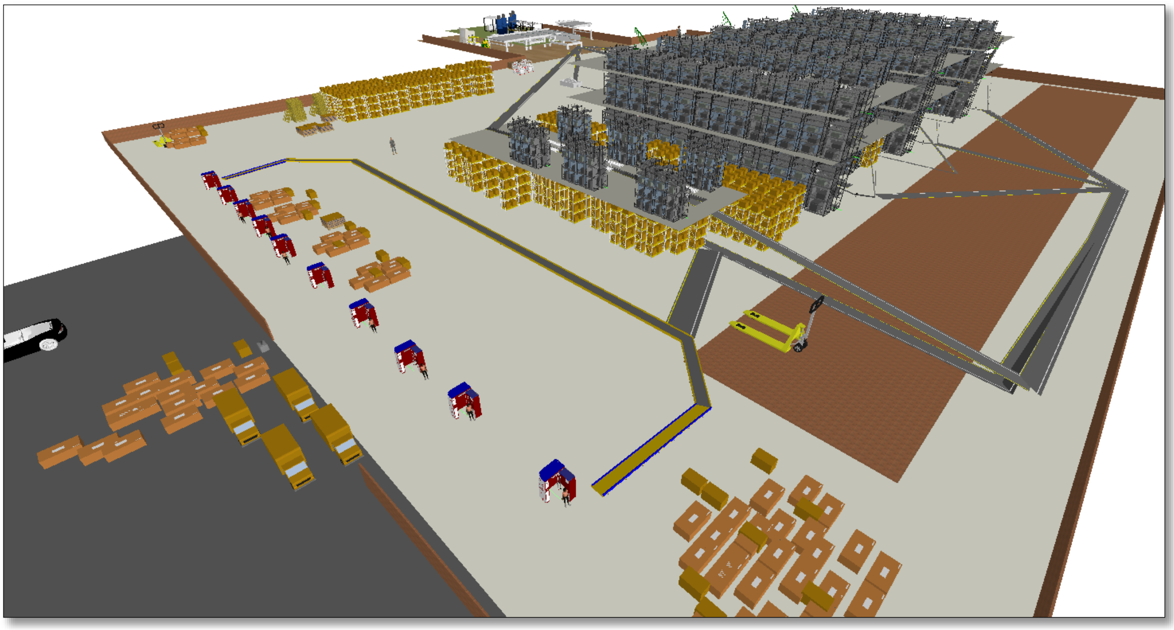

Figure 5: Simulation model of Distribution Center

The results between single simulation and hierarchical model are comparable, which means that the hierarchical model is verified successfully.

6. Conclusion

This paper presents a hierarchical simulation model of a distribution center. The presented hierarchical model would help the distribution center personnel to forecast their throughput by optimizing the number of workers. The hierarchical model is designed in a way that its submodels can be easily extended and modified to build a complete simulation model of another distribution center. The model is currently limited to zone picking strategy and does not consider the replenishment. The research would be further extended to apply different picking strategies. The future work would also consider the replenishment part of the distribution center as replenishment and picking are related to each other. Currently, the model is also limited to a distribution center which uses workers for picking. The future work would include a submodel that would consider a distribution center where picking is done by AS/RS. The goal of this research is to build a complete hierarchical simulation model that is much more advanced and comprises of all the operations of a distribution center.

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