26 STOCKYARD LAYOUT MANAGEMENT FOR PRECAST CONCRETE PRODUCTS USING SIMULATION

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Abstract

Identification of stockyard layouts for efficient storage and retrieval of standard concrete products is a very complex process. The demand in the industry is seasonal, and a massive stock is built in winter for the dispatched in summer. The problem is unique to the industry as the products are heavy in weight, different handling requirements and, large scale production (1000~1500 different products are produced and stocked). The industry is experiencing long throughput time for the distribution lorries, space congestion for both storage and dispatch of products. A case study shows that the throughput time to service an order varies form 60 to 90 minutes, the queuing time for the lorries being 1.5 times the loading time. A simulation model "SimStock" has been developed to assist managers in designing and managing the stockyard layout. Through the simulation model "what- if " analysis is made for different storage methods, different loading policies and vehicle routings through the yard. A satisfactory layout can be selected for the implementation by visualising the loading and dispatch process, and evaluating the throughput time, space utilisation and cost of loading and dispatch. This paper presents the simulation model "SimStock" which was developed using ARENA (SIMAN), the methodology to populate the simulation model and the results of the simulation model using a detailed case study.

Keywords: *stockyard layout, simulation, precast concrete products*

INTRODUCTION

Stockyard layout is considered as one of the major factors to influence the storage and retrieval of precast concrete products. A work-study conducted in one stockyard site of UK precast concrete product manufacturing company (Dawood and Marasini, 2000) suggests that the throughput time (time required to load a lorry to serve an order) is very high (average 80.31 minutes). The queuing time of lorries in the yard (49.56 minutes), which is 61% higher than the actual loading time (30.75 minutes). The study has suggested that the throughput time is dependent on layout of the stockyard in terms of location of products, the route to be followed by lorry and the number of resources available within the stockyard for loading. It is worthwhile to mention that the loading and dispatch process is unique to the industry. A distribution lorry arrives in the stockyard to serve an order placed by the customer. In the entry gate, a pick-slip is given to the lorry and the loaders with forklifts, clamps or cranes pick up the products from different locations. The lorry travels through the main path where as forklift trucks move to different aisles find the product and load into lorry. When the loading for the products stored in one location is finished, the lorry and loaders forward to next location along the main route and the process is repeated to load all the products ordered. As thousands of different products are produced and stocked on the stockyard, the retrieval of products from the different storage locations becomes very difficult. The products produced first should be dispatched first, and new products will occupy the resultant vacant space (not necessarily by the same type). The rotation of products to strategic locations ease loading and dispatch process is also necessary. A computerised model is being developed to address these issues and identify suitable methodology to manage stockyard layout and operations.

STOCKYARD LAYOUT AND SIMULATION

As no relevant study was found in stockyard layout management techniques, facility planning techniques (manufacturing industry) and temporary facility layout planning (construction industry) were conducted. The details of review were presented in Marasini and Dawood, 2000. The facility layout in manufacturing is static in nature whilst the temporary facilities layout planning in construction industry are dynamic. The stockyard layout planning is also dynamic in nature as space is occupied after production and freed through the dispatch process to be occupied by similar or different products. Therefore, the layout scenario will be changed with the passage of time. Dawood and Marasini, 2000 proposed a knowledge-based layout generation and simulation based evaluation architecture as a suitable methodology to solve stockyard layout problems, and simulation model presented in this paper is one of the main components of the stockyard layout management model.

Simulation is the process in which real-life problem is represented by a computer model, and the model is then used for experimentation work to evaluate alternatives. The main objective of simulation is to examine how a real system behaves over a period of time. The model describes entities (the basic elements of a physical system), their attributes (main characteristics and interrelationships) and how they interact with each other (Doukidis and Angelides, 1994). Simulation models are seen appropriate to study the behaviour of complex systems, and when decision has to be made among several alternatives. Simulation involves building a model of a system and experimenting with the model to determine how the system reacts to various conditions. Simulation does not provide an optimum solution, since it is a descriptive model

(Tompkins et al 1996). It helps in predicting the behaviour of the system and analysing "what if" scenarios and the configuration that best satisfies certain criteria can be chosen. As large number of variables are involved in the decision making process, the management of stockyard layout is considered a complex process. The complexity of the stockyard operations offers difficulties to use analytical tools as a method of investigation. When there is a random component to be evaluated, the analytical tools cannot be used and simulation is the only method that can account of randomness in the input variables (Dewdney, 1968). The simulation systems can be used in analysing and processing large quantities of data e.g. production estimates, waiting time computations, quantification of various bottlenecks on the system performance (Touran, 1990). Simulation is commonly used in most functional areas of business and industry. Several computer simulation models have been developed to simulate the manufacturing processes (refer Narayanan et al, 1998; Cochran and Kim, 1994) as well as construction processes (Martinez and Ioannou, 1999; Shi, 1999; Oloufa, 1993). The simulation of the layout of several machines in a manufacturing environment is used to decide the machine layouts. The layout planning of seaports (Wadhwa, 2000), warehouse layout planning (Caron, 2000; Randhawa, 1995) provide other examples that utilise simulation in layout planning. This research studies the application of discrete event simulation model to optimise stockyard layouts for precast concrete products and evaluates different layout scenarios. The simulation acts as an evaluation tool rather than a design tool. The simulation model specifications and development issues presented in this paper is one component of the computerised stockyard model being developed which is used to evaluate the layout being generated using knowledge rules. The simulation model can also be used as a separate model to evaluate any given layout and testing different policies e.g. identifying optimum number of resources required, testing different order picking policies etc. Integrated with the graphical user interface (GUI) and optimisation component, it provides a means to evaluate different layout scenarios with different product storage allocations and select most appropriate solutions for implementation.

STEPS IN DEVELOPING THE STOCKYARD LAYOUT

The steps included in developing the stockyard layout are as follows:
Step 1: Process and analysis of order (sales) history data

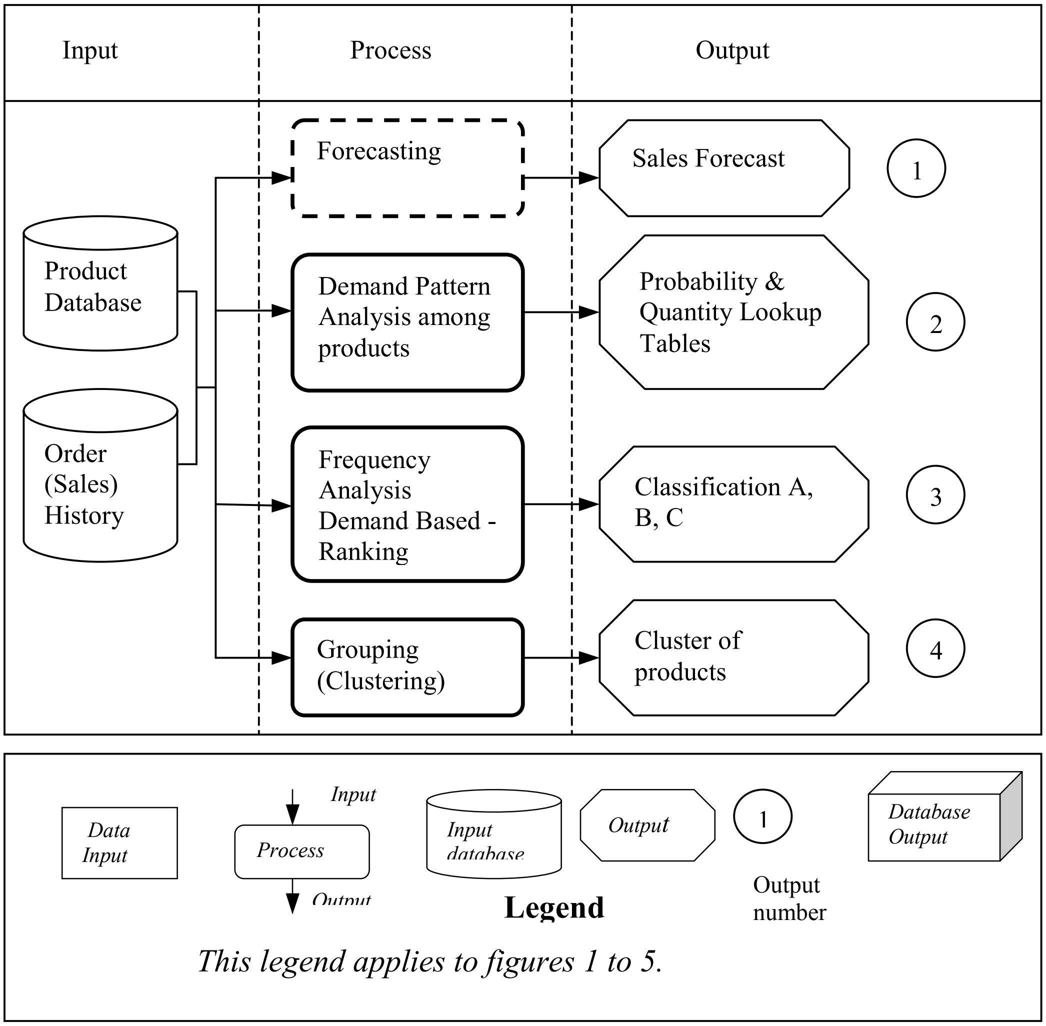


Figure1: Order History data Analysis to derive simulation input

Order (sales) history data are analysed to study the frequency of product in orders, the relationship between the product demands, and to create a group of products that are frequently ordered together. Figure 1 shows the inputs and outputs of the order analysis process. The analysis processes considered are:

Forecasting: Forecasting, the process of predicting sales, is done separately as there are many techniques (Dawood 1994) for forecasting and commercial software are also been used in the industry.

Demand Pattern analysis: This is utilised to generate the probability that a product could be in an order. For each product, probability that product will be in an order is calculated. Maximum, minimum and average quantities demanded are also calculated. The result of this analysis is written in Microsoft Excel.

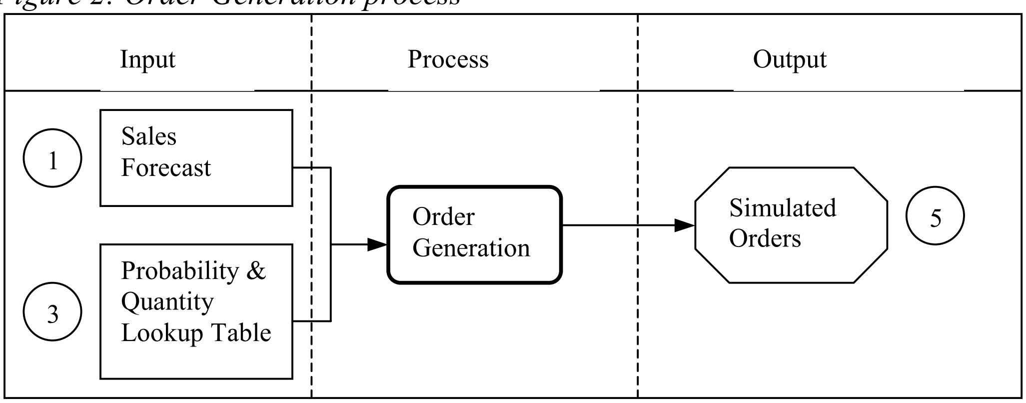
Frequency Analysis: This is a simple calculation of frequency of orders per period for each product. The products that are ordered once per day in a week are classified as class "A" products; those once a week as "B" class products and the products having frequency less than once per week are classified as "C" class products.

Clustering: The objective of clustering is to group concrete products that are frequently requested together so that the time of retrieval of the products to serve an order is minimised. One or more groups of products are assigned to a storage location.

Step 2: Generate "Simulated Orders"

"Simulated orders" are generated using sales forecast and probability and quantity lookup tables for each simulation period, say months. The steps involved in the generation of simulated orders are presented in Marasini et al 2000.

Figure 2: Order Generation process



Step 3: Design new layout or use existing layout

Using AutoCAD 2000, existing or new stockyard layouts are generated. The storage areas, distances, position of loading stations are linked and integrated to the database and updated automatically whenever the spatial objects are modified.

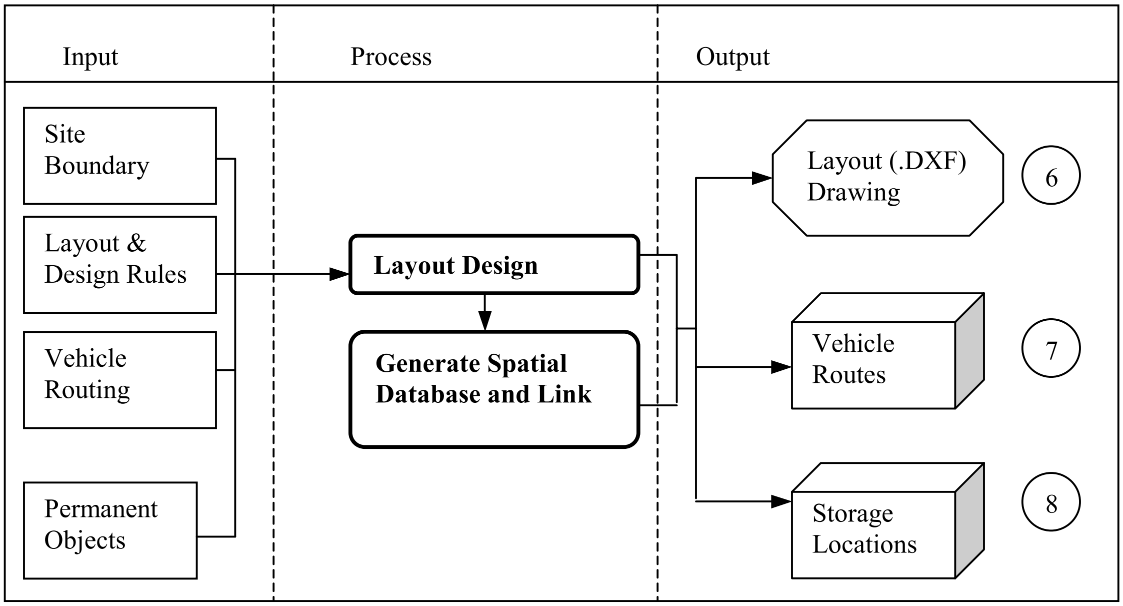


Figure3: Input and Output to the Layout Design process

Step 4: Generate layout Scenario with the product clusters assigned to storage locations

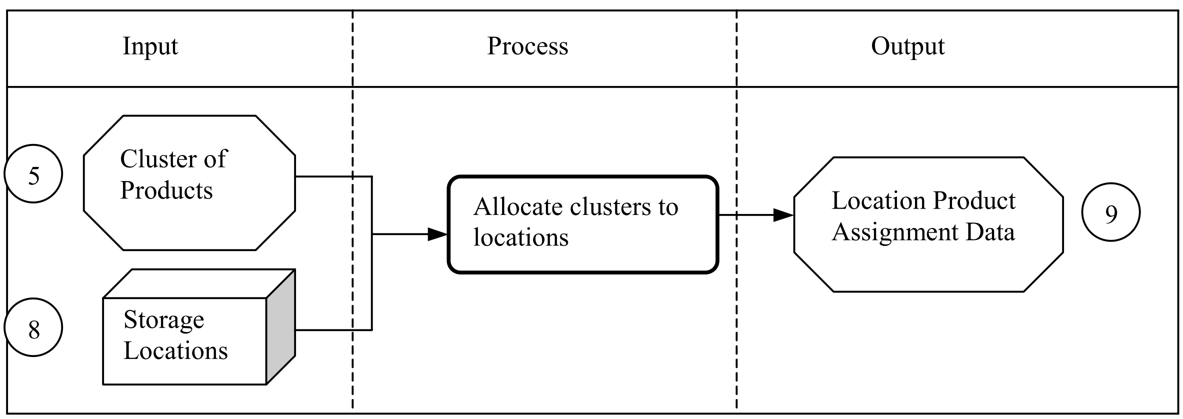


Figure 4: Storage Location and Product assignment

Step 4: Import DXF drawing and generate simulation model: The layout generated in step 3 is imported to Arena simulation environment, simulation model is generated using spatial information, model logic, databases and schedules. Figure 5 shows the inputs and outputs of the simulation model.

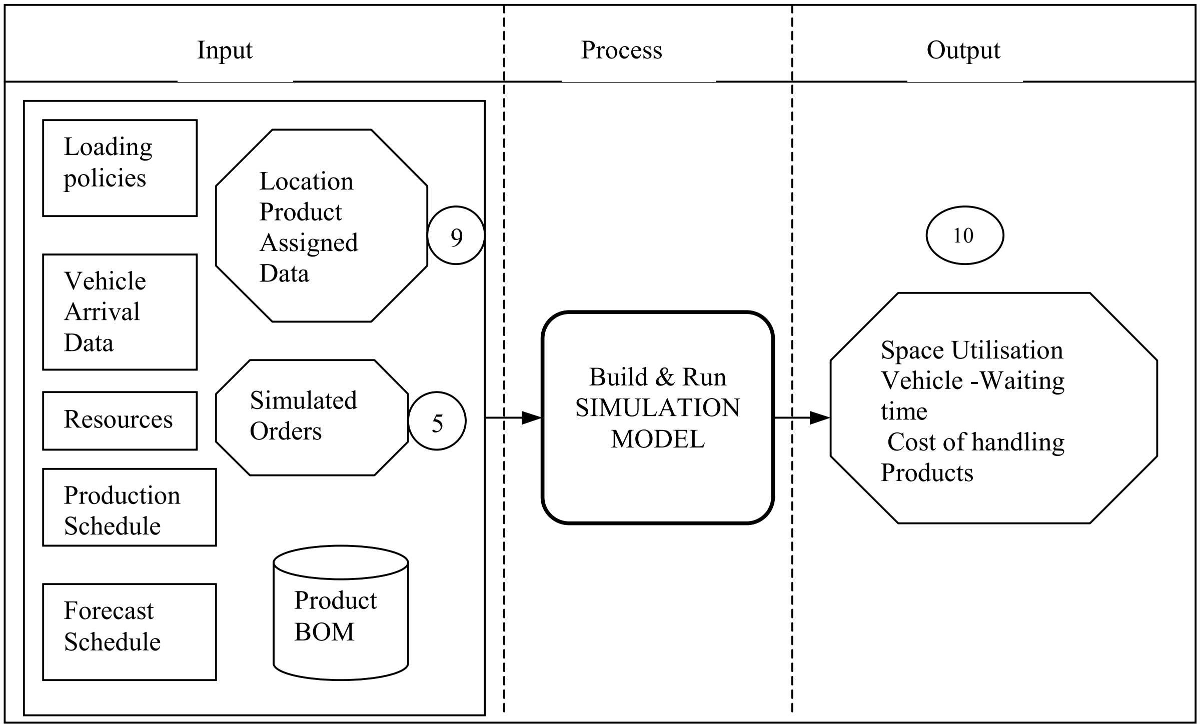


Figure5: Simulation model Input- Output

Step 5: Collect and analyse vehicle arrival pattern for loading and dispatch: this process includes the establishment of vehicle arrival patterns for daily, weekly and / or monthly variations.

Step 6: Run a simulation model

Step 7: Evaluate the objective parameters: the following parameters are evaluated the through the simulation model for a layout scenario.

i. $C_{TOT} = C_T + C_R$

Where,

C_{TOT} = Total cost of handling products

C_T = Cost of Transport from Plant to storage,

= Cost of Pickup (C_P) + Transport Distance Cost (C_D) + Cost of Stacking (C_S)

C_R = Cost of retrieval

= Cost of Pick Up (C_P) from stack + Transport Distance Cost (C_D) + Cost of Loading (C_L)

ii. Throughput time on stockyard for a lorry loading for the purpose of dispatch

iii. Vehicle waiting times and queue length in the stockyard

Step 8: Repeat steps 2, 3, 4, 6 and 7 until a satisfactory solution is obtained.

SIMULATION MODEL DEVELOPMENT

The main objective of the simulation model is to evaluate designed or existing layouts in terms of their performance and help managers to decide with the resources, routing and loading policies. A prototype simulation model has been developed using ARENA (SIMAN based simulation software, Systems modelling corporation, Kelton *et al* 1998). As SIMAN uses process interaction strategy to develop the simulation models, the process oriented discrete simulation approach has

been utilised in the modelling process. The loading and dispatch process is simulated to visualise the stockyard operations.
The simulation model evaluates the effects of different layouts on lorry waiting and throughput times. The layouts differ from each other in design of roads and exit-routes, location of products, number of resources (forklift and clamps) and methods of product loading. The lorry arrival to serve a particular order, the cycle time to load a product for the forklift trucks and the time of loading for different products are the random variable inputs to the model.

The efficiency of stockyard through the simulation model is determined through certain performance indicators. These are: loading time, queuing time, service level, loading resource requirements, ease of rotating stocks, etc. Using a knowledge-base system developed, a suitable layout is generated. Using production and dispatch schedules, the loading and dispatching process for different layout scenarios, are simulated.

"MS excel" is widely used in the industry practice to develop production and dispatch (forecast) schedules (Case Study & Industry survey, 99). Therefore, schedules produced in "MS Excel" are considered as input. Visual Basic for Applications (VBA) procedures were developed in the course of this research to integrate "MS Excel" and "MS Access" with the simulation model. The simulation model development and associated components are described as follows.

Assumptions

The simulation model is based on following assumptions:

i. The factory site considered consists of production, storage and distribution operations through a single site.
ii. For a given layout, the storage locations on the stockyard are fixed and the storage capacity of each location can be calculated for the products to be stored.
iii. The layout of roads in terms of width requirements and aisle spaces required for the manoeuvre of transport and loading vehicles is adequate. Proper layout of roads will be ensured with the layout design module of the "SimStock" model.
iv. The production and dispatch schedules are the major input variables. They do not constitute major decision variables but feed back can be provided through the simulation model.

Entities

While developing a process interaction simulation model, the identification of entities that flow through the system and the resources the entities compete must be chosen prudently (Martinez and Ioannou, 1999). The entities considered in the simulation model development are finished concrete products which arrive in the stockyard according to production schedule, stay in the stockyard and are removed from the yard according to dispatch schedules. Similarly other entities are orders, and associated lorries. The loading vehicles are considered as resources, however, these are modelled as transporters of entities (products) from storage locations to lorry for loading or from plant to storage locations. Their service method is dictated by the order picking policy described later in this paper.

Schedules

The production and dispatch schedules define which product is produced when and where, and when it will be dispatched. The integration of these schedules provides information to calculate the state of inventory at any time; plant and products relationship; and product status in the yard relating time dimension. The period when maximum space required for each product and maximum space required for all products is obtained through the simulation. The production and dispatch schedule has been integrated with the simulation model through "VBA" interface in "ARENA" so that the output is also saved in "MS Excel" for analysis.

Products Loading (Order Picking) Policies

In general, applied to warehouse operations, order picking is the process of retrieval of number of items from their warehouse storage locations to satisfy one or more customer orders. In our case, it is refers the process of loading products into a customer lorry to satisfy one or more order by a customer. The policy followed in order picking (products loading) also affects the resource allocation and throughput time on the yard. The policies considered are Area, Zone or Sequential-Zone approaches.

In area system items are stored in a particular manner and the order pickers (forklifts or clamps) circulate through the area until entire order is filled. This policy has been a current practice in the industry.

In zone system, the yard is divided into zones and the order is distributed among order pickers, each picking item from his or her assigned zone. Once the products stored in one location are loaded, the lorry moves into other zone and requests for service.
In sequential zone system, each order is divided into zones and the order is passed from one zone to another. Many orders can be processed simultaneously as each proceeds from one zone to the next.

Optimisation

The decision to select which criteria should be given high priority and which one should be compromised is left to the managers so that there will be flexibility in decision making process and simulation model will be transparent. The optimisation considered in this research is to find the allocation of products to different locations so that cost of storage and retrieval is minimum and efficiency of stockyard is maximised. The genetic algorithms will be used to do so. The safety of operators and products in stockyard is ensured through the appropriate layout considerations such as stacking heights, width of road and proper routing of vehicles.

CASE STUDY

A detailed case study has been conducted to define the input parameters required to calibrate the model for validation. One of the stockyard sites of a major precast building products company in the UK (not named for confidentiality) was used as a case study. The company adopts make-to-stock principle to produce concrete products to meet the seasonal demand. Thousands of different products produced during winter are stocked on the yard. As an order is received, the products are shipped from stockyard to customers. A study conducted on the site reveals that the products are delivered countrywide utilising a fleet of between 65 and 205 vehicles per day. The stockyard occupies 76 acres of land. Through the analysis of 14000 orders, products were classified into A, B and C. A class, 24% of the products manufactured out of 1046, products comprised of 87% of orders. The details about how to generate simulated orders, lorry arrival patterns, frequency analysis results and modelling of stockyard in ARENA has been described in Dawood and Marasini, 2000; Marasini et al 2000).

An AutoCad drawing of the existing stockyard was developed using site survey and storage locations were identified to model the existing stockyard situation. The spatial inputs for the simulation model were derived from AutoCAD such as distances, loading stations and roadways.

REPRESENTATION OF LAYOUT IN ARENA

The layout is modelled in ARENA using distances, stations, queues, storages and free transporters. A typical layout and loading and dispatch animation has been presented in figure 7.

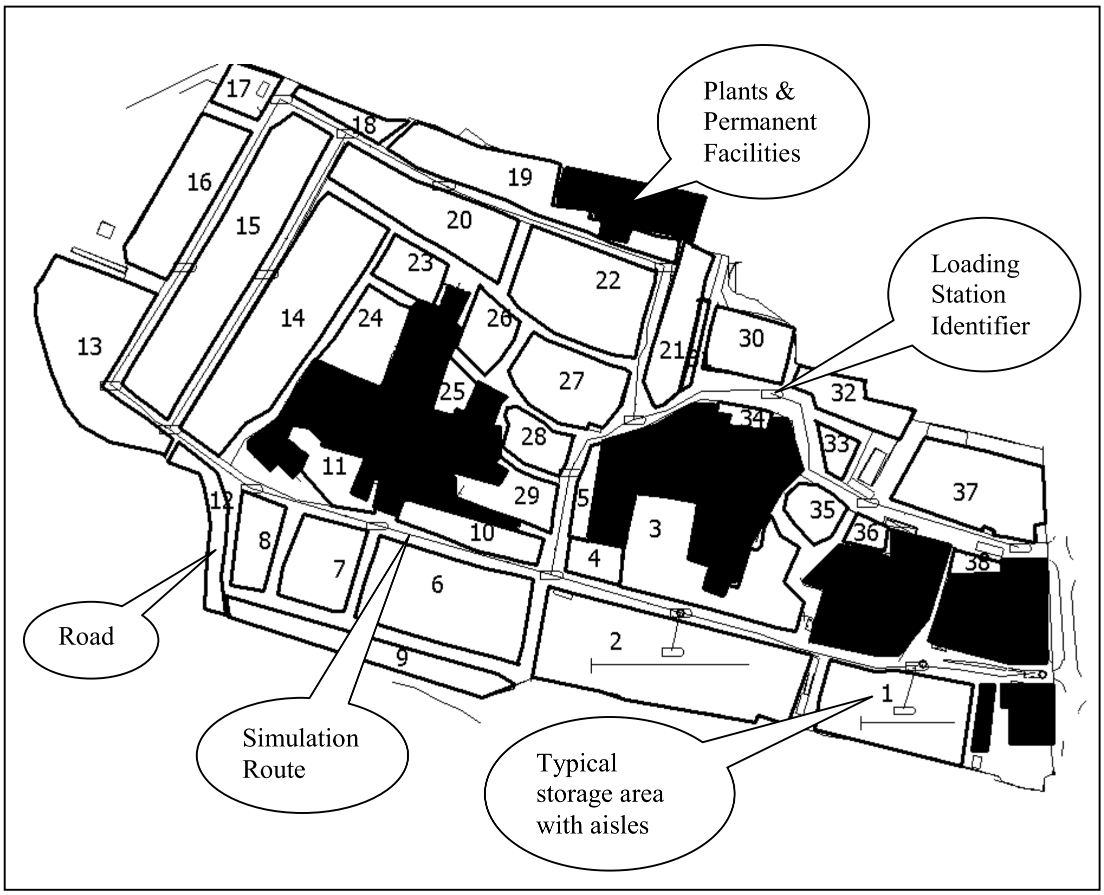
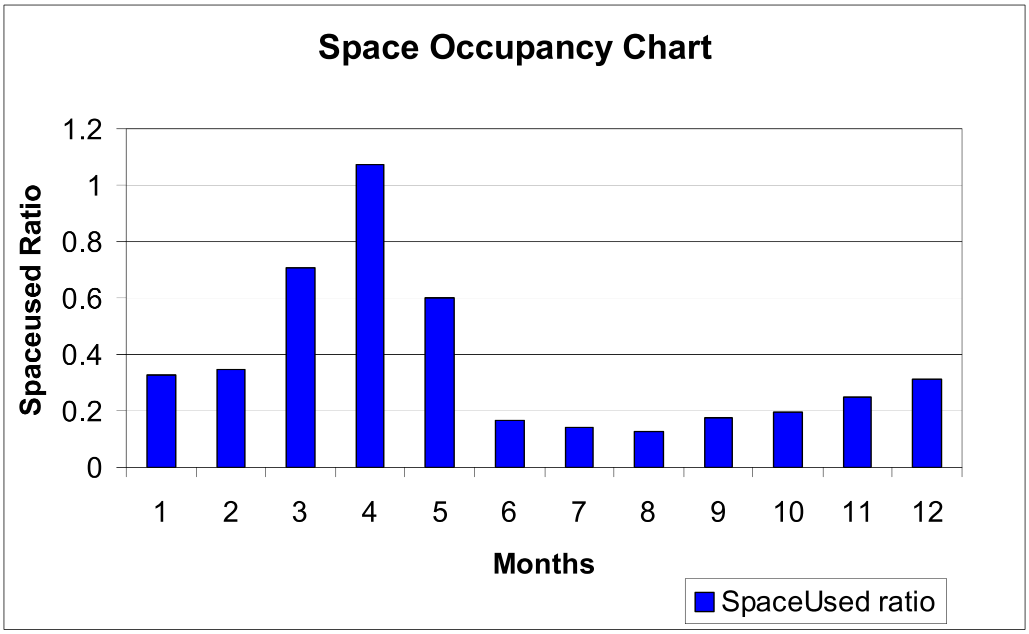


Figure7: Layout representation in ARENA 4.0

Simulation model run

With the large number of products involved, it was decided to model the stockyard with the class-"A" products for the first implementation and zoned area concept of order picking. The model was run using monthly production and forecast data to evaluate 1-day scenario for each month. Figure 8 shows the variation of space requirement for each month. The variation in arrival of vehicles in different hours of the day, monthly variations were accounted in the model. August was found as the average month.

26.1.1

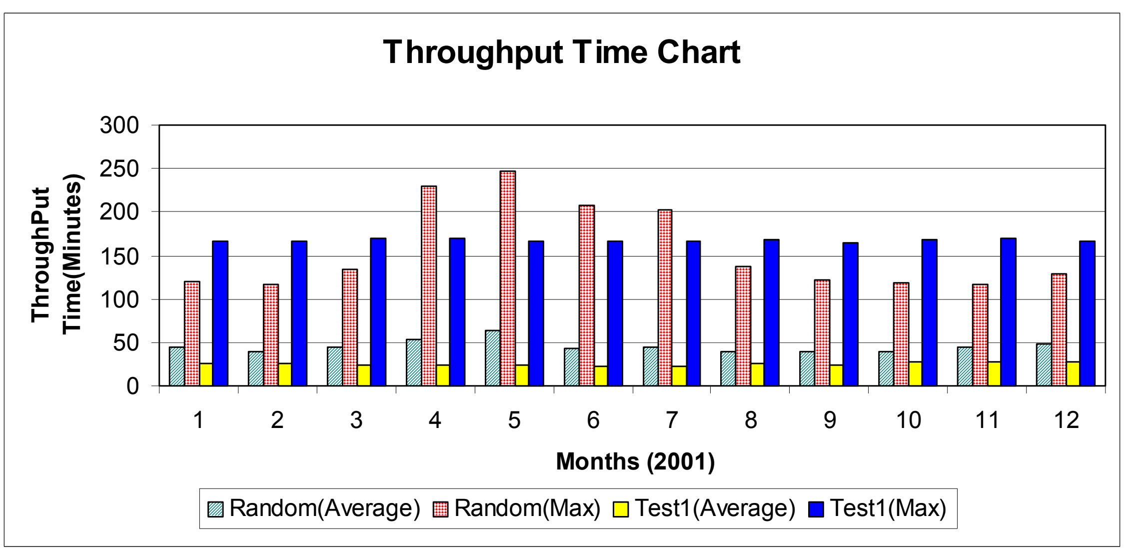


26.1.2

26.1.3 Figure 8: Variation of Space occupied

The queuing and throughput time has been plotted for two different scenarios created with different product- storage locations using 10 forklifts. One scenario was created with random allocation of products, and the second scenario using grouping of products.

Figure 9: Variation on throughput time with different assignment of products to storage locations



It can be seen from figure 9 that the allocation of products to different locations has considerable effect on throughput time. The throughput time is significantly improved from random allocation to grouped allocation (test1 scenario).

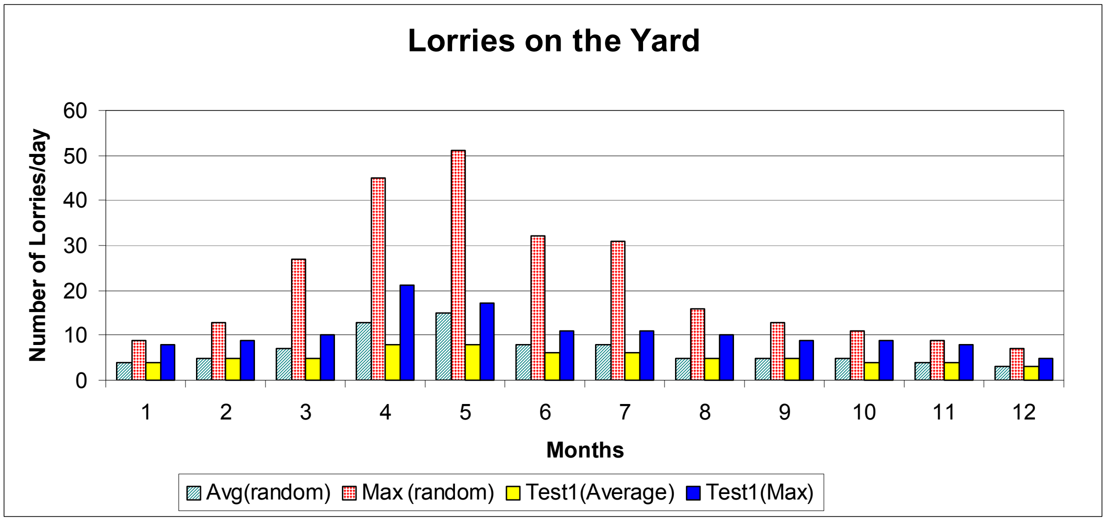


Figure 10: Number of Lorries on the stockyard

FUTURE INVESTIGATIONS

The complete analysis for the loading policies, routing policies, product allocation policies will be conducted. The integration of the 2D model with 3D visualisation, optimisation of allocation of products to storage locations using genetic algorithms will be studied.

CONCLUSIONS

In this paper the methodology to develop a stockyard layout for efficient stocking and retrieval of precast concrete products has been presented. A simulation model has been specified and developed using actual industrial data and Arena 4.0 as simulation modelling environment. The integration of production and dispatch schedules with the simulation has been achieved through visual basic for applications interface. To calibrate the model, data collection and analysis has been made. The preliminary results obtained from the simulation model revealed that the adopted methodology is suitable to optimise a stockyard layout. The model should be able to assist factory managers, stockyard managers, and production planners making a better decision regarding stock layouts.

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