SIMULATION APPROACH TO OPTIMISE STOCKYARD LAYOUT: A CASE STUDY IN PRECAST CONCRETE PRODUCTS INDUSTRY

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ABSTRACT: The precast concrete products industry supplies 2,000 to 4,000 of different products to the construction industry. The demand for the products is seasonal. The industry builds up the stock in winter to meet the high demand in summer. As large numbers of products varying sizes and weights are involved, different handling and stacking requirements, the process of deciding appropriate locations to stock the products and track them while loading into lorries for dispatch becomes complex. Due to lack of appropriate methodology to manage stockyard layout, the industry experiences space congestion for both the storage and dispatch of products on the yard. During dispatch process, greater retrieval time is required, long queues of lorries (shipping vehicles) are formed, and desired level of service cannot be maintained. This paper describes an ongoing research that addresses the stockyard layout management problem through development of a simulation model, which investigates the effects of using different layout scenarios and handling equipment on the performance of stockyard. A prototype model is being developed using ARENA/SIMAN, a general-purpose simulation language. The model integrates production and forecast schedules, evaluates "what-if" scenarios with different layout, product allocation to storage locations and order picking policies. The performance of stockyard is evaluated through vehicle waiting time, vehicle queue lengths, stockyard space utilisation and the cost of storage and dispatch of products. This paper presents the simulation modelling concepts, input data analysis, first prototype model development and the strategies used to develop an integrated layout evaluation simulation model.

KEYWORDS: simulation, stockyard layout, precast concrete products

1. INTRODUCTION

The stockyard considered in this paper is an area where precast concrete products are transported for storage after the production from the plants. To gain adequate strength, the minimum time of storage is the time for curing i.e. about four weeks. Some products need extended curing period of six weeks as well. Due to seasonality of demand, the products produced during winter stay for 4-5 months on the stockyard. The allocation of products to different storage locations on the stockyard influences the time for storage and retrieval of 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.

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). The review of literature in manufacturing facilites planning and on-site temporary facility planning in construction industry (Dawood and Marasini, 2000) has identified knowledge based layout generation and simulation based evaluation technique as a suitable methodology to solve stockyard layout problems. Touran, 1990, Doukidis and Anglides, 1994 discussing the issues and advantages of integrating simulation with expert systems/ artificial intelligence suggest that simulation models can be effectively utilised as evaluation tools. The simulation model specifications and development issues presented in this paper is one component of the computerised model being developed which is used to evaluate the layout generated using knowledge rules. The simulation model can be used as a separate model to evaluate any given layout and testing different policies for any given layout e.g. identifying optimum number of resources required, testing different order picking policies etc. Integrated with the graphical user interface (GUI) and optimisation component (Figure 1), it provides a means to evaluate different layout scenarios with different product storage allocations and select most appropriate solution for implementation.

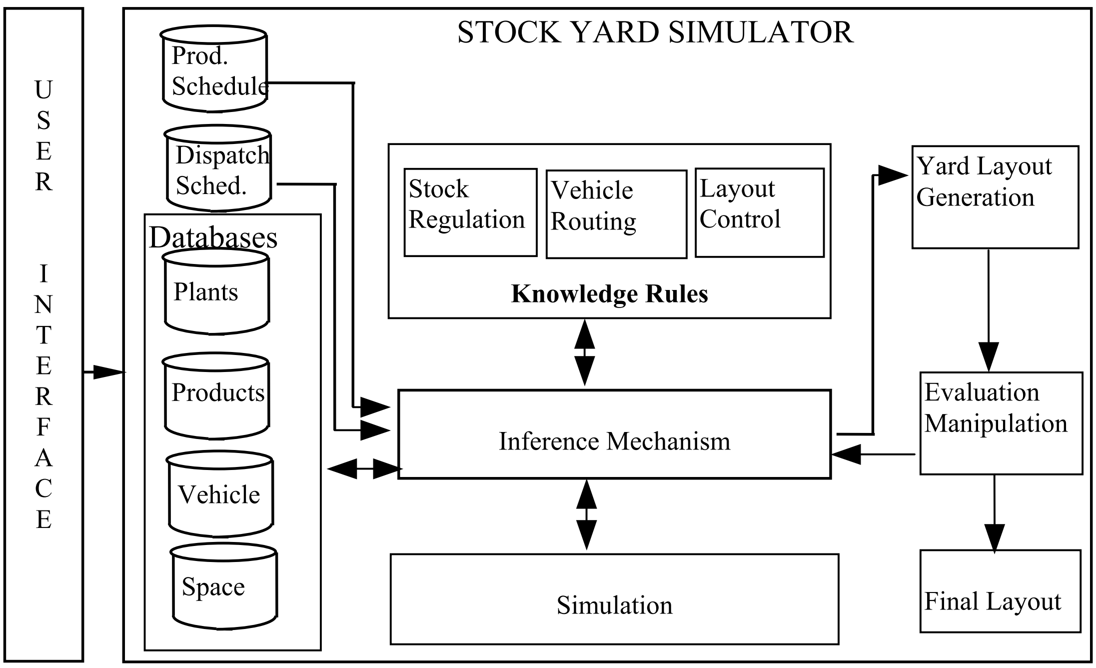

Figure 1. Stockyard Layout Management Model

2. SIMULATION MODEL

The simulation model is one of the component of stockyard layout optimisation model (Figure 1), which acts as a testing tool for a given stockyard layout. The simulation model is being 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 modelling. Three different processes viz. order processing, product transportation from plants to storage locations, and loading and dispatch process are simulated.

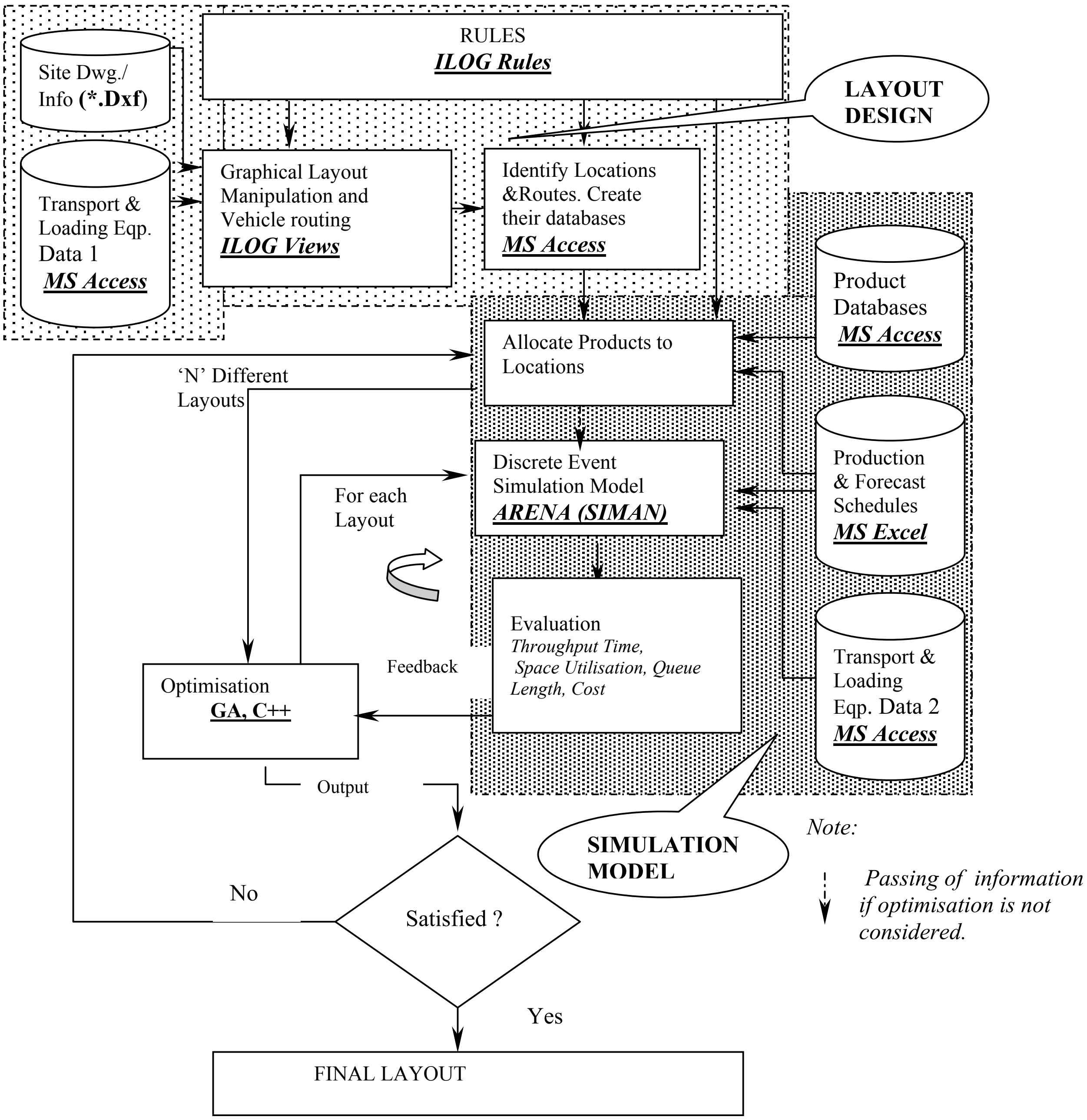

Figure 2. Simulation model and its integration with other components of Stockyard Layout Management Model

The simulation model evaluates the effects of different layouts on lorry waiting times and throughput time. 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 in terms of loading time, queuing time, service level, loading resource requirements, ease of rotating stocks, etc. Using knowledgebase system, a suitable layout will be generated. For a given production and dispatch schedule, the factory processes, including the loading and dispatching process for different layout scenarios, are being simulated.

The industry practice is to use "MS excel" to develop the production and dispatch schedules (Case Study & Industry survey, 99). So "MS Excel" schedules are considered as input. Using the VBA (Visual Basic for Applications) interface was developed to integrate "MS Excel" and "MS Access" with the simulation model. The simulation model development and associated components are described as follows.

2.1 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. This will be ensured with the layout component of stockyard layout management 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.

2.2 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 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.

2.3 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.

2.4 Testing Policies

2.4.1 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 may be:

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.

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.

Sequential Zone system

Each order is divided into zones and the order is passed form one zone to another. Many orders can be processed simultaneously as each proceeds from one zone to the next.

2.4.2 Single vs. multiple storage locations of products

The traditional approach has been to use single location for each of the products, though the location varies. The behaviour of stockyard when multiple storage locations for the fast moving products is considered, will be studied. The multiple allocation is based on correlation among item demands, thus allowing different exit points.

2.5 Simulation Modules

The simulation model integrates the following three distinct processes.

i. Order Processing,
ii. Products Transport into the Yard, and
iii. Products Loading and Dispatch Process

These three modules have been modelled separately and linked to study the holistic behaviour of the stockyard.

2.6 Evaluation

The simulation model evaluates the following:

i. Total Cost = Cost of Transport from Plant to storage, C_T + Cost of retrieval, C_R
Where,

C_T = Cost of Pick Up (C_P) + Transport Distance Cost (C_D) + Cost of Stacking (C_S)
C_R = 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

2.7 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.

3. 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, consists of 16 plants, 63 products storage locations and uses 12 loading vehicles.

3.1 Lorry Arrivals

The number of lorries arriving per hour were recorded for 29 days data during the month of May and June on the case study site. The data were analysed using data Arena Input Analyser. The arrival pattern of lorries is best described by Normal distribution with $(\mu,\sigma) = (13.5, 6.22)$.

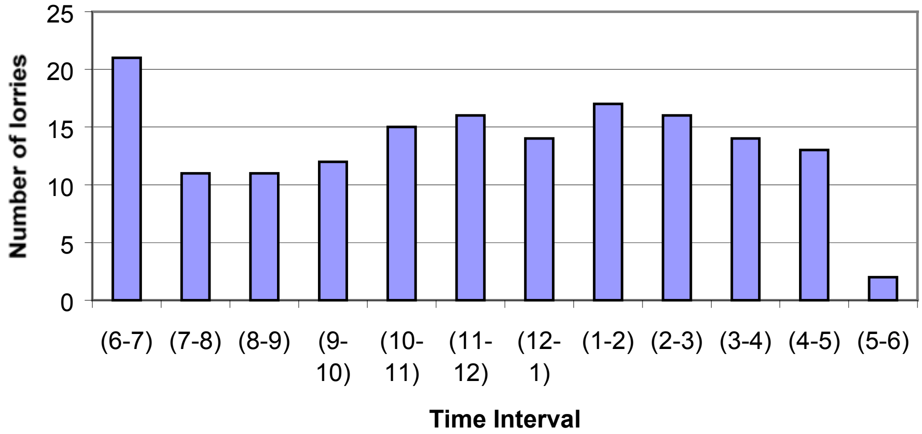

Figure 3. Hourly Lorry Arrival Graph

Figure 2 shows the average lorry arrival rates during different hours of the day. In order to model the hourly variation during the day, these data have been considered in the model.

3.2 Frequency Analysis

The historical data for the orders received from April to July'99 were also collected, and 14861 orders were analysed using frequency analysis that consists of determining the number of occurrences of each of the products in the samples of orders studied.

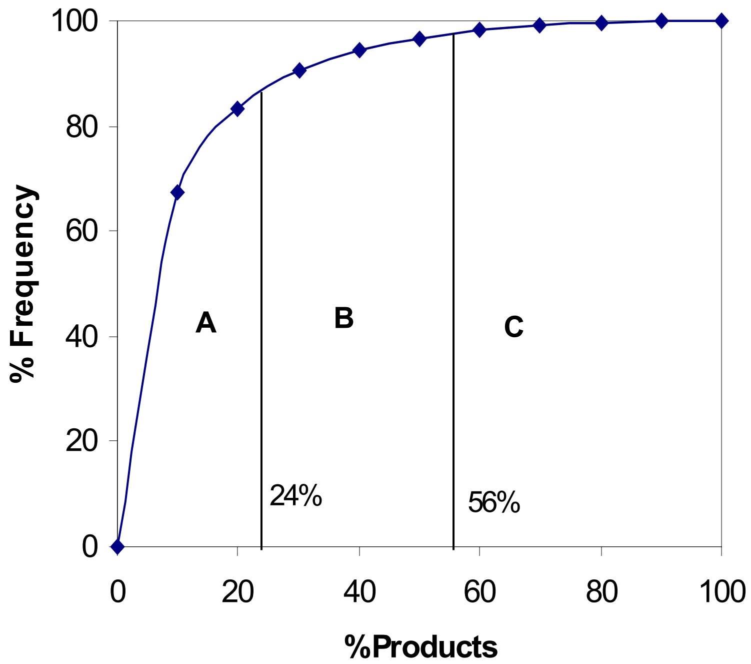

Figure 4: Frequency analysis of products based on orders

The objective of frequency analysis was to identify the most frequent products and allocate them in strategic locations on the stockyard. The analysis shows that, based on frequency, products can be grouped into different category such as popular products (A), medium products (B), and less popular products(C). The products having average frequency of one or more per day were classified as 'A' class; those having frequency less than one per day and greater than or equal to one per week were classified as B class products. Similarly, the products having frequency less than one per week were classified as 'C' class products. The graph of percentage products vs. percentage frequency in orders analysed has been presented in Figure 4. Among the products analysed, A class (24%) products constitute 87% of frequency; B class (32%) constitute 10.6% frequency and C class (44%) constitute only 2.4% frequency. It is thus seen essential to focus on 24% of products from management point of view on a first priority in modelling stockyard.

Other aim of frequency analysis was to correlate order and quantities with lorry arrivals in order to generate simulated order. Then probabilities for each of the products that will be in an order are calculated. The highest percentage that a product will be in an order is 6% i.e. in 100 orders, in the maximum 6 orders will contain a particular product. The maximum and minimum numbers of products in the orders analysed were found 49 and 1 respectively with an average of 6 products. The probability distribution that best describes the number of products in an order was analysed using ARENA input analyser, which is exponential with mean 5.65. The expression is 0.5 + EXPO(5.65).

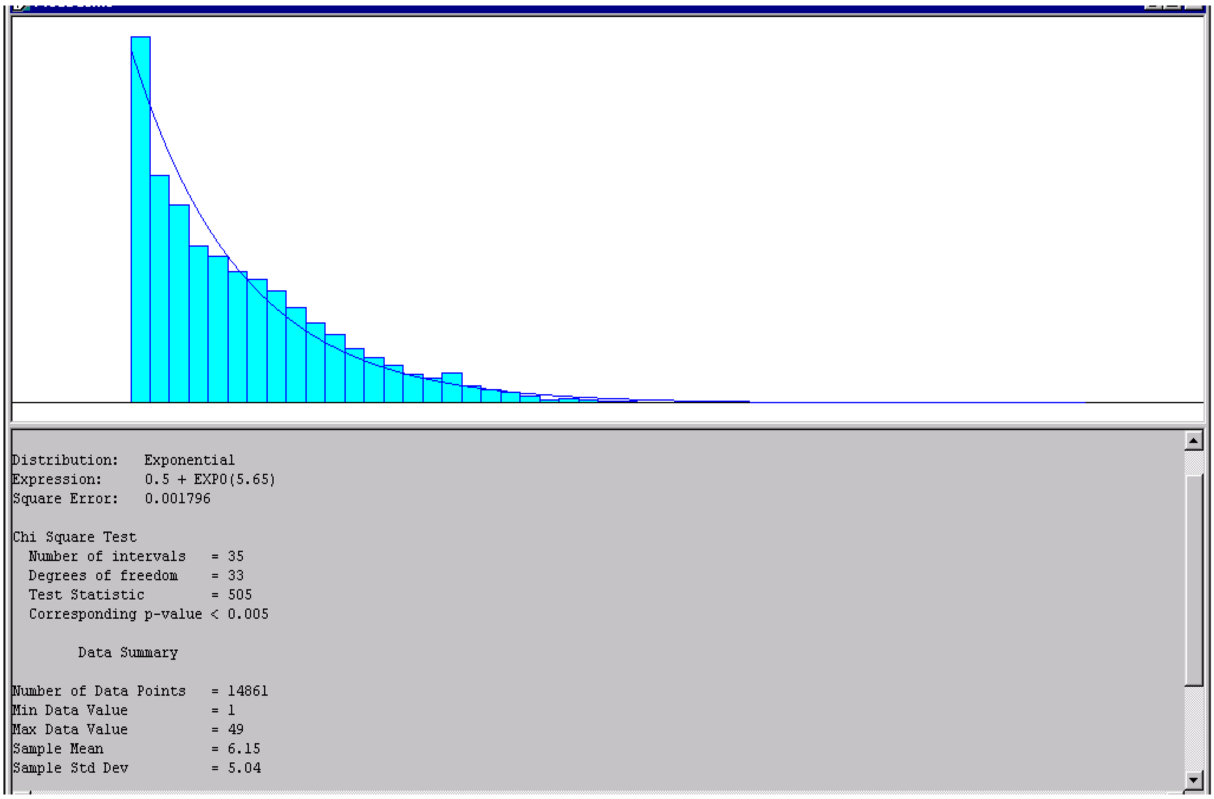

Figure 5: Probability distribution for number of products in an order (output from ARENA Input Analyser)

3.3 Service time for loading

The service time for loading depends on the number of products and quantity to be loaded. Using the velocity of travel, the distance to be travelled to find the product and unit load of handling for a given product, the service time is calculated within the model.

3.4 Layout Representation

The existing stockyard drawing was created using AutoCAD and imported as DXF file in ARENA. The concept of "station" and the "distance" elements used by ARENA (SIMAN) was used to identify locations and the route to travel. A sample representation has been shown in Figure 6 below. Each storage location is treated a queue where products produced according to production schedule are transported from plant drop-off points to storage locations (bays), encounter of delay of storage time, and removed from queue through loading and dispatch process.

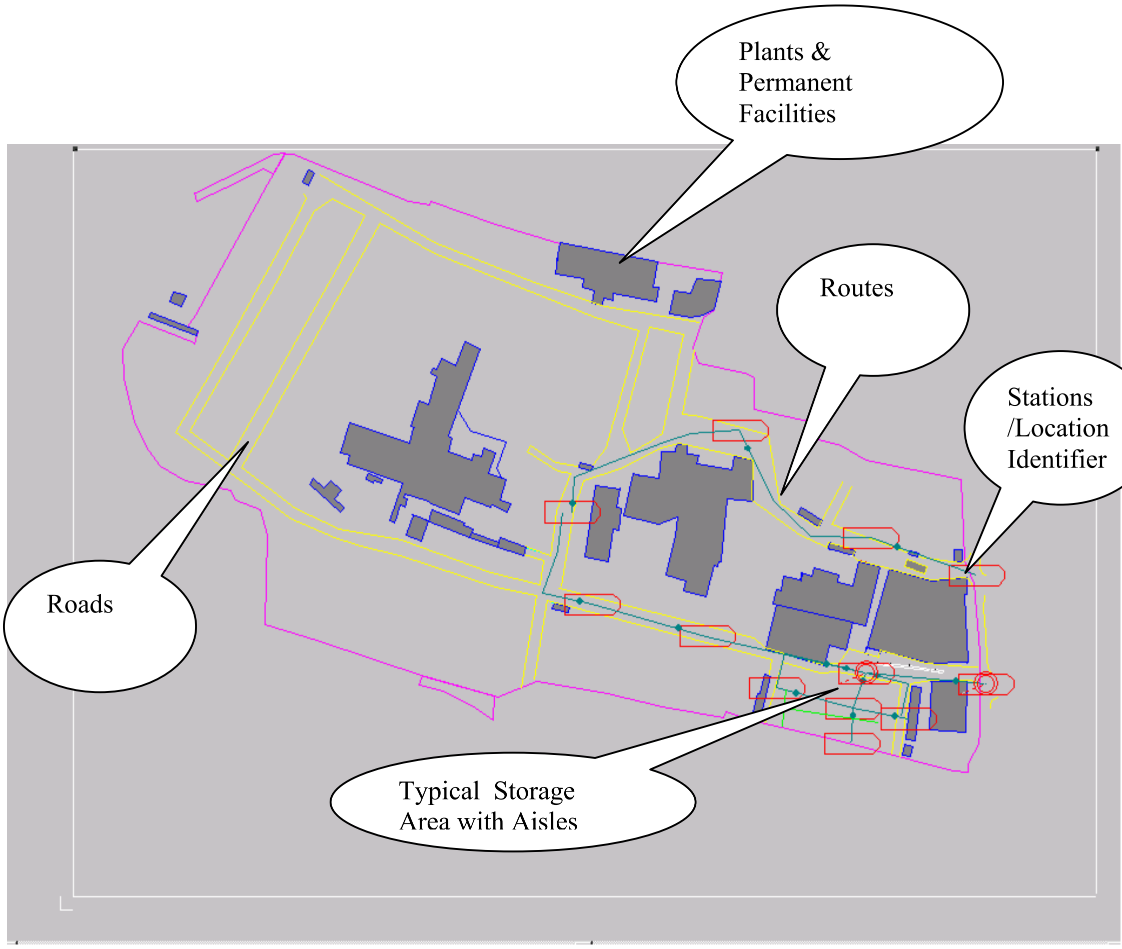

Figure 5: Sample layout and modelling of stockyard operations in ARENA

4. MODEL OUTPUT

With the large number of products involved, it was decided to model the stockyard with the class "A" products for the first implementation. The details presented in this paper have been designed using sample of five products only and zoned area concept of order picking. At this stage of development, though final outcomes could not be presented, the outcomes are promising to suggest that the methodology is appropriate to develop the simulation model.

5. CONCLUSIONS

This paper has presented the methodology and specifications utilised to develop a simulation model to evaluate the stockyard layout. The modelling strategy in ARENA (SIMAN) are presented. 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. With the full development of the model, it will be able to test the suitability of a given stockyard layout.

REFERENCES

Dawood, N and Marasini, R. (2000), Optimisation of stockyard layout for precast building products industry, in Eds Li, H., Shen,Q., Scott D., and Love, PED. *Implementing IT to obtain a competitive advantage in the 21st century, INCITE'2000 conference*, Hongkong, pp. 626-628.

Deukidis, G.I. and Angelides, M.C. (1994). A framework for integrating artificial intelligence and simulation. *Artificial Intelligence Review*, 8(1).

Dewdney, A.E. (1968), Simulation in planning freightliner terminals, in Seminar manual: The *Role of Computer in Distribution Management*, University of Bradford, management centre, pp 21-27.

Martinez, J.C., and Ioannou, P.G. (1999), General-purpose systems for effective construction simulation, Journal of Construction Engineering and Management, 125(4), pp.265-276.

Kelton,W.D., Sadowski, R.P. and Sadowski, D.A.(1998), *Simulation with ARENA*, McGraw-Hill, Boston, MA.

Touran, A. (1990), Integration of simulation with expert systems, Journal of Construction Engineering and Management, 116(3), pp.480-493.