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SimStock: A Stockyard Layout Planning Tool for Precast Concrete Products Industry

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Abstract
A prototype "SimStock" was developed for realising efficient stockyard layouts in Precast Concrete Products industry. SimStock consists of a process simulation model (developed in ARENA-simulation software) and the inputs to the simulation model include spatial data about the stockyard (derived from AutoCAD 2000), MS Excel production and forecast schedules, and sales and other data stored in MS Access databases. The simulation model evaluates throughput time for loading and dispatch of the products to service customer orders, queuing and waiting times of lorries in the stockyard and cost of loading of products in the stockyard for a given allocation of products to storage locations. Genetic algorithms were developed to identify the optimum allocation of products to the storage locations.The findings from the experimentation of SimStock using a case study are analysed and discussed and the suitability of the prototype is presented.

Keywords
Simulation, Stockyard Layout, Precast Concrete Products, Genetic Algorithms

1. Introduction

Precast concrete products industry is one of the major contributor of UK national economy and produces 1000-1500 different types of standard precast concrete products. The major clients are the Do-It-Yourself (DIY) stores and the construction industry. The demand for the products in seasonal; the industry adopts "make-to-stock" production philosophy and builds up huge stock of concrete products for supply in peak sales period, the summer. The industry invests huge capital in carrying stock and hence carries a great risk. In addition to cost and quality, efficient and timely delivery of the products is crucial to the industry for competitive advantage.

Stockyards under study store concrete products after production from the presses (plants) within the factory or transferred from other factory sites and the products are distributed to the customers from the stockyard. During the peak sales, the industry is facing space congestion for storage and retrieval of the products, queuing of distribution vehicles, long throughput time in the stockyards and wrong deliveries.

The stockyard layout is considered to be a major factor influencing throughput time for loading the concrete products for dispatch to the customers (Marasini et al., 2001). Previous production planning studies in the industry have not considered storage spaces as one of the major variables in developing production schedules. This study has investigated stockyard spaces and layout together with the business processes associated to the storage and retrieval of the precast concrete products. The stockyard is a hob of information about production, stock and sales. Therefore, a holistic approach to production, sales and stock management in consideration to storage and retrieval of products was used to model the stockyard layouts. A prototype "SimStock", was developed to support dynamic allocation of products to storage locations (and bays) and efficient vehicle routing in the stockyard.

2. Model Objectives

The objectives in developing SimStock to cater for the stockyard layout planning were to:

1. Identify the layout modeling approach for stockyard layouts,
2. Identify the key performance indicators for the stockyard layout planning,
3. Integrate production and sales forecast information to study space requirements,
4. Identify the efficient routing of vehicles in the stockyard, and
5. Enable dynamic allocation of products to storage locations for efficient storage and retrieval of the precast concrete products.

Details about the methodologies used and findings about the layout planning approaches and application of simulation modeling have been presented in Marasini and Dawood, 2000.

3. Inputs and Outputs of the Model

Databases, spatial information about the stockyard layout (output from graphical layout design), production and dispatch schedules constitute the inputs to the simulation model. In addition, vehicle arrival patterns, loading (order picking in general) policies, and orders (demand patterns) are also required to develop the simulation model. For a given layout, production and dispatch schedules, the loading and dispatch process is simulated to evaluate the objective parameters such as throughput time, loading time, queuing time, space utilization and loading resource requirements. Detail description of inputs to the simulation model has been presented in Marasini et. al. 2001. In summary, the inputs are:

- *Production and dispatch patterns*
- *Storage locations, their position and sizes*
- *Roads and their position*
- *Distances* between the storage locations and the travel routes, and velocity of vehicles are required to calculate the travel time and travel cost.
- *Knowledge of stacking requirements of products*: Bill of Materials (BOM) for each products with unit weight of storage unit, size of storage unit and recommended height of stock shell based on safety considerations;
- *Handling weight*: Unit weight of products in terms of number of storage units of products) handled by the forklifts for loading and stacking.
- *Loading equipment details:* Number of forklifts and clamps available for loading and transportation, their unit loads.
- *Lorries arrival pattern:* Lorries arrive at different rates during the service hours and their hourly arrival rates or inter arrival times are considered to develop the model.
- *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 this study, 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 and Zone System

- *Cost information:* The costs for use of forks to transport the products from the plants to the stockyard, to retrieve and load the products have been considered.
- *Mode of storage:* the concrete products are kept either in pallets or in a pack. Thus, the mode of storage in terms of packaging is fixed. Using the size of the storage units, the area required for a given amount of stock is calculated.

The key performance indicators (model outputs) to evaluate stockyard layouts were selected as following.

- Storage Space Utilization (SSU) ratio = storage space occupied / total available storage space
- Total Cost of storage and dispatch.
- Total cost = Cost of Transport from Plant to storage + Cost of retrieval
- Throughput time on stockyard for a lorry loading for the purpose of dispatch
- Vehicle waiting times and queue length in the stockyard

4. Development of the SimStock

Figure 1 shows development architecture of SimStock and the integration of information form different windows applications mainly AutoCAD (Autodesk, Inc), MS Access, MS Excel and Arena 4.0 (Rockwell, Inc.). The integration of information presented in the different applications format for stockyard layout planning was achieved using Microsoft's Component Object Model (COM) technology mainly using ActiveX automation, Data Access Objects (DAO) and ActiveX Data access Objects (ADO). The strength of Visual Basics for Applications (VBA) has enabled the development of customized integrated simulation model. The development of SimStock was achieved through the development of the following components:

- Development of user interfaces and design of databases to store and retrieve inputs to develop and run the simulation model.
- Development of simulation model logic and linking with other windows applications.
- Optimization of simulation model inputs, where applicable, to obtain desired outputs.

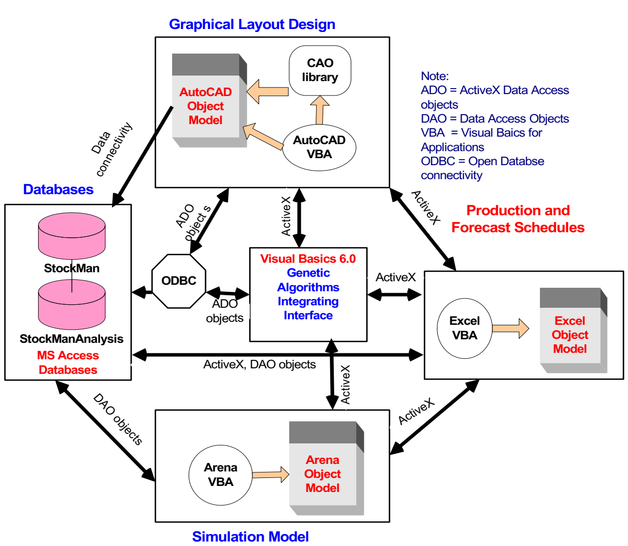

Figure 1: SimStock Architecture and Integration

Figure 2: Loading and Associated Stockyard Processes

The spatial layout of stockyard with roads and aisle network for experimentation and "what-if" analyses are designed in AutoCAD through a semi automated procedure. Users can use their experience or knowledge rules included in the system to develop the layout. The spatial information of stockyard is then exported to databases through the interfaces designed in AutoCAD using VBA; the 2D layout is imported in Arena simulation environment in DXF format, and the simulation model is built.

The simulation model represents loading and dispatch process of precast concrete products in the stockyard and consists of stock initialization (product arrival), order processing, lorry arrival in the stockyard, vehicles routing and loading processes (Fig. 2). The loading and dispatch process is as following. A distribution lorry arrives in the stockyard to serve an order placed by the customer. In the entry gate, a pickslip 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.

Specially designed templates in Arena (Marasini, 2002) are used to generate models quickly. In the simulation model, travel routes were modeled as a network of graphs. The sequence of visiting different storage locations to pickup the products to serve an order are calculated using the Fencl's heuristic algorithm (Fencl,1973). Dijkshtra's shortest path algorithm has been used to find shortest route to travel to different locations in the stockyard. The simulation model, which is customized to perform complicated tasks by linking it with MS Access and Excel using Visual Basics for Applications programming. The database structure used to derive inputs to the simulation model has been presented in Dawood and Marasini, 2001; Marasini, 2002. The inputs can be changed easily to generate and study several "what-if" scenarios; space requirement for different production and sales scenarios can be calculated and dynamic allocation of products to storage spaces is possible. Figure 3 presents an Arena animated simulation model run representing loading and dispatch of the products in the stockyards.

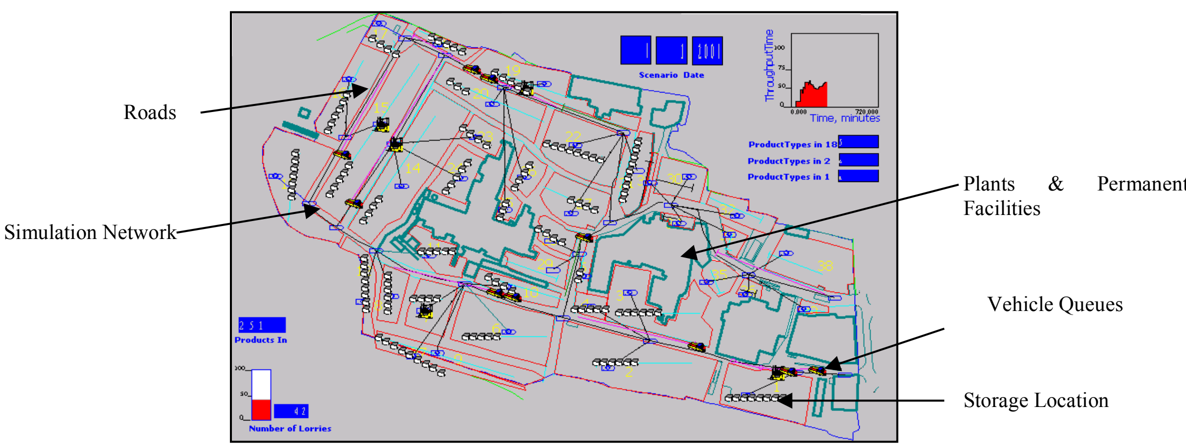

Figure 3: Running and Animation of the Loading and Dispatch Process

5. Simulation Run and Optimization

The stockyard layout simulation belongs to terminating type of simulation models (Refer Kelton et al., 1998 for detail descriptions). The simulation will start and terminate according to some specified rule or condition. For instance, the loading and dispatch process starts at 6 AM and finishes at 6 PM (until lorries being served are finished). The model runs 1-day scenario, which could represent a day for daily scenarios or an average day for the week based on weekly scenarios or average day for each month of the year for monthly scenarios being simulated. Due to unavailability of daily or weekly schedules, this study has used monthly scenarios and hence the model runs an average day for each of the month of a year. Therefore, the model runs to simulate one day scenario for each month to evaluate stockyard layout design by measuring the key performance indicators (KPI). For each replications, the run length was set to 720 minutes (6 AM to 6 PM). Statistics are collected about the entities, resources, variables, queues and cost of loading of the products.

In order to find out the optimum allocation of the concrete products to storage locations that will ensure minimum throughput time required in loading and dispatching the products from the stockyard, we have developed simple GA with integer representation in VBA and integrated with the simulation model. The optimization process and GA development could not be described in this paper due to limitations of space. The details have been presented in Marasini and Dawood, 2001.

7. Experimentation Using a Case Study

A case study was used to test and validate the simulation model in one of the major UK precast concrete products manufacturing company. Lorry arrival patterns, service times and generation of simulated orders for the purpose of simulation have been described in Marasini et al., 2001. Analyzing three peak months' sales history data, it was found that 24% (251 out of 1056 products) were ordered 87% of times with average frequency of one per day. These products were referred as A-class products. The production and sales information about A-class products was used to run the simulation model. The model was run by varying spatial configuration, production and sales schedules, resources, vehicle routing policies and order picking policies. Some of the examples are described as follows.

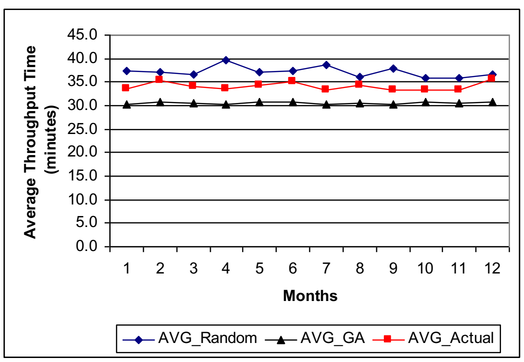

Figure 4: Variation on Average Throughput Time with Different Assignment of Products to Storage Locations

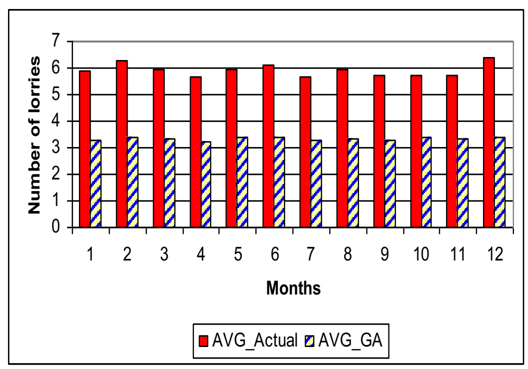

Figure 5: Number of Lorries on the Stockyard on Progress

To study the variation in average throughput time in different months of the year, the results of 25 replications made for each month for the existing, random and GA allocations were analyzed. Figure 4 shows the simulated average throughput time values for each months of year 2001 with a comparison of average values for existing, random and GA allocation. From the experimentation (Marasini, 2002), it is concluded that:

- The allocation of products to storage location in the stockyards has significant impact on throughput time for loading and dispatch of concrete products. The queuing of lorries in the stockyard is also reduced.
- The GA allocation of products has reduced average throughput time by 3.13 and 6.68 minutes as compared to existing and random allocation of products for the analyzed scenarios. The average

throughput time for GA allocation being 30.5 minutes. This has proved the potential of GA to solve the allocation of products to storage locations.

Figure 5 shows the average number of lorries being serviced in the stockyard for different months. The existing (referred as actual) scenario has shown higher number of lorries. It is inferred that the GA based allocation has reduced number of lorries in service in the stockyard and therefore, queues will be smaller. It should be borne in mind that the figures are indicative due to the use of A-class product's production and forecast of sales data. However, it justifies the objective of the study.

8. Conclusions

The study presented in this paper has investigated in-depth the stockyard layouts, the allocation of products to storage spaces and stockyard space utilization for different production plans. A process simulation model was developed that demonstrates a methodology to model stockyard layouts. Genetic algorithms were developed and used to identify the clusters of products that are frequently ordered together and to assign the developed clusters to storage locations. The integration of genetic algorithms with the simulation model has demonstrated an approach to optimize simulation model inputs to obtain desired outputs; an example is the identification of allocation of products to storage locations to reduce throughput time to service orders in the stockyard. Genetic algorithms, integrated with the simulation model, have proved to be potential techniques to identify the allocation of products to storage locations. This was justified by the significant improvement in average throughput time to service orders using GA-based allocation of products to storage locations as compared to the random and existing allocation of products in the case study site. It was established that process simulation model could be efficiently used for stockyard layout planning and their evaluation. The model aids decision-making process by providing a means to evaluating different "what-if" scenarios with different production schedules, storage policies, loading (order picking) policy and different spatial layout of stockyards.

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