Simulation of a Libyan Cement Factory

Elbahlul M. Alghadafi and Muhammad Latif

Abstract-**Due to the inherent complexity of decision making in supply chain management (SCM), there is a growing need for modelling supply chain systems with different methodologies. A large number of manufacturing organisations in particular the cement industry in Libya is seeking techniques that can help, identify and implement strategies for developing and improving their supply chain network. Developing a supply chain management system requires the analysis of the manufacturing processes from the initial sourcing to the end customers.**

The paper reports that the Libyan cement industry has problems related to its productivity. In order to face these problems, cement factories need to increase their production. To accomplish this, they require a clear strategy towards an efficient supply chain.

The paper discusses the need to investigate SCM strategies that will enable the cement manufacturing industry of Libya to move towards an increase in cement production and reduce its costs. Witness simulation software has been used to model the manufacturing operations at a specific cement plant in Libya. The various stages of cement production are identified and used in the model construction. It is believed the model constructed through experimentation and optimisation will enable the most productive and cost effective changes to be made to improve their SCM and performance.

Keywords: Supply Chain Management, Cement, Simulation
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1. Introduction

Libya like many countries in the Middle East has been facing productivity-related problems in its manufacturing industries. More specifically, in the coming years, Libyan cement factories have realised the need to increase their production to achieve the construction demand of the country [1]. One methodology being considered is to review Supply Chain Management (SCM) of the cement industry.

Supply Chain Management refers to a managerial process, concerned with the process of planning, organizing, and controlling the flow of materials and services from suppliers to the end users/customers [2]. This integrated approach incorporates suppliers, customers and logistics. SCM is often used to balance customer's demands with the need for profitable growth; many companies worldwide have moved aggressively to improve SCM. Management of the cement supply chains will enable manufacturing operations and integrated logistics into seamless pipelines to maintain the continual flow of cement from the raw materials source to the final customers [3].

Libya has recently started their economic and structural growth. This growth will need to be increased in order for the infrastructure to be developed within five years [1]. This requires extensive and intensive operational and country-wide efforts. Libya will face challenges in the future, more so than they do at present [4].

2. Cement Manufacture

Cement plays a key role in our lives; it is a basic material for all types of construction, including housing, roads, schools, hospitals, dams and ports and may even be used in decorative items such as tables and bookcases. In general, cement is a mixture of limestone, sand, clay and iron. The most common type of hydraulic cement is Portland cement. The term hydraulic cement is used because cement hardens when mixed with water. According to the Portland Cement Association [5], Portland cement is a closely controlled chemical combination of calcium, aluminium, iron and small amounts of other ingredients to which gypsum is added in the final grinding process. Portland cement may be grey or white, but blends can be generated based on the two products. Cement is the major component of concrete. Concrete is an artificial rock, a material made from a proportioned mix of hydraulic cement, water, fine and coarse aggregates, air [6], and sometimes additive concrete can also be made from a ready-mix formula in a concrete plant. Concrete is one of the most important and widely spread building materials in the world. The process of cement supply chain is shown in figure 1 [7]. Figure 1 show how the upstream cement supply chain operates, including sourcing of raw material, manufacturing and delivery from the plant.

There are two main steps in cement production. The first step is the production of clinker from raw materials. The second step is the production of cement from clinker. The first step requires raw materials to be transported to the plant and to be crushed and homogenized using a large rotating drum called a kiln. The kiln is heated to very high temperatures, and then it is inclined, allowing the raw materials to roll to other end, where they are quickly cooled. The result is a solid grain called clinker. The second step is the transformation of clinker into cement in the grinding mill. Additional elements like gypsum, and perhaps other minerals, might be aggregated to obtain a fine powder called cement. Finally, cement is moved into storage until a customer places an order.

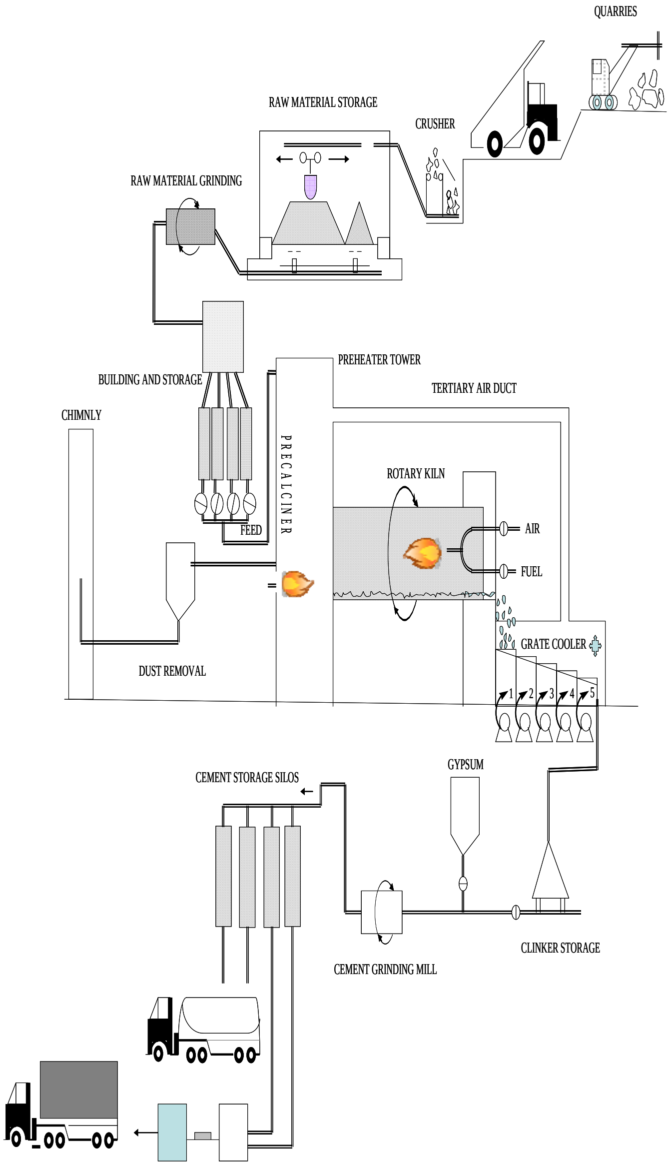

Figure 1: Upstream Cement Supply Chain [7]

3. Current Status of the Libyan Cement Industry

Libya is a developing country located on the coast of the Mediterranean Sea. It is mainly a petroleum producing country with a cement industry, required to develop the country's infrastructure. However, it is recognised that the cement industry is unable to meet the construction demands of Libya and international markets [8] According to World Report International [9] some industrial companies and plants within Libya are operating below their potential, achieving only 50% of their full production capacity. The current status, taking into consideration all the facts, suggests opportunities exist to improve the manufacturing sectors in Libya [4]. The Libyan cement industry primarily needs to meet the internal demand. The International Advisory Board [9] concludes that there is no overarching strategic plan in Libya; it points out the need for better management of industrial organisations that will contribute to competitiveness and growth of the country.

The international cement production industry is considered to be a highly competitive industry. It is important to Libya because of its strong contribution to GDP. Libya has paid strong attention to this industry as all the raw materials required to produce the cement are internally available. The importance of cement to the construction sector as well as infrastructure development is paramount because it is extensively used in most major civil engineering projects. The government should be planning a new strategy to reach requirement national market. This makes the cement industry an extremely important manufacturing entity requiring further development and better organisation. Because of its importance, the cement industry in Libya has been targeted as a high priority for upgrade with advanced manufacturing technologies. It must be managed effectively, requiring application of recent advances in manufacturing technologies and managerial techniques. The country is committed to developing its manufacturing ability to produce cement effectively, to meet the needs of the present markets and aims to achieve World Class Manufacturing (WCM) status.

4. Research Objectives

The problem is that cement production in Libya is operating at substantially below full capability. Modern manufacturing methodologies, such as Just in Time (JIT), Manufacturing Resource Planning (MRPII) and Total Quality Management (TQM) are known to have solved some capacity problems within other manufacturing industries of Libya [4]. However due to inherent localised operational issues such methodologies are likely to face severe implementation problems. To assess the management commitments on implementing the most effective managerial and philosophies techniques are JIT, MRPII and TQM [10]. Implementation of these techniques could play a big role in increasing the cement production and reducing the cost [4]. Libya is committed to satisfy the customer needs, and this satisfaction cannot be achieved without using computing models as success has been achieved using these techniques in the cement industry of Romania [11]. Solving the problem by using computer based simulation would minimise the risks associated with any operation changes and could play a big role in leading to an increase in production and reduction in cost [12].

The overall aim of the research is to investigate SCM strategies that will enable the cement manufacturing industry of Libya move towards (WCM). However, this paper focuses on exploring cement manufacture in Libya and the development of a simulation model using Witness software.

5. Simulation of Cement Manufacture

Modelling and computer simulation are accepted problem solving methodologies for the solution of many real-world problems [13]. One of the largest application areas for simulation modelling is that of manufacturing systems. Computer simulation refers to methods for studying a wide variety of models of real-world systems by numerical evaluation using software designed to imitate the system's

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operations or characteristics, often over time [14]. SCM is used by every successful organization, thus, a production planning and control model that focuses on all the aspects of the operations is needed. The supply chain management model should also perform the task of managing and coordinating activities upstream and downstream in the supply chain. Of course, such a model in its entirety becomes very complex and can not be used without a sufficient computational infrastructure.

Simulation is a concept that involves building a model, which mimics reality. Visual interactive simulation software creates a dynamic, computer-based model representing a physical system. Several processes may take place and includes simulation structure, resources and activities. Simulation involves the modelling of a system as it progresses through time. It gives the ability to model random events based on standard or non-standard distributions and to predict the complex interactions between those events. The process of designing a Mathematical-logical model of a real system and experimenting with that model using a computer is the basis of computer simulation [15]**.**

Simulation is used to describe and analyze the behaviour of a system, ask what if questions about the real system, and aid in the design of real system both existing and conceptual systems can be modelled with simulation. Also simulations are helpful for managers to understand their working environment for solving the complexity of system, documentation and to produce quick reports [16].

In the first instance it was decided to use Discrete Event Simulation (DES) and then migrate to a combination of discrete and continuous simulation. DES is a process through which a model mimics the behaviour of a discrete system event by event. Qualitative and quantitative data from the process are obtained to predict the behaviour of the system and its level of performance. Simulation has two basic motives, quick response to determine the correctness of system behaviour and performance prediction. Some performance measures of interest are throughput, resource utilization, buffer capacity, yield, and effects of failures. The software model can capture all the dynamics and interactions of real system. Since real manufacturing systems are expensive to build. Simulation is an important means to predict performance accurately, investigate effects of parameter changes, identify bottlenecks and choose the best design among alternative [17]. A model contains entities, attributes, events, activities and the interrelationships among them. The collection of entities and their statuses define the system state [15]. A system state may change only at discrete points in time.

Cement manufacture is inherently complex to model and simulate. In this respect, company X (a Libyan cement factory) agreed to participate in the research project and provide the necessary operational information for the construction of a simulation model using Witness software.

6. Stages of Cement Manufacture

The production of cement involves a number of processes and stages as shown in figure 2, these are introduced next.

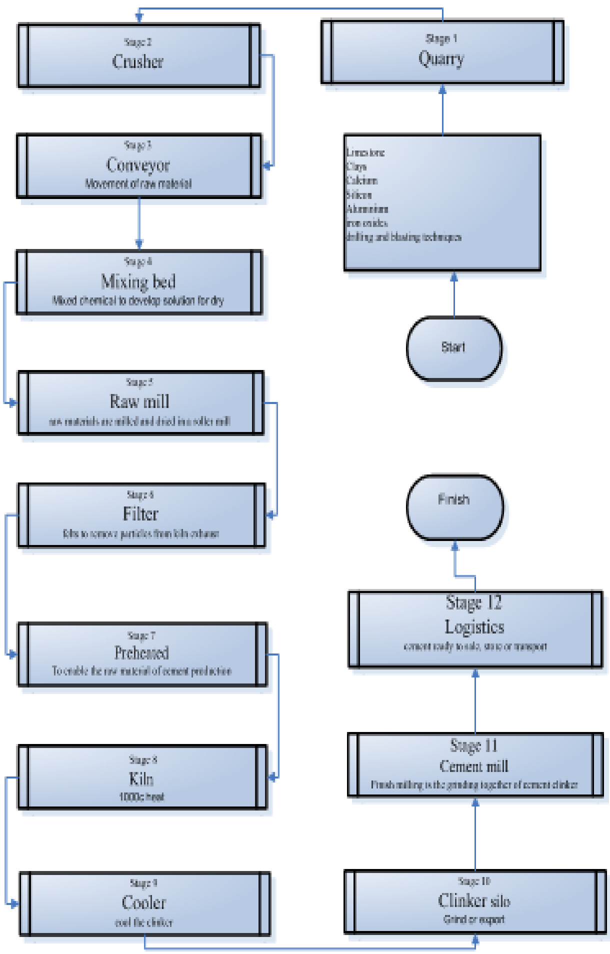

Figure 2: Stages in Cement Production

<u>Stage1: Quarry</u>
Typically limestone, and clays as well as other materials containing the required proportions of calcium, silicon, aluminium and iron oxides are extracted using drilling and blasting techniques. In this stage transportation of raw materials from the quarry using trucks and loading/unloading facilities specific to the cement plant are also considered

<u>Stage 2: Crusher (Grinding)</u>
The quarried material is then reduced in size by compression and/or impact in various mechanical crushers, Crushed rock is reduced in size from 120 cm to between 1.2 and 8 cm drying of raw material may also be necessary for efficient crushing and blending.

<u>Stage 3: Conveyor</u>
Transportation of the crushed material throughout the plant is achieved using some form of powered conveyor.

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Stage 4: Mixing bed
The crushed limestone and clay is homogenized by stacking and reclaiming in a long layered stockpile. The material is then ready for milling and drying in the kiln.
Stage 5: Raw mill
The raw materials are milled and dried in a roller mill. Heavy rollers are held over a rotating table and the course material is milled until it is fine enough to be carried by air to a homogenizing silo.
Stage 6: Filter
Bag filters comprise filters of either woven fabric or needle felts to remove particles from kiln exhaust. The exhaust gas from many kilns is used for drying raw materials, thus improving the energy efficiency of the plant.
Stage 7: Preheating
Cyclone pre-heaters enable the raw material of cement production to be preheated before entry in to the kiln. This increases the energy efficiency of the kiln as the material is 20-40% calcined at the point of entry into the kiln.
Stage 8: Kiln
The kiln is designed to maximize the efficiency of heat transfer from fuel burning to the raw material. In the preheated tower, the raw materials are heated rapidly to a temperature of about 1000^{o}c, where the limestone forms burnt lime. In the rotating kiln, the temperature reaches up to 2000^{o}c. At this high temperature, minerals fuse together to form predominantly calcium silicate crystals-cement clinker.
Stage 9: Cooler
The molten cement clinker is then cooled as rapidly as possible. The ambient air used to cool the clinker is then fed into the kiln as combustion air-ensuring high utilization of the heat produced.
Stage 10: Clinker silo
The clinker may be either stored on site in preparation for grinding to form cement or transported to other sites.
Stage 11: Cement mill
Finish milling (cement) is the grinding together of cement clinker, with around 5% of natural or synthetic gypsum.
Stage 12: Logistics
Final cement is stored or transported.

7. Model Building using Witness

To model the manufacture of cement in company X it appeared logical to use the stages already described in the earlier section.
Each processing stage was mapped directly into the discrete elements available within Witness. The basic elements enabled entities (quarry materials) to the flow through the manufacturing processes using activities, buffers, resources, transporting elements etc.

Model Stage 1

The first stage of the model is demonstrating the initial steps of the cement manufacturing processes. Raw material(s) from the Quarry is transported by vehicles (trucks) that move on a track that follow a truck route to the separator machine (figure 3). The separator machine separates the heavy and light weight raw materials into two different process lines for the crushing (grinding) operation. After grinding the raw material a conveyer transfers the raw material to a pre-blending plant.

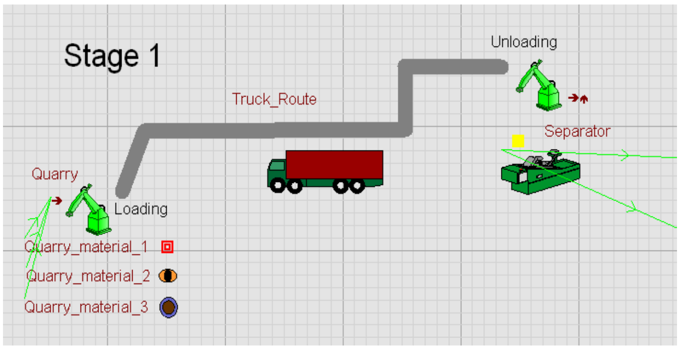

Figure 3: Model Stage 1

Model Stage 2

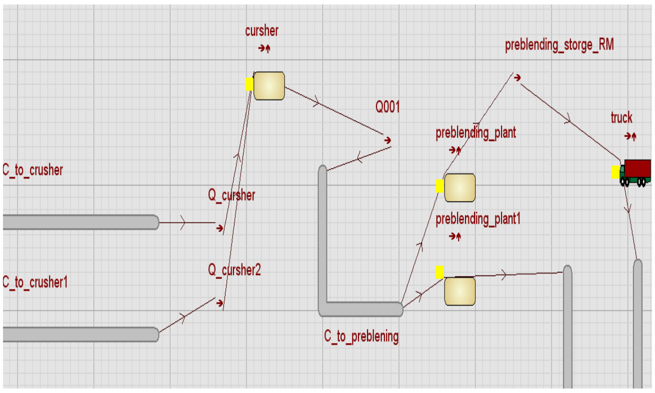

Figure 4: Model Stage 2

Figure 4 illustrates the grinding process. The grinding process in cement industries is performed by addition of liquid. So after preparing the raw material it is necessary to store the raw material for further processes in preparation for the next stage.

Model Stage 3-11

These stages were implemented as appropriate using the necessary Witness modelling elements. Details of these stages are not given here but will form the basis of another publication.

Model Stage 12

Figure 5 illustrates the final stage. The final stage is filtration and packaging. After filtration, another machine dries the product and the packaging process starts. Finally cement may be transported pre-bagged or as a bulk powder. The method of transportation varies according to location – and may include transport via truck, rail or ship.

8. Simulation Run

The length of the simulation was 14 hours (840 mins) as this reflected the observational data that was available. In addition the time period was chosen in order to detect any variance in the time scale with relation to the system. For example the separator period may be apparent or the lead- time may have notable peaks.

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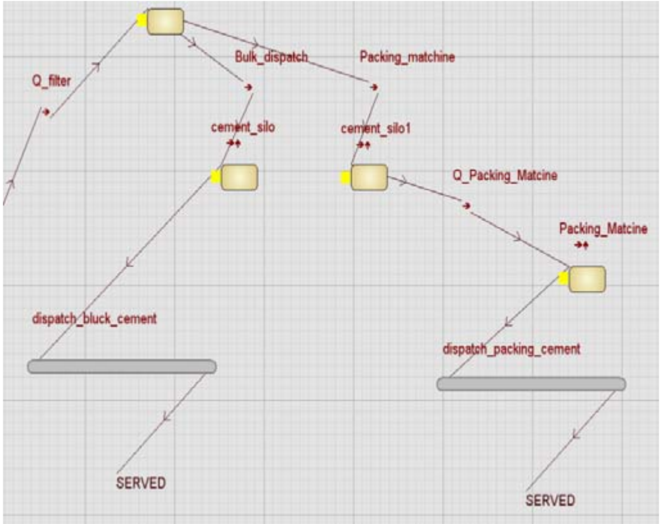

Figure 5: Model Stage 12

The simulation model was executed and the resulting animation observed to verify its correctness.

The model verification process at this stage is incomplete but is being performed to ensure that the constructed computer simulation models the system properly. After numerous iterations and careful examination of the logic structure, inputs, and outputs were correctly represented in the computer model, verification is still ongoing. Simple cases and common sense will form the basis of the verification process.

It is planned that Witness animation and associated techniques will facilitate the validation process; this ensures that the model is an accurate representation of real system. Once this is achieved the model developed has the potential to be used as substitute for the actual system for experimentation and the predication of performance with a high level of confidence.

From the simulation runs, it became obvious some inconsistencies existed as bottlenecks exist in various stages of the model. Therefore it is inappropriate to discuss results obtained so far.

9. Conclusion

SCM often spans a large number of inter business departments and across several businesses to deliver the product that the customer requires. In this research more emphasis is given to the design of supply chain management by simulation processing industry (Libyan cement industry). It addresses the importance to implement computer simulation through a system example. Simulation would support and develop the present SCM of the cement factory X. Simulations can be created modelling each separate part of cement supply chain. To begin building the model, there was a need to divide the cement manufacture processes into stages; each stage would be directly mapped into the simulation model. The idea of the model was to create a working map of any stage considered. Stages were used in Witness as they provided a timed event when the entity flowed through the processes modelled. The time between manufacturing stages can be reduced. A manufacturing system can be changed, analysed and reported without disturbing the ongoing production process. Variant disturbances of duration affect the production schedules can be configured with the use of simulation. A change in the production can be investigated for plausibility before being implemented. Production times can be recorded from the simulation software and a comparison made to other operations. Alternative statistics may be produced from the system at any given stage in a production run, for example increase the capacity feed bin, increase supply of raw materials. The second major objective is to validate and verify the simulation model by using pilot data obtained from company X. The simulation model constructed so far has huge potential as a test bed to perform experimentation. It is planned to verify and validate the current simulation model until strong confidence in its results is obtained.

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