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Investigative SCM in Africa Bottling Operations LTD By Using Simulation Modeling Software Arena

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***Abstract*— Today's global beverages companies invest huge amount of capital as assets where the surge of the globalization has swept across all industries. The isolated national economics change situation completely because today's economic systems reorganized in united common global and dependent economic system. The performance of production line is highly influenced by bottlenecks, blockages and stoppages. The research demonstrates a new approach in solving problems with capacity issues associated with machines and conveyors when applying SCM process in the factory to meeting customer demands. While we increase input load to meeting customer demands in certain level the issues start to arise as bottlenecks appear and further backlogs and blockades, so that no directly implementation of SCM philosophy due to disruption to the actual organization, no smooth flowing of materials throughout the entire system, increase in process inventory level and long period of time is required. Hence before enable SCM to work we need to ask that "what will be the end result" on other hand necessary investigate or test SCM process in beverages factory before implementing SCM. we solve the problems by using Arena simulation Package that enables the development of discrete and continuous simulation models used as management tool support SCM implementation, by examine existed plant manufacturing process at different simulation scenarios in small period of time without disruption to the actual organization. A simulation model is developed by using ARENA simulation software**

used to analyze and test several bottlenecks that are causing severe congestions in different areas on the production line and could resolve all of these bottlenecks. The simulation model run as rebuilt (15) replication with (22.5 Hr) runtime and (6 Hr) Warm up period. Simulation results show the line bottlenecks, workstations utilization, buffer capacities, line production rate and efficiency for each scenario. The result as production line in Africa Bottling Operation ABO unsustainable for SCM implementation (unsatisfactory) because the factory subjected to capacity issues as start to implement SCM process as case of high risk (Risk Avoidance).

Keywords— Supply Chain Management, Just in Time, Total Quality Management.

I. INTRODUCTION

Fierce competition in today's global markets, the introduction of products with shorter life cycles, and the heightened expectations of customers have forced business enterprises to focus attention on their supply chains[1]. One of the most products consumed in the world are beverages so beverage industry in Libya need to improve to satisfy customer and required more competition in local markets. The surge of globalization has swept across all industries and has accordingly provided many opportunities for the well-established industries . Prior to the globalization surge, national economies were isolated one from another, change situation completely because today's economic system united on common global and dependent economic products consumed in the world are beverages so beverage industry in Libya system.

Globalization brings opportunities and challenges to the beverages industry [2]. It simply provides the opportunity for the international beverages company to increase their investment by increasing their production to meet local growing demand and also the opportunity to expand their businesses in newly growing international markets. On other hand beverages industry faces new challenges of higher competitions . Customers demand in areas of quality and time are even increasing and to win the competition, companies need to cooperate more than before. All these elements bring supply chain management (SCM) to front of company managers.

Supply Chain Management integrates supply and demand management within and across companies, have also defined SCM as " The task of integrating organizational unites a supply chain and coordinating materials, information, and financial flow in order to fulfill (ultimate) customer demands. SCM is used to help increase efficiency by meeting customer demands in an effective manner. The simulation modeling software (Arena) used as a Benchmark tool to facilitate of innovate or applying of SCM in beverages factory and combat capacity and efficiency issues [3].

II. AFRICA BOTTLING OPERATION (ABO)

ABO uses continuous flow for manufacturing its products and uses the product-focused strategy. It has set standards of its products that are produced in high volume with low variety[4].

ABO currently has three line operational PET 1, PET 2 and CANS. These lines use continuous planning for production. They forecast their sales for each week and then produce accordingly. Each line produces Approximately (30,000) cases of beverages daily and for every change in beverage the equipment is cleaned which is time-consuming approximately from (4-6 hours) and costly. Once the PEPSI Company converts the ingredients into the syrup. The product concentrates are shipped to bottling plants across the globe. At the bottling plant, the process starts from manufacturing of bottle and preparation of final syrup. The treated and cooled water is mixed with the final syrup and, for sparkling drinks, with the carbon dioxide that gives the product its characteristic effervescence. The manufacture of bottles starts from the preform tubes. The preform tubes are made of plastic and thrown into the equipment that blows these tubes into bottles in milliseconds by Blower machine then bottling process, whether in glass or PET (plastic), is very similar except for the change in material from which preform is made and blowing equipment. These bottles are then passes to Labeller machine by air conveyor, where the bottles are labeled and dated after that bottles are transferred by air conveyer to filler where the drink in the mixer tank is ready to pump to the filler in simultaneously with feeding filler ring by empty bottles to filled drink in the bottles by filler machine, then forwarded to next capper machine to be sealed by the closure, after being sealed the bottles are then ready for inspection. Surprisingly, even the quality check is automated: the machine rejects any bottle filled below or above the required level by reject machine. Lastly, the bottles transferred by belt conveyors are put together in form of their cases: six bottles in a case of 1.5L or 2L bottles and 12 bottles in a case of 0.5L bottles then the cases are clinked with a plastic sheet by Packer machine (SMI) and then transferred by belt conveyor to palletizer to palletize the cases in layers of one pallet then passes the pallet by roller conveyor to stretcher to wrap the pallet by plastic sheet after that forklift carrying the wrapped pallet to the warehouse where pallets are ready to distributed by the truckers to the customers. ABO [5,6] in SCM has migrated from just in time (JIT) to lean and was enhanced by the addition of total quality management (TQM), resources, building and delivering products to the demand-pull of the customer, business partners can deliver continuous improvement.

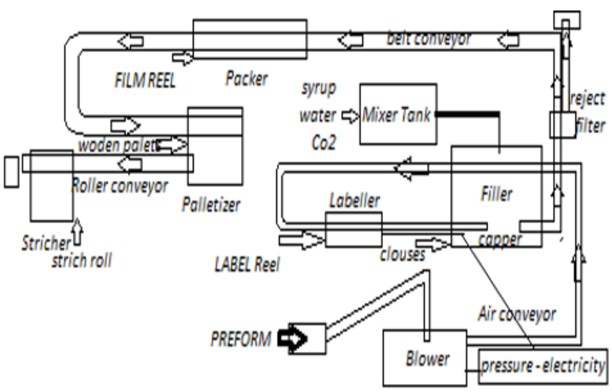

Figure 1. Upstream ABO Supply Chain.

The process of ABO supply chain is shown in figure 1. show how the upstream ABO supply chain operates, including sourcing of raw material, manufacturing and delivery from the plant [7]

III. RESEARCH OBJECTIVES

The key objective of the research is investigate SCM philosophy in bottling plant using simulation scenarios to test or exercised manufacturing stages (machines ,conveyors) in manufacturing line are ready to introduce SCM process in beverages factory with smoothly flow of materials or fragile when increase input loads as not be case in real life .

This paper solving problems with capacity issues within bottling factory using Arena simulation Package that enables the development of discrete and continuous simulation model to these process. The model used as management tool support SCM implementation, by examine existed plant manufacturing process at different loads in small period of time without disruption to the actual organization (Risk avoidance).The Target is SCM where the integrity of organization unites in supply chain satisfaction Customer demands in time . The model test the plant if the result satisfactory or beverages manufacture running smoothly and effectively to SCM target, then the organization can work towards this target, Knowing how all the process should flow from start to finish from simulation models based on assumptions (exactly control). If result unsatisfactory SCM target implementation SCM in beverages factory considered as not be case in real life. Management systems such as capacity planning, Maintenance and quality management use simulation models as decision making tool to obtain appropriate control, where everything in a simulated environment can be precisely monitored and controlled to setting up beverage factory more preferred to SCM process .The overall aim of the research is to investigate SCM strategies that will enable the ABO in Libya to move towards (WCM) by development of a simulation model using Arena software [8,9].

IV. SIMULATION OF ABO

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.

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.

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.

The complexity of the modeling of ABO PET-2 production line decreased when construct the models based on assumptions, Where the assumptions are[10]:

- The assumption as modeling of breakdowns is entire based on machine operational state with no duration of an idle state. The MTBF model is suitable for useful life stage based on historical data with regardless for chance breakdowns influencing factors or unpredictable breakdowns.
- The MTBF model based on the assumptions that failures can only occur after a certain time only considers the time between one failure to another diminishing the chance of an early failure(operation dependent failure).
- Steady state simulation models are appropriate for the analysis of systems, which in theory could run indefinitely so a 6 hours warm- up period is taken.
- It might be appropriate to consider the product as a discrete unit in particular the batches come in a discrete tank batch, also the forklift van come out the same discrete value.
- The entity which the simulation package operates on the capacity of the Mixer tank, is unloaded to the Filler with diminishing Mixer breakdowns. The three entities Rinser, Filler and Capper are summed as a single entity (Filler station)where the probability of two failures or two repairs are negligible.
- Geometric distribution for machine up and down time.
- The system behavior is a discrete state, continuous time Markov process.
- Chemicals and other materials are readily available to be added, all the materials have to be flow through the entire system in the designated loads , staff are always available to cater for need of production.
- No effect of the Rejection machine on conveyor transfer rate.
- ABO agreed to participate in the research project and provide the necessary operational information for the construction of a simulation model using Arena software.

To use the Arena Packaging template, you attach the Packaging panel to the Arena development environment. The Packaging panel contains a collection of objects or modules. Each module defines the logic, data, animation, and/or statistics collection for a particular element in a model (for example, machines, conveyors, or operators).The Packaging panel contains the following modules [11] :

A **Machine** module for modeling the physical components of a line where the actual processing or conversion of units takes place.

A **Conveyor** module for modeling the accumulating conveyors between machines where units are transferred and buffered.

Machine Link and **Conveyor Link** modules for linking machines and conveyors directly together.

Merge, Split, and **Switch** modules for modeling transfer points between conveyors where product flow is split or combined (that is, flow controls).

Palletizer and **Storage** modules for modeling the physical components of a line where units are stored on or removed from pallets.

Valve and **Tank** modules for modeling fluid constraints of filling operations.

An **Actions** module for performing actions on a high-speed system (for example, changing run speeds of machines, adjusting valves, or adding pallets to a storage)using discrete entities and logic.

A **Label** module for labeling a particular portion of the model logic, where by discrete entities can be sent easily to the label from other locations in the model.

A Simulate module for advanced model options (for example, units of measure or statistic collection switches).

V. MODELING SIMULATION OF PET-2 PRODUCTION LINE IN ABO

This model simulates a single bottling line. In the front half of the line we have three different types of machines. We use a conveyor machine to represent the buffer and inspection, a filling machine to represent the filler. We also have a Mixer tank to inject syrup to the filler and a valve to control flow into the tank.

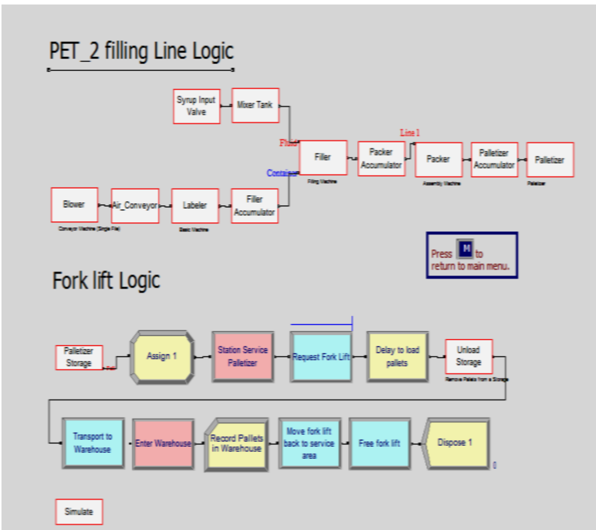

Figure 2. The Modeling logic of PET-2 production line in ABO.

The Packer is the center of the back half of the line. It is fed bottled product via conveyor from the filler. Boxes leave the Packer via a conveyor to be formed into pallets and stored by the Palletizer. Discrete logic is used here to model movement of pallets into the warehouse. It starts with the storage module which creates an entity each time the storage becomes full. Logic then requestsa fork lift and moves it to the palletizer. The Actions module is used to remove two pallets from storage. Set parameters of each module including (speed, reliability, loss and cost)[11] .

Animation accompanies most of the Arena Packaging modules. As you define the behavior of your system's components, you can use these graphics to build a picture of your system quickly.

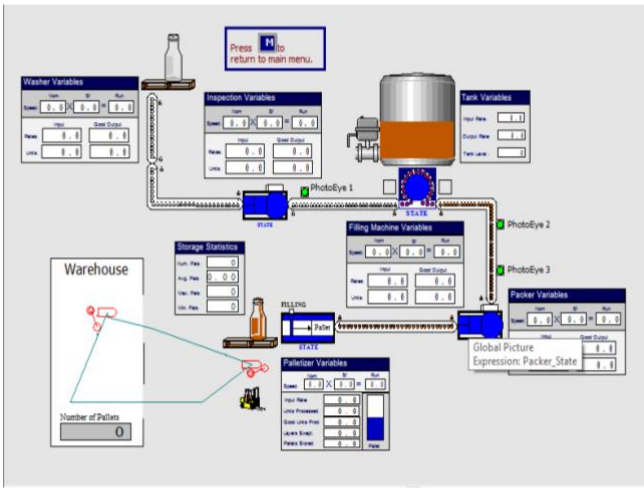

Figure 3. The animation of PET-2 production line .

VI. MODEL VERIFICATION AND VALIDATION

The animation method is used to show the movement of entities inside the model and to insure that the movement is similar to what the designer think which called Face Validity. Validation of the ARENA model is done by comparing the model output with the real system output which called statistical validation or walkthrough validation [12].

Rate count 225 pallets per day in Warehouse. The simulation model run as rebuilt (15) replication with (22.5 Hr) runtime and (6 Hr) Warm up period where the result as shown in Figure (4).

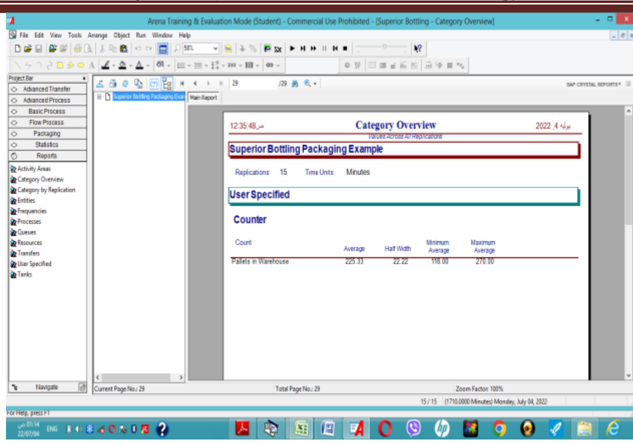

Figure 4. Statistical report output production

The number of Pallets produced per day from the model is compared with the number of Pallets produced per day from the real system. The number of Pallets produced per day from the model is 225Pallets, which is equivalent to 29,700.000 Packet while the real system production rate per day about 227 Packet , which are equal 30,000.000Packet per day, which is considered valid. The nature of this production system is a steady state because it works continuously for 22.5 Hr a day , 6 Hr warm up period and 15 day replication length. 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[13].

VII. PERFORMANCE MEASURES AND THE RESULTS

A) First Scenario : Each workstation work as in real life operation (usually case)

$$\text{The line production rate} = \frac{\text{Number of entities out}}{\text{total simulation time}}$$

$$= \frac{(226.27\ Pallets * 6\ Layer * 22\ Cases)}{(22.5\ Hrs)}$$

The line production rate= 1328 Case/ Hr.

$$\text{System Efficiency (SE)} = \frac{\text{Actual output}}{\text{System capacity}}$$

$$\text{Efficiency of the Blower} = \frac{Total\ good\ unites\ produced}{Machine\ capacity} = \frac{(357{,}876)}{(420*60*22.5)} = 63.12\%.$$

$$\text{Efficiency of the Filler} = \frac{(357{,}419)}{(567{,}000)} = 63.04\%.$$

$$\text{Efficiency of the Labeler} = \frac{(357{,}570)}{(416*60*22.5)} = 63.67\%.$$

$$\text{Efficiency of the Packer} = \frac{(29{,}783)}{(50\ Pbm*60*22.5)} = 44.12\%.$$

$$\text{Efficiency of the Palletizer} = \frac{(226\ Pallets)}{(350\ Pallets)} = 64.54\%.$$

$$\text{Efficiency of production line} = \frac{\text{Actualoutput}}{\text{Systemcapacity}}$$

Efficiency of production line= $\frac{(357,876+357,419+357,570+357,396+357,540)}{(567,000+567,000+561,600+810,000+554,400)}$

Efficiency of production line = 58.42%.

System utilization degree of production capacity= 64.12%.

This indicate that the performance of the line in the lower limitation due to lower utilization degree of available production capacity. Here the situation is critical for production line where the increase in machine capacity to increase output production rate is bad decision making because any increase in machine capacity execute decrease in system efficiency. Specially long starved time for both Packer and Palletizer (476.9 min and 471.82 min) respectively but also the decrease in capacity of Packer and Palletizer to increase line efficiency is not virtual control due to lower capacity rate and long starved time. The clearly now front of the line Blower and Filler have dominant effects to the line productivity because long Failed time (284.79 min and 155.04 min) respectively. The blockages are appears in both Blower and Labeler which have long time block (211.57 min and 166.91 min) respectively. so that in this situation the decrease in capacity rate of Blower and Filler is good decision making due to increase in breakdown time and decrease in Labeler performance.

B) Decrease Speed of Blower and Filler.

In this case the decision is decease speed of Blower down to 410 bpm and slowest Filler speed to 416 bpm.
By monitoring to simulation environment the production line become more smoothly flow of elements due to decrease in total Number of blockages from (52) Block to (35) Block and decrease total starved time from (1572.47) min to (1119.36) min .

The line production rate = $\frac{\text{Number of entities out}}{\text{total simulation time}}$

$= \frac{(227.2\ Pallets * 6\ Layer * 22\ Cases)}{(22.5\ Hrs)}$

The line production rate= 1333 Case/ Hr.

$$\text{System Efficiency (SE)} = \frac{\text{Actual output}}{\text{System capacity}}$$

Efficiency of the Blower= 65.31%.

Efficiency of the Filler= 64%.

Efficiency of the Labeler= 64.05%

Efficiency of the Packer=44.37%.

Efficiency of the Palletizer =65.37%.

Efficiency of production line= $\frac{\text{Actualoutput}}{\text{Systemcapacity}}$

Efficiency of production line = 59.4 %.

System utilization degree of production capacity= 65.51 %.

Slightly improvement in line productivity, efficiency and utilization degree about one percent due to decrease in blockages , failed time and starved time. In this scenario more smoothly of flow of assembles but utilities breakdowns specially for Blower and filler have dominant effect in line efficiency. The situation unexpected as decrease in speed of machines cause increase in line productivity where the machine reliability is very important speed control function. The efficiency of the Packer is very low due to high capacity rate with long starved time.

C) Increase Speed of Blower, Labeler and Filler

In this case the decision is increase the speed of Blower, Filler and Labeler up to 422bpm. In this situation the incremental speed of each workstations obtain negative results, where the failure time, starved time and blockages take negatively affects regardless of capacity of the machine when increase machine velocity other issues of breakdowns increased such as bottles jamming and foaming also the situation need to critical requirements of low failure rate and high reliability (High risk).
The blockages increase up to (69) block per day respect to high machines velocity rate with long Failed time for Blower and Filler (294.6 min and 152.42 min) respectively.

The line production rate = $\frac{\text{Number of entities out}}{\text{total simulation time}}$

$= \frac{(217.2\ Pallets * 6\ Layer * 22\ Cases)}{(22.5\ Hrs)}$

The line production rate= 1274 Case/ Hr.

$$\text{System Efficiency (SE)} = \frac{\text{Actual output}}{\text{System capacity}}$$

Efficiency of the Blower= 60.61%.

Efficiency of the Filler= 60.27%.

Efficiency of the Labeler= 60.31%

Efficiency of the Packer=42.38%.

Efficiency of the Palletizer =61.62%.

Efficiency of production line= $\frac{\text{Actualoutput}}{\text{Systemcapacity}}$

Efficiency of production line = 56.2 %.

System utilization degree of production capacity= 61.9 %.

The efficiency of production line unacceptable due to low utilization degree of available machines capacities and lower production rates which are in processes become more costly. Very clearly now the increase in machines capacity not provide increase in production rate due to long breakdowns times and blockages more appears which that reflects the low reliability of production line in high velocity rates. In other hand the number of blockages of labeler machine become more sensitive to Filler breakdowns in high velocity rates, especially when infeed problems in the Filler station such as bottles foaming and jamming happening frequently. The simulation environment give animation about the flow of assembles through PET-2 line where the observations are fluctuation in flow of materials due to bottlenecks. The overall reliability of production line out of synchronization with machines capacities for that reason bottling operation made short for bottles size (1.5) Liter which that influence in variety of products respect to customer satisfaction.
The main function of SCM is connect suppliers to demands through the organization but the factory are fragile to SCM

(Unsatisfactory), the factory subjected to capacity issues if organization start to implement SCM processas case of high risk. On other hand the organization need to development to become more flexible to implement SCM.

VIII. QUALITY MEASUREMENTS

The procedures of quality management in ABO bottling operation concerned with quality control which represented in rejection machine which that made inspection for the bottles by laser scan to detection the level of syrup in the bottle, dimensions and bottle cap closely.

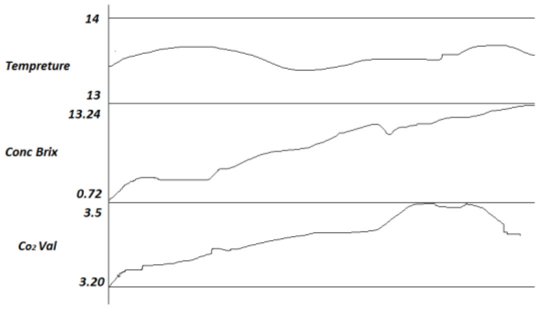

Figure 5. Quality control measurements for Syrup concentration.

The rejection machine detect approximately from (250 to 300) defected bottle every (8 Hr) . Also there are other reasons of defects as bottles foaming and jamming, in feed mechanical issues and utilities breakdowns. The quality department responsible to evaluate syrup in the Mixer controllable by three indicators Brix, Co2 percentage and Temperature as shown in Figure (5).

IX. MAINTENANCE MANAGEMENT

The jobs of maintenance department in ABO is concerned with scheduled maintenance and run to fail maintenance so that we need to enhancement maintenance procedures to upper level as predictive maintenance and Total Protective Maintenance (T.P.M).The machines in technical life extension need to replacement with other machines in useful life to decrease breakdowns and improvement line efficiency.

The improvements including need to give priority to monitoring indicators about machine influence factors such as vibration, mechanical torque synchronizations, Temperature and pressure to identification real reasons of failures.

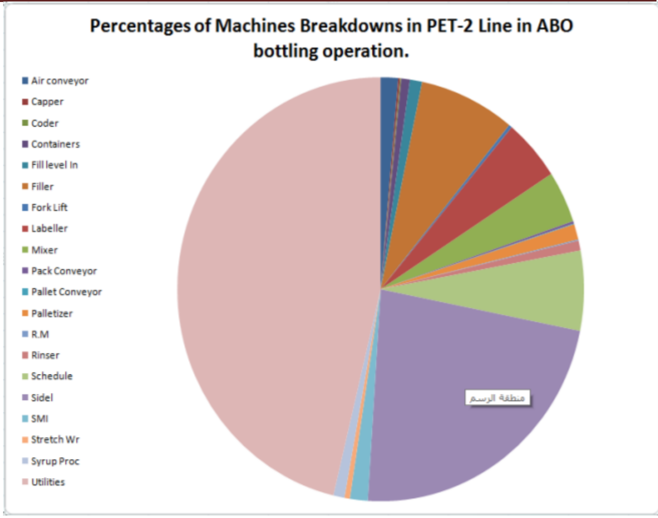

Figure 6. Shown percentages of machines breakdowns in PET-2 Line in ABO.

Now we observe that about (40%) percentage of breakdowns come from utilities breakdowns (electricity, compressed air, Co2 and water) downstream also the Blower (Sidel) and Filler must be in first priority.

X. CONCLUSTION

The result as production line in Africa Bottling Operation ABO unsustainable for SCM implementation (unsatisfactory) because the factory subjected to capacity issues as start to implement SCM process as case of high risk (Risk Avoidance). The blockages increased up to (69) block per day respect to high machines velocity rate with long Failed time for Blower and Filler (294.6 min and 152.42 min) respectively. The efficiency of production line unacceptable due to low utilization degree of available machines capacities and lower production rates which are in processes become more costly where the efficiency of production line = 56.2 % and system utilization degree of production capacity= 61.9 %. To let bottling operation more flexible to implement SCM need to improve level of quality management from Q.C to T.Q.M and enhance maintenance procedures to predictive maintenance and Total protective maintenance (T.P.M) where percentage of utilities breakdowns about (40%) which that give indication to combat them to change the situation completely also maintenance department must be take attention about front section of the line due to long failure time.

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