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Production Scheduling Analysis: A Perspective of the Ghanaian Food and Beverage Manufacturing Industry

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ABSTRACT
The food and beverage industry has systematically developed into a major propeller of global competitiveness of nations. Notwithstanding the vast agricultural resources in most developing countries, the inefficient and sub-optimal production scheduling and workforce planning practices of local food and beverage firms have rendered them non-competitive. This article therefore seeks to assess the efficiency of production planning and scheduling practices implemented by food and beverage manufacturing firms in Ghana, in order to recommend a production scheduling optimization model that assures efficient human and machine resource allocation, overall production cost leadership, profit maximization and international competiveness.
Powered by a multi-case study research strategy and data from secondary sources, a multi-objective and multi-product Mixed Integer Linear Programming (MILP) model was formulated as genetic algorithms in Microsoft Excel Evolver solver to find optimal production schedules. The study puts forward key recommendations and implications based on the findings. It is recommended that firms in Ghana's food and beverage manufacturing industry should apply multi-functional mixed inter linear programming algorithms to optimize their production system, and as well consider an enterprise wide approach to production planning.
While at all this, the theory of queuing must be strongly applied to reduce manufacturing cycle time and hence consumer waiting time. Subjecting the data collected to multi integer linear optimization test in Excel Evolver solver indicates optimal solution for the maximum profit and minimum cost. This resulted in an optimized manufacturing cycle time, minimize overall total cost, meet customer demand, exceed customer expectation, and maximize total revenue.

KEYWORDS: Food and Beverage Industry, Production Scheduling, Production Optimization, Production System, Ghana.

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I. INTRODUCTION

The food and beverage industry has systematically developed into a major propeller of global competitiveness of nations, serving other sectors and the critical socioeconomic needs of buoyant economies across the world. Statistics evident from several countries across the world has confirmed the overwhelming contribution of the food and beverage industry towards growth in international trade and economic growth. In the United States, the food and beverage industry in California directly and indirectly generated $150 billion from sales of agricultural exports, $221 billion economic activities in 2014 and currently employs about 760,000 people (Committee for Economic Development of the Conference Board, 2017). Similarly, in Asia Pacific, key drivers of growth in the food and beverage industry include optimal consumer satisfaction for nutrients and bioactive compounds, efficient distribution and storage and the dynamic product packaging abilities (Corbo et al., 2014). Consequently, the industry contributes about 50% of the total market value (US $168 billion) of food products in 2019 (Cong et al., 2020). In Africa, the African Development Bank Group (2020) confirmed a diversified food and cuisine industry with about $313 billion food and beverage markets projected to reach $1 trillion by 2030.

To sustain the above successes discussed above, firms in the industry have deployed competitive strategies along their value chains. It is crucial to coordinate and allocate processes and resource effectively towards minimizing cost and maximizing overall profit. Effective planning and control of material flows are key to the success of a manufacturing company. In the Food and Beverage industry in Kenya for instance, firms are striving to gain advantage and lead the fierce market competition by enhancing their production plant capacities, mainly due to the increasing demand for processed foods and agro products (Mutunga and Minja, 2014). Five major determinants of sustainable competitiveness of the food and beverage industry outlined include; decreasing costs of food production and distribution, enhanced integration of production and capital, high quality of products, advanced technological prowess, optimal management information system of organizations (Szwacka-Mokrzycka, 2010). In addition, it is crucial to consider available resource capacities, production periods, accurate supply and demand forecast values, and integrate production planning and production scheduling or control in order to avoid disruptions in production (Cai et al., 2011). Generally, production-scheduling system rely on human decision-makers and many of them need assistance dealing with the swampy complexities of real-world scheduling (McKay and Wiers, 2004).

Notwithstanding the vast agricultural resources in most developing countries, multinational firms from developed countries have outclassed a chunk of food and beverage manufacturing firms in developing countries. The inefficient and sub-optimal production scheduling and workforce planning practices of local food and beverage firms have rendered them non-competitive. Firms in the beverage companies in Ghana for instance, have lagged in implementing modern production management systems that considers set up time and processing times separately in order to facilitate production processes, optimize manufacturing cycle time, increase profitability and enhance customer satisfaction (Boahen, 2015).

Consequently, this paper seeks to explore the efficiency of production planning and scheduling practices implemented by food and beverage manufacturers in Ghana, examine associated problems, and propose a production scheduling optimization model that guide human and capital resource allocation. The paper will take the background (introduction) into account and will discuss the literature on production scheduling in Ghana’s food and beverage manufacturing firms. In addition to providing a synthesis of the key issue,a collection of data on key variables and parameters that form the basis of illustrating the best possible production operations in Ghana’s food and beverage industry, brief review on Ghana’s Food and Beverage Production Scheduling and finally ending with the conclusion of the study.

II. LITERATURE REVIEW

2.1 Review of Concepts of the Study

This section providesa foundation and background knowledge on the subject matter of this research which spans the food and beverage industry, production demand, production scheduling, production line, production cycle time/ flow time, production optimization, and Human-Machine interaction. A critical review of the aforementioned areas of interest to this research does not only place the thesis within the context of existing literature but also makes a case for why further research is needed in this area and as well operationalizes the definitions of these variables.

The Food and Beverage Industry

The food and beverage industry encapsulates all firms or organizations that are into processing, packaging and distributing raw food materials: in includes prepared, fresh, and packaged foods as well as alcoholic and non-alcoholic beverages. In fact, any product that is made for human consumption apart from pharmaceutical ones are classified under the food and beverage industry. According to a report by Global Edge (2018) the food and beverage industry is made of two major segments: the production segment and the distribution (of edible goods) segment. The production segment is concerned with processing of raw food materials like meat, cheese, and the making of alcoholic and non-alcoholic beverages, and packaged foods. The distribution segment is charged with transporting finished goods to the final consumer.

According to Owusu-Mensah et al., (2020) a plethora of studies have been conducted from the academic and business perspectives with focus mainly on the key aspects of production processes that enhances productivity to satisfy customers and improve product quality. It however looks like there has been very little focus on developing optimization models for production scheduling especially in the food and beverage industry. The global trends in this industry in line with socio-economic development but almost nothing on optimization. In Europe, the food and drink sector has blossomed thanks to the effective supply chain management strategies implemented by retailers: in fact, the industry has employed about 4.2 million people reflecting 1.8% of Europe’s gross value and over 1.2 billion Euros turnover in 2015 (Zhong et al., 2017) hence adding great economic value to the continent. Also, the low cost of raw materials, good exchange rates, access to quality water, and low cost of production in Canada were found to be the drivers of a thriving food and beverage industry that gained a total of 28% and 22% of manufacturing revenue and manufacturing sector employment (Ashton et al., 2014). In all this, a trend of consistency in production processes is noticed and is justifiable to say that proper production scheduling plays a critical role. In 2018, the food and agricultural unit of the United nations (UN) analyzed the food and beverage industry in sub-Saharan Africa and found the production activities and Agro-processing to be stagnated and losing revenue: this was attributed to inefficient production scheduling among other factors.

Owusu-Mensah et al., (2020) emphasized the importance of pinpointing the critical success factors of having competitive advantage in the food and beverage industry to ascertain the extent to which optimal production scheduling can place a firm in a more competitively advantaged position than others have. The food and beverage industry has been found to blossom if operational constraints are effectively managed by enhancing formulation strategies that adds more value (Infor, 2012). To remain competitive, food and beverage industry players must deliver products with higher nutritional value, create more formula agility, consistently reduce production cost, and minimize environment impact. For example, the food and beverage manufacturing industry in UK blends eco-design, regulation compliance, clean production, and product development as strategies to become more competitive and increase market share (Nee et al., 2013). Similarly, Enzing (2009) explored in the Dutch food and beverage industry and found that companies apply a prospector strategy, extensive market assessment, and high level of product innovation to gain competitive advantage.

Production Demand

In economics, demand refers to the desire of a consumer to patronize goods and services hinging on a willingness to pay a certain price for a specific good or service. It is common knowledge in economics that, an increase in the price of goods and service results in a decrease in demand and vice versa. Production on the other hand is the process of combining material and immaterial inputs in order to create a consumable output. In other words, it involves creating a value-added output, a good or service that contributes to the utility of individuals. In this study, production demand is operationalized to mean the ability of food and beverage companies in Ghana to produce is goods to meet the requirements of their consumers. It is more like an ability to expand capacity to create an enabling situation for just-in-time production.

Production Scheduling

Scheduling entails a clear definition of starting and finishing time frames and allocation of resources to each task within the main job: scheduling is restricted by many constraints like resources and tasks (Elwany, Shouman, and Abou-Ali, 2003). To Fera et al. (2015), scheduling is essentially the short-term execution plan to execute a production. A good production schedule details which specific tasks will be performed by whom or what and at what time. To always, be in absolute control of affairs, manufacturing companies constantly generate and update production schedules, which are defined as plans that details when specific activities like processing of jobs based on resources should take place (Hermann, 2007). In the words of Cox et al. (1992), scheduling is "the actual assignment of starting and/or completion dates to operations or groups of operations to show when these must be done if the manufacturing order is to be completed on time". Generally, the functions of a production schedules spans ensuring timely ordering of raw materials, identify conducive time periods for preventive maintenance, determine if delivery promises can be met, and identify resource conflicts in a coordinated manner to ultimately translate into increased productivity and a minimized operation cost.Systems developed for production scheduling depends on humans (managers) as many of them need help in handling the overwhelming challenges and problems of production scheduling (Mckay and Wiers, 2004). Production planning and scheduling are critical to production in order to allow for time accuracy and flexible use of the production area (Baumung and Fomin, 2018). Baki (2006) states the four stages of production management as planning, scheduling, execution, and control: scheduling and planning are considered the most important phases (Xinyu et al., 2010; Wolosewicz er al., 2015). Production scheduling allows for meeting the framework of manufacturing operations within a stipulated period: the framework as a matter of convention must be designed to fit into company goals of meeting consumer needs at a reduced cost. Mouli et al., (2006) confirms that aggregate scheduling is a critical strategy for determining production constraints like overtime, inventory levels (for cost minimization), and levels of workforce among others: inventory manipulation, production rate, and subcontracting are some strategies for aggregate scheduling. According to Hermann (2006), the history of production scheduling can be dated as far back as 100 years ago. Critical production scheduling can yield great results but it is a difficult task in an environment with limited capacity (Leandro et al., 2012). These researchers brought up, analyzed a backward scheduling problem in manufacturing for developing a shop-floor scheduling system by using the Ant-Colony Optimization (ACO), and found that it is equally effective as branch-and-bound but ACO is fasters in execution. Ben-Awuah et al., (2012) also found that the Mixed Integer Linear Goal Programming (MILGP) model effectively ensures a smooth and uniform production schedule in waste management and disposal. With an objective to optimize system performance through scheduling, Lodree and Norman (2006) emphasized that the overall performance and efficiency of a production system depends a lot on how the personnel ae scheduled. Dileep and Sumer (2007) focused on multi-machine and multi-product lot size and production scheduling problem and developed a model to minimize inventory costs through a heuristic approach as a solution to achieve a conflict-free and cyclic production schedule. Also, Kumral (2010) researched on production scheduling of open pit mines utilizing the robust stochastic optimization (RSO) model (an approach that is requires a trade-off between feasibility and optimality) and found that, the RSO is very efficient in solving production scheduling problems.

Production Line

A production line spans a set of sequential operations established in a factory where components are assembled to make a finished product: it encapsulates the processes involved in putting raw materials through refining to produce an end-product that can be consumed. In a typical situation, raw materials like metal ores, food stuff, and textile sources like cotton must undertake a sequence of treatments to make them useful. In the context of this study, a production line is defined as a line of machines and workers (Human-machine interaction) in a factory in a food and beverage company in Ghana that a product moves along while being produced. Within the production line, each machine and individual perform a specific task that needs to be completed before the product moves to the next stage in the line.

Production Cycle time

Production cycle time refers to the total time used to complete one unit of production from start to finish. A general method of determining the time taken to complete one cycle of production is to track completed items and net production time (NPT). Jovanovic, Milanovic, and Djukic (2014) emphasized that the key things to focus on when investigating a production cycle time is the set of activities including defining optimum production lot, production preparation, quantity of required parts, cycle scheduling, and analysis and investigation of material flow among others. They further assert that; manufacturing cycle determines the duration of business activities and production that must be in place for the entire manufacturing process to be carried out to produce a certain quantity of products within a minimum time flow while simultaneously utilizing maximum manufacturing capacity and optimal use of financial resources. Lati and Gilad (2010) developed an algorithm called MinBIT (Minimizing bottleneck idle time) for cutting down on loses in the semi-conductor industry. They also emphasized this method as not only being useful to the semi-conductor industry but also to host of other industries as it has proven effective in reducing production cycle times and throughput increases. Production cycle time comes with very critical complexities which can translate into massive profits or loses depending on how it is managed. In light of this, Hermann and Chincholkar (2001) brought up a decision support system to assist product development teams in their bid to reduce manufacturing cycle time as much as possible during product design phase. Named the design for production (DFP) tool, it tells how developing a new product design affects the sufficiency an entire manufacturing system considering available capacity and cycle time. Several other approaches to get the best out of production cycle time has been developed by various researchers including real time production bottleneck control (Li et al., 2009), preventative maintenance prioritization for machine fleet (Patti and Watson,2010), optimizing initial buffer adjustment (Schultz, 2004), cut down of machine set up time (Kusar et al., 2010), and predicting lead times for orders (Berlec et al., 2008) among others. Ko et al. (2004) also explored the extent to which cycle times could be reduced in mass production by smoothing up input and service rates and found that, a generally effective and accepted method is to use flow coefficient as a benchmark for the efficiency of the manufacturing processes hinging on comparing accomplished and technological values to the cycle time.

Production Optimization

Holdaway (2014) explains production optimization in a very clear and vivid manner. To him, production optimization is based on providing an enabling situation for more critically efficient decisions to be made: this is important because it is through sound judgements on which strategies and approaches to use across a production line that can ensure an optimized workflow and hence performance. By necessary implication, production optimization leverages the experienced human capital to transform methods of production that translates into optimized operations. In all this, it is important to note that aside a skilled workforce, the processes and technologies used in production also determines the level of quality and excellence. Holdaway (2014) further espouses that many approaches have been developed for the purposes of achieving production optimization but at the center of all of is the need for refinement to include data-driven models. Well-planned activities geared towards production optimization, results in reduction of unexpected shutdowns and managed spending. This in turn enables reserves to be exploited hence increasing asset production.

Human-Machine Interaction (HMI)

Human-machine interaction also commonly known as human computer interaction generally refers to the study of how people interact with computers, machines, and other technologies. This interaction includes waking up to digital radio alarm clocks, using a laptop at work, communicating through phones, and travelling on a train among others. It is in this vein that Gautam and Singh (2015) believed that computer systems form an active part of contemporary society and humans constantly interact with them. They also further intimated that, Human-Machine interaction (HMI) as a field has played important roles in enhancing our understanding interactions with computer-based technologies. Lopes (2016) describes Human-computer interaction as being multidisciplinary drawing from fields like computer science, organizational and social sciences, psychology and cognitive science to help understand how people accept, use, and experience technology. From this backdrop, it is clear that human-machine interaction needs both qualitative and quantitative methods to collect and analyze information for its systems to operate smoothly. Lopes (2016) agrees that, methods used in human-machine interaction are necessary to optimize organizational performance and competitiveness as it helps to fine tune technology capabilities with the requirements of a company. The methods applied in the human-machine learning field can be grouped into the categories of interviews, observations, and interviews (Shafer, 2009). HMI is focused on two main areas: organizational resilience and information technology. Organizational resilience explains the ability of an organization to survive all threats in its internal and external business environment (Hollnagel et al.,2006). Informational technology on the other hand deals with stability and quality of service while individual use and interact with machines. Industry 4.0 is described as an age of smart production which allows human beings or objects, animate or inanimate to interact with each other through the internet (Aksoy,2017).

2.1.1 Theories and Models for Production Planning and Schedule Optimization

Theories and models for optimizing production systems is rife in existing literature. In more recent times, most operations management research have generally been founded on four generic theories including; business process redesign (BPR), reconfigurable manufacturing systems, six sigma and lean manufacturing. Mohapatra (2013) explains Business process redesign as the core process of rethinking and radical redesign of business processes to achieve rapid improvements along with product development, optimal performance, cost leadership, quality assurance, supply chain service responsiveness and enhanced customer service experience. A related theory is the Reconfigurable manufacturing systems. This production theory considers the erratic nature of changes in the production value chain of firms, and develops flexible hardware and software components that allows prompt changes to be effected to meet customer needs. It ensures that the production plan is resilient enough to quickly adapt to inherent market or system changes.

According to Zu et al. (2008), Six Sigma was developed between 1985 and 1987 at Motorola to assist in understanding trend and potential defect in a production system. It is essentially designed to deploy sequential steps in reviewing a production system in order to identify factors that affect the quality of products. It ensures an optimal implementation of total quality management measures.

Lean manufacturing theory can be referred to as lean enterprise or lean production. It was derived from Toyota's Production System in Japan in the 1970s and 1980s. Ultimately, the theory aims to eliminate waste, reduce work-in-progress and finished goods inventories, ensure total quality assurance and overall cost of the manufacturing process (Čiarniene and Vienazindiene, 2012). The theory is committed to ensuring only production processes that adds value to the final product and satisfy customer requirements. This is achieved by cutting waste in the production mainly caused by excess human resources assignment, over usage of energy and high inventory holding cost.

2.2 Production Scheduling Optimization Models

Several studies have applied the multi-machine, multi-product lot size determination and scheduling problem in finding optimal solutions for production costs and revenue maximization (Bixby et al., 2006). Key parameters and variables considered in these models are inventory-related operational cost, the capacity of men and machines, and the overall production time expended. By developing heuristic formulation, the models ensured that, a conflict-free, repetitive, and cyclic production schedule for a general production spectrum is achieved. Similarly, Clark (2003) also developed heuristic solution for a mixed integer-programming model for the beverage industry. The model based its algorithm on the Capacitated Lot Sizing Problem (CLSP) to derive an optimal solution for the processes involved with filling cans and bottles, and capping. Meanwhile, Ferreira et al. (2009) leveraged the effectiveness of the General Lot Sizing and Scheduling Problem (GLSP) in mixed integer programming model to optimize lot sizing and scheduling problem in a soft drink company, using setup costs and setup times as part of its variables. More so, the problem of large-scale job shop scheduling was resolved in Gavareshki and Zarandi (2008) as they applied Shifting Bottleneck (SB) heuristic approach. Two sub-models were embedded in this approach, where single machine scheduling was first formulated using the Schrage algorithm before presenting the elaborate heuristic approach for job shop scheduling.

Moreover, Leandro et al., (2012) also juxtaposed branch-and-bound and the Ant Colony Optimization (ACO) and applied both models in optimizing shop-floor production scheduling, considering a single-stage processing, parallel resources, and flexible routings. It was explicit that Ant Colony Optimization was superior to branch-and-bound in terms of execution. Another production scheduling optimization model is the simulated annealing model. Hui et al. (2010) effectively applied this model in optimizing production schedules of multiproduct continuous manufacturing facilities: polyamide fiber plant. Key variables considered include range of products and the number changeovers.

For a single milk production line, Javanmard and Kianehkandi (2011) designed a Mixed Integer Linear Programming (MILP) model to optimize production scheduling. Key constraints embedded in the model include material balances, inventory limitations, machinery capacity, labor shifts and workforce restrictions. The objective function was to achieve minimized overall variable costs including changeover cost, inventory cost and labor cost. The model finally specifies the sequence and quantities of products that should be produced daily, as well as determines the final inventory levels daily.

Furthermore, another production scheduling optimization model considered in the literature is the Mixed Integer Linear Goal Programming (MILGP) developed by Ben-Ewuah et al. (2012). The model combines mixed integer linear programming and goal programming using clustering and pushback techniques to optimize mining production scheduling and minimize waste production as a result efficient resource allocation.

III. DISCUSSION AND IMPLICATIONS

Methods selected and used for this paper are extensively discussed in a systematic and logical manner (Saunders et al., 2009) with an aim of not compromising on validity, originality and generalizability of research findings (Kumar, 2010). Leedy and Ormod (2001) explicated research methodology as being a systematic process of collecting, analyzing, and interpreting data for thorough understanding of a phenomenon and presenting results within the right framework. This chapter is focused on clearly elucidating the philosophy, the research approach, the research design and the specific optimizations modelling tool to be applied to illustrate production scheduling optimization by food and beverage companies in Ghana.

3.1 Data Analysis Model and Tools

The nature of production plants and lines installed and operated by firms in Ghana's food and beverage industry is multi-functional and multi-product, coupled with complex manufacturing supply value chain and erratic resource assignment problems. Therefore, to achieve an optimal production output, a multi-objective and multi-product production scheduling optimization model is proposed, using Mixed Integer Linear Programming (MILP), formulated as genetic algorithms in Microsoft Excel and solved with the embedded Evolver solver. The model derived is from those put forth by Al-Ashhab and Fadag (2018).

The described and formulated parameters and variables of the proposed production scheduling optimization model are below. Let;

$S = \ Set\ of\ suppliers.$
$C = Set\ of\ customers.$
$T = Number\ of\ planning\ periods.$
$P = Set\ of\ products$
$Ff = fixed\ cost,$
$DEMANDcpt = \ demand\ of\ customer\ c\ for\ product\ p\ in\ period\ t,$
$IIfp = Initial\ inventory\ of\ product\ p,$
$FIfp = Final\ inventory\ of\ product\ p,$
$Ppct = unit\ price\ of\ product\ p\ at\ customer\ c\ in\ period\ t,$
$Wp = weight\ of\ product\ p,$
$MHp = processing\ hours\ for\ product\ p,$
$Dij = distance\ facilities\ i\ and\ j,$
$CAPst = supplier\ capacity\ in\ period\ t,$
$CAPMft = \ raw\ material\ store,$
$CAPHft = \ manufacturing\ capacity\ of\ the\ production\ line\ in\ hours,$
$CAPFSft = \ final\ product\ storing\ capacity,$
$MatCost = \ material\ cost,$
$MCft = manufacturing\ cost,$
$MHp = Required\ processing\ hours\ for\ product\ p,$
$NUCCf = non - utilized\ capacity\ cost\ per\ hour,$
$SCPUp = shortage\ cost\ per\ unit\ per\ period,$
$HC = holding\ cost\ per\ unit\ weight\ per\ period\ at\ the\ factory\ store,$
$Bs = \ batch\ size\ from\ supplier\ s,$
$Bfp = batch\ size\ from\ the\ productionn\ line\ for\ product\ p,$
$TC = transportation\ cost\ per\ unit\ per\ kilometre,$

The above parameters are formulated and solved in the quest to derive optimal answers to the following decision variables;

$Qijpt$: $number\ of\ batches\ moved\ from\ production\ line\ i\ to\ j\ for\ product\ p\ in\ period\ t,$
$Iffpt$: $number\ of\ batches\ stored\ for\ product\ p\ in\ period\ t,$
$Ifcpt$: $number\ of\ batches\ transported\ from\ the\ store\ to\ customer\ c\ for\ product\ p\ in\ period\ t,$
$Rfpt$: $residual\ inventory\ of\ the\ period\ t\ at\ the\ store\ of\ the\ factory\ for\ product\ p.$
$CSLc$: $Customer\ Service\ Level\ of\ customer\ c.$

The objective function of this model is set therefore to maximize overall profit by scheduling production value chain processes in a manner that satisfy customer demands optimally at minimized costs.

Material and manufacturing costs are included in the first production-planning period together with the initial inventory cost, whiles the next production-planning period captures the material and manufacturing costs together with the final inventory cost. However, the cost of holding inventory depends on residual inventory. The derived profit, revenue and cost optimization functions are as follows:

$$Total\ Revenue = \sum_{c\in C}\sum_{p\in P}\sum_{t\in T}(Qfc_{cpt} + Ifc_{cpt})\, Bf_p P_{pct}$$

$$Fixed\ Cost = Ff$$

$$Material\ Cost = \sum_{s\in S}\sum_{t\in T} Q_{sft} B_s MatCost_{st} + \sum_{p\in P} IIf_p W_p MatCost_{st} - \sum_{p\in P} FIf_p W_p MatCost_{st}$$

$$Manufacturing\ Cost = \sum_{c\in C}\sum_{p\in P}\sum_{t\in T} Q_{fcpt} Bf_p MH_p Mc_t + \sum_{p\in P}\sum_{t\in T} Iff_{pt} Bf_p MH_p Mc_t + \sum_{p\in P} IIf_p MH_p Mc_t - \sum_{p\in P} FIf_p MH_p Mc_T$$

$$Non-Unitilized\ Factory\ Capacity\ Cost\ (NUCC) = \sum_{t\in T}\big((CAPH_{ft})L_f + \sum_{p\in P}\sum_{c\in C}\big(Q_{fcpt} Bf_p MH_p\big) - \sum_{p\in P}(Iff_{pt} Bf_p MH_p\ )\big) NUCCf$$

$$Shortage\ Cost = \sum_{p\in P}(\sum_{c\in C}(\sum_{t\in T}(\sum_{1}^{i} DEMAND_{cpt} - \sum_{1}^{i}(Q_{fcpt} + Ifc_{fcpt})\, Bf_p))\ SCPU_p$$

$$Transport\ Cost = \sum_{t\in T}\sum_{s\in S} Q_{sft} B_s\ Tc\ D_{sf} + \sum_{p\in P}(\sum_{t\in T}\sum_{c\in C}(Q_{fcpt} + Ifc_{cpt})\, Bf_p W_p\ Tc\ D_{fc}$$

$$Inventory\ holding\ Cost = \sum_{p\in P}(Iff_{pt} Bf_p W_p\ HC + \sum_{p\in P}\sum_{t=1}^{T-1} Rf_{pt}\ Bf_p W_p\ HC$$

For the model to remain valid, it necessary to integrate the constraints from supply side, through the factory's capacity and the factory store capacity in a balanced manner. These constraint models are as follows:

$$Qsf_t B_s \le\ CAP_{st} L_s\ , \forall t\in T, \forall s\in S$$

$$\sum_{s\in S} Qsf_t B_s \le\ CAPMf_t L_f\ , \forall t\in T,$$

$$(\sum_{c\in C}\sum_{p\in P} Qfc_{cpt} Bf_p + \sum_{p\in P} Iff_{pt} Bf_p)\ MH_p \le\ CAPHf_t L_f\ , \forall t\in T$$

$$\sum_{p\in P} Rf_{pt} Bf_p W_p \le\ CAPFS_t L_f\ , \forall t\in T,$$

3.2 How Production Scheduling Operations Are Implemented by Food and Beverage Manufacturing Firms in Ghana

In general, production scheduling in food and beverage manufacturing firms in Ghana is based on historical data and hindsight experience of long serving production managers. A closer search for organizational surveys revealed that the initial inventory of Pioneer Food Cannery Limited at the beginning of January, 2011 was 8,653 cartons. The firm applied both regular and overtime production shift systems with product costing GH¢30.80 and GH¢35.20 respectively, and a storage cost of GH¢8.40 per month (Opoku, 2013). Owusu-Mensah et al. (2020) explored another survey of the production planning and scheduling measure implemented at GIHOC Distilleries. The firm's cluster of production line consists of one major production plant at its head office, which is dedicated to the production of dedicated production line for Castle Bridge and two other multi-production lines, which could produce either Mandingo or Herb Afrik. The capacities are specified as follows; 30 pallets a day for the Castle Bridge line, 50 pallets for Herb Afrik and 40pallets for Mandingo. Long-term production schedules are reprogramed into daily work plans. Finished and packaged products are temporarily stored on pallet within the production unit before transferred to the finished goods warehouse. Order processing time takes between two weeks and at most sixteen weeks (Owusu-Mensah et al., 2020).

Moreover, Sutton and Kpentey (2012) investigated the production planning system of Plot Enterprise Ghana Limited: A Free Zones company. With an annual initial bean input capacity of 48,000 mt the firm has a total output of 25,600 mt of liquor, butter and cake. The firm further conforms to international standards of operation particularly derived from the European levels (Sutton and Kpentey, 2012).

Dankwah (2011) assessed the optimality of the production scheduling system of Guinness Ghana Company. The firm brews and package Malta Guinness into 300ml bottles and cases. Production cost parameters for the product consist of brewing materials, packaging materials cost and utilities. Manufacturing cycle time runs for 24 hours, in three shifts of 8 hours per shift in a day. Production schedules drawn on monthly basis to decide the quantities of products to produce. Regular and overtime production costs per case is GH¢14.00 and GH¢14.22 respectively. Inventory holding cost per case per month is pegged at GH¢0.25. It was further noted that at the beginning of July 2008, the company held an inventory of 120,000 cases. After running the production scheduling optimization model, Dankwah (2011) observed that, for the production period under review, the company incurred a total regular production cost of GH¢ 46,396,000 and overtime cost of GH¢23, 562,540. Implying that an overtime cost of GH¢69,958,540 was expended to produce to meet the total customer demand of 2,790,000 bottles of Malta Guinness (Dankwah, 2011).

IV. GHANA'S FOOD AND BEVERAGE PRODUCTION SCHEDULING

Ghana's food and beverage manufacturing firms often lacks the application of optimal techniques that ensures high profits and minimized cost. Planning and scheduling processes are based on historical data on demand trend, the experiences of production managers and the influence of production value-chain problems; such as raw material shortages, limited production capacities and lack of credit facilities. It is therefore necessary for production plans to encapsulate every aspect of the production value chain and how best to integrate human and manufacturing plant units. The data tables presented below are indicative of the typical production operation values and the customer demand estimates for GIHOC Distilleries Ghana limited for the first six-month period in a year. Total estimated fixed production cost is $10,000.00. Production line capacity runs for about 24,000 hours with a factory store capacity of 4,000kg for the period. Weights of products range between 2kg to 6kg. Manufacturing and material cost per kilogram of product are estimated at $20.00. Initial and final product inventory range from 100 to 300, and 200 to 300 respectively. Refer to table 1. The demand forecast for the top product brands of the firm (Castle Dry Gin, Madingo, Herb Afrik, Takai, Kaiser and Sorento) are estimated for the six-month period are also shown in table 2; where the highest customer demand is recorded in the month of January and June. Three key suppliers and customers are considered.

Table 1. Derived Production Scheduling Parameter Data for GIHOC Distilleries Limited

Production Scheduling Parameters for GIHOC Distilleries Limited		
No.	**Parameters**	**Value**
1	Number of Periods	6
2	Number of Products	6
3	Fixed Costs ($)	100,000.00
4	Factory Capacity in Hours (hrs)	24,000
5	Weight of Products (kg) (1-6)	2; 4; 6; 2; 4; 6
6	Price of Products	200.00; 300.00; 400.00; 200.00; 300.00; 400.00
7	Material Costs ($/kg)	20
8	Manufacturing Cost ($/hr)	20
9	Initial Products Inventory	100; 200; 300; 100; 200; 300
10	Supplier Batch Size	20
11	Factory Batch Size	2
12	Holding Cost per period ($/kg)	10
13	The Capacity of each Suplier (kg)	24,000
14	Transportaion Cost per km per kg ($)	0.002
15	Machine time of Products (1-6) (hrs)	2; 4; 6; 2; 4; 6
16	Raw Material Store Capacity (kg)	20,000
17	Factory Store Capacity (kg)	4,000
18	Final Products Inventory	200; 300; 400; 200; 300; 400

Source: *Field Survey, 2020*

Table 2. Derived Data on the Demand of Customers for Top Product Brands for A Typical Half-Year Period (January to June) at GIHOC Distilleries Limited.

Period	Products					
	Castle Dry Gin	Mandingo	Herb Afriq	Takai	Kaiser	Sorento
January (1)	1540	1540	1540	1540	1540	1540
February (2)	1180	1180	1180	1180	1180	1180
March (3)	600	600	600	600	600	600
April (4)	600	600	600	600	600	600
May (5)	1180	1180	1180	1180	1180	1180
June (6)	1540	1540	1540	1540	1540	1540

Source: *Field Survey, 2020*

4.1Solving the Production Planning and Scheduling Problem of GIHOC Distilleries Limited

The output of the model after subjecting the above data to multi integer linear optimization test in Excel Evolver solver indicates optimal solution for the maximum profit and minimum cost. As specified in the methodology section, the objective of the model is to optimize product quantities supplied to the factory, delivered from the factory store to customers and the residual inventories at the end of each period. Table 3 shows the quantities of various products that is supplied to the firm's factory, indicating the constraints of suppliers and as well confirming the challenge of unavailable raw material supplies.

Table 3. Product Quantities Transferred from Three Suppliers to Factory

Period	Suppliers			
	Supplier 1	Supplier 2	Supplier 3	Weights
January (1)	0	2000	0	20000
February (2)	0	2000	0	20000
March (3)	0	2000	0	20000
April (4)	0	2000	0	20000
May (5)	0	2000	0	20000
June (6)	0	2000	0	20000
Total	0	12000	0	120000

Source: *Field Survey, 2020*

The solution further shows the quantities of various products that must be shipped from the factory to customers in order to achieve optimal profit and the lowest possible cost, given the defined cost variables and capacity constraints. As shown in table 4, customer (2) is scheduled to receive the highest quantity of product orders received for the six-months period (38640kg), followed by customer (1) (38560kg) and customer (3) (38160kg). However, for the month of January, customer (3) is to be served the highest quantity of products (8636kg); with the Sorento liquor and Herb Afrik dominating (1540kg each). In the month of March, Customer (1) must receive a total of 9760kg of product orders, which is the highest compared to customer (3) (5724kg) and customer (2) (4052kg). Castle Dry Gin, Mandingo, Takai and Kaiser were the most delivered products (1780kg each).

Table 4. Product Quantities Transferred from Factory to Customers

Period	Customer 1						
	Castle Dry Gin	Mandingo	Herb Afrik	Takai	Kaiser	Sorento	Weight
January (1)	1540	1540	0	1540	1540	0	6160
February (2)	0	0	2000	0	0	2000	4000
March (3)	1780	1780	1320	1780	1780	1320	9760
April (4)	1800	1800	1320	1800	1800	1320	9840
May (5)	0	0	2000	0	0	2000	4000
June (6)	1200	1200	0	1200	1200	0	4800
Total Weight							**38560**
Period	**Customer 2**						
	Castle Dry Gin	Mandingo	Herb Afrik	Takai	Kaiser	Sorento	Weight
January (1)	1540	1540	674	1540	1540	674	7508
February (2)	1180	1180	1520	1180	1180	1520	7760
March (3)	600	600	826	600	600	826	4052
April (4)	600	600	826	600	600	826	4052
May (5)	1180	1180	1520	1180	1180	1520	7760
June (6)	1540	1540	674	1540	1540	674	7508
Total Weight							**38640**
Period	**Customer 3**						
	Castle Dry Gin	Mandingo	Herb Afrik	Takai	Kaiser	Sorento	Weight
January (1)	1438	1340	1540	1438	1340	1540	8636
February (2)	0	1180	1180	0	1180	1180	4720
March (3)	1782	600	480	1782	600	480	5724
April (4)	1782	600	480	1782	600	480	5724
May (5)	0	1180	1180	0	1180	1180	4720
June (6)	1438	1340	1540	1438	1340	1540	8636
Total Weight							**38160**
Overall Total Weight for all three customers for the six-months period							**115360**

Source: *Field Survey, 2020*

Moreover, the solution further indicates the quantities of various products that should be transferred from the factory store to customers, in order to facilitate customer order fulfillment. Customer (1) must not be supplied any product from the factory store. Meanwhile, 600kg of products should be delivered to customer (2) and customer (3) from the factory store. This can be explained by the dynamics of cost variables such as transportation and inventory holdings well as material capacity of store. In so doing, a balance can be strike between the total cost and total revenue. See table 5.

Table5. Product Quantities Transferred from Factory Store to Customers

Period	Customer 1						
	Castle Dry Gin	Mandingo	Herb Afrik	Takai	Kaiser	Sorento	Weight
January (1)	0	0	0	0	0	0	0
February (2)	0	0	0	0	0	0	0
March (3)	0	0	0	0	0	0	0
April (4)	0	0	0	0	0	0	0
May (5)	0	0	0	0	0	0	0
June (6)	0	0	0	0	0	0	0
Total Weight							**0**
Period	**Customer 2**						
	Castle Dry Gin	**Mandingo**	**Herb Afrik**	**Takai**	**Kaiser**	**Sorento**	**Weight**
January (1)	0	0	300	0	0	300	600
February (2)	0	0	0	0	0	0	0
March (3)	0	0	0	0	0	0	0
April (4)	0	0	0	0	0	0	0
May (5)	0	0	0	0	0	0	0
June (6)	0	0	0	0	0	0	0
Total Weight							**600**
Period	**Customer 3**						
	Castle Dry Gin	**Mandingo**	**Herb Afrik**	**Takai**	**Kaiser**	**Sorento**	**Weight**
January (1)	100	200	0	100	200	0	600
February (2)	0	0	0	0	0	0	0
March (3)	0	0	0	0	0	0	0
April (4)	0	0	0	0	0	0	0
May (5)	0	0	0	0	0	0	0
June (6)	0	0	0	0	0	0	0
Total Weight							**600**
Overall Total Weight for all three customers for the six-months period							**1200**

Source: *Field Survey, 2020*

Table 6 and table 7 respectively show quantities of products that must be moved from factories to factory store and the residual inventory in the factory at the end of each period.

Table6. Product Quantities Transferred from Factory to Factory Store

Period	*IFF*						Weight
	Castle Dry Gin	Mandingo	Herb Afrik	Takai	Kaiser	Sorento	
January (1)	0	0	0	0	0	0	0
February (2)	0	0	0	0	0	0	0
March (3)	200	300	400	400	300	200	1800
April (4)	200	300	400	400	300	200	1800
May (5)	0	0	0	0	0	0	0
June (6)	0	0	0	0	0	0	0
Total Weight							**3600**

Source: *Field Survey, 2020*

Table 7. Residual Inventory in Factory Store at the end of each Period

Period	*Rf*						Weight
	Castle Dry Gin	Mandingo	Herb Afrik	Takai	Kaiser	Sorento	
January (1)	0	0	0	0	0	0	0
February (2)	0	0	0	0	0	0	0
March (3)	200	300	400	400	300	200	1800
April (4)	200	300	400	400	300	200	1800
May (5)	0	0	0	0	0	0	0
June (6)	0	0	0	0	0	0	0
Total Weight	**400**	**600**	**800**	**800**	**600**	**400**	**3600**

Source: *Field Survey, 2020*

4.1.2 Discussion of Optimization Report

Discussing the above solution in terms of the quantities demand, received and shortages of each product, it is evident that the highest final shortages occurs at customers (3) (1680) followed by customer (1) (1380) and customer (2) (1200). Meanwhile, the minimum intermediate shortage of 604 also occurs at customer (3) which perhaps is the nearest customer to the production facility (table 8).

Table 8. Quantity Demand, Received, and Shortage of all Products for Six Months

Customer 1

Period	Castle Dry Gin			Mandingo			Herb Afrik			Takai			Kaiser			Sorento			Final Shortage
	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	
January (1)	1540	1540	0	1540	1540	0	1540	0	1540	1540	1540	0	1540	1540	0	1540	0	1540	3080
February (2)	1180	0	1180	1180	0	1180	1180	2000	-820	1180	0	1180	1180	0	1180	1180	2000	-820	3080
March (3)	600	1780	-1180	600	1780	-1180	600	1320	-720	600	1780	-1180	600	1780	-1180	600	1320	-720	-6160
April (4)	600	1800	-1200	600	1800	-1200	600	1320	-720	600	1800	-1200	600	1800	-1200	600	1320	-720	-6240
May (5)	1180	0	1180	1180	0	1180	1180	2000	-820	1180	0	1180	1180	0	1180	1180	2000	-820	3080
June (6)	1540	1200	340	1540	1200	340	1540	0	1540	1540	1200	340	1540	1200	340	1540	0	1540	4440
Final Shortage			320			320			0			320			320			0	1280

Customer 2

Period	Castle Dry Gin			Mandingo			Herb Afrik			Takai			Kaiser			Sorento			Final Shortage
	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	
January (1)	1540	1540	0	1540	1540	0	1540	674	866	1540	1540	0	1540	1540	0	1540	674	866	1732
February (2)	1180	1180	0	1180	1180	0	1180	1520	-340	1180	1180	0	1180	1180	0	1180	1520	-340	-680
March (3)	600	600	0	600	600	0	600	826	-226	600	600	0	600	600	0	600	826	-226	-452
April (4)	600	600	0	600	600	0	600	826	-226	600	600	0	600	600	0	600	826	-226	-452
May (5)	1180	1180	0	1180	1180	0	1180	1520	-340	1180	1180	0	1180	1180	0	1180	1520	-340	-680
June (6)	1540	1540	0	1540	1540	0	1540	674	866	1540	1540	0	1540	1540	0	1540	674	866	1732
Final Shortage			0			0			600			0			0			600	1200

Customer 3

Period	Castle Dry Gin			Mandingo			Herb Afrik			Takai			Kaiser			Sorento			Final Shortage
	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	Demand	Received	Short.	
January (1)	1540	1438	102	1540	1340	200	1540	1540	0	1540	1438	102	1540	1340	200	1540	1540	0	604
February (2)	1180	0	1180	1180	1180	0	1180	1180	0	1180	0	1180	1180	1180	0	1180	1180	0	2360
March (3)	600	1782	-1182	600	600	0	600	480	120	600	1782	-1182	600	600	0	600	480	120	-2124
April (4)	600	1782	-1182	600	600	0	600	480	120	600	1782	-1182	600	600	0	600	480	120	-2124
May (5)	1180	0	1180	1180	1180	0	1180	1180	0	1180	0	1180	1180	1180	0	1180	1180	0	2360
June (6)	1540	1438	102	1540	1340	200	1540	1540	0	1540	1438	102	1540	1340	200	1540	1540	0	604
Final Shortage			200			400			240			200			400			240	1680

Source: *Field Survey, 2020*

A further critical consideration of the relationship between the quantities demanded from customers, the products supplied by raw material suppliers, quantities delivered to customers, residual inventory at factory stores and the factory material capacity revealed interesting results (figure 5.1). In January, it is noticed that the quantity of products required by customers (27720kg) exceeds the material capacity of the factory (20000kg). Meanwhile, the quantities delivered to customers also exceed the factory's material capacity and the quantities received from suppliers by 2304kg. This can be explained by the initial inventories that yielded significant shortage in production hours. In the month of February, the quantity of products demanded by customers (21240kg) exceeds the factory capacity by 1240kg. Quantity delivered was 16480kg, which is way below the quantity demanded. However, in March and April, quantities of products delivered to customers (19536kg) far exceeds the customer demand of (10800kg), which is intended to satisfy as much as possible the shortages incurred in the previous months.

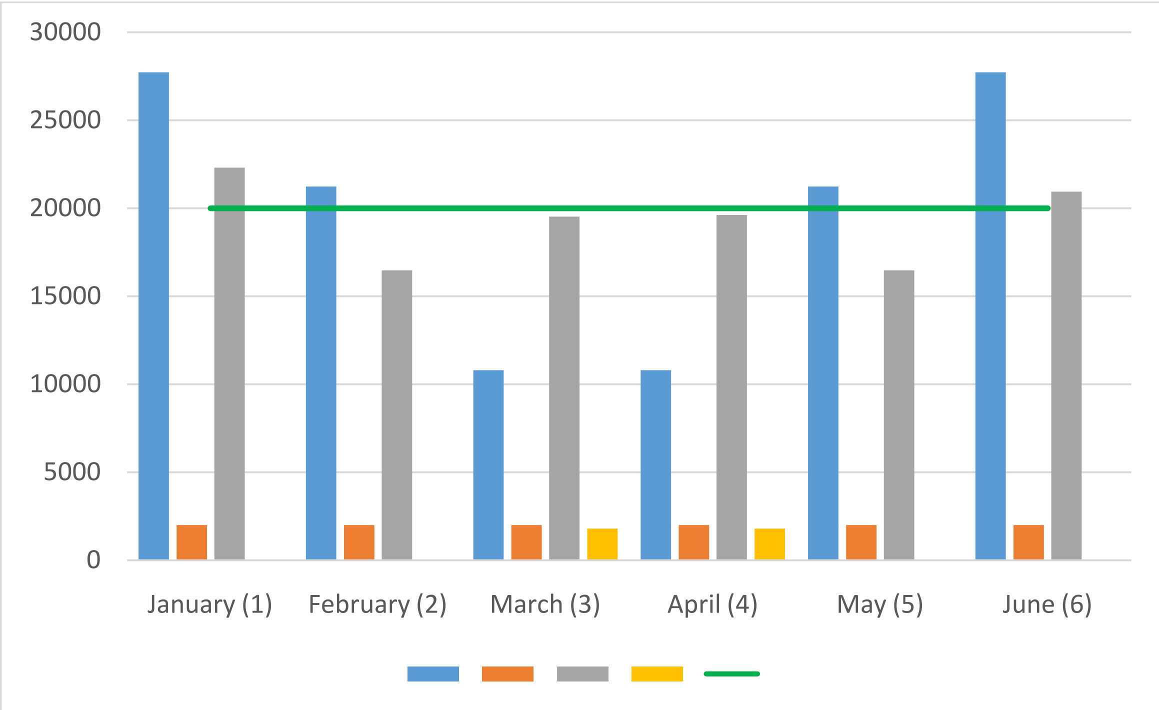

Figure 1: Customer Demand, Materials Supplied to the factory, Products Delivered to the Customer, Residual Inventory and Factory Material Capacity for Six Months

Source: *Field Survey, 2020*

Finally, the overall value of optimal profit, costs variables and revenues as presented in table 9. There is no doubt the model is effective for planning the production system of firms in the manufacturing industry, where the exact quantities to produce, deliver or store, as well as the number of human resources to deploy and what time, are specified along with the total revenue and cost achievable. In the case of GIHOC Distilleries limited, the production scheduling would assure the firm over $34 million having expended about $4.6 million for the six-month study period.

Table 9. Quantity Demand, Received, and Shortage of all Products for Six Months

No.	Cost	Excel Evolver
1	Fixed Costs ($)	100,000.00
2	Holding Costs ($)	12,000.00
3	Material Costs ($/kg)	2,331,200
4	Manufacturing Cost ($/hr)	2,331,200
5	Shortages	71,200
No.	**Cost/Revenue**	**Excel Evolver**
1	Non-Utilized Capacity Cost	60,000.00
2	Transportation Cost	67,088.00
3	Total Cost	4,972,688.00
4	Total Revenue	$34,968,000.00
5	**Total Profit**	**$29,995,312.00**

Source: *Field Survey, 2020*

The model illustrated above, produce optimal values that can ensure higher profits for firms that deploy them effectively. It must be added that, the production planning horizon should always span the entire production value chain to render it effectively. The horizon for the scheduling plan should be understood in the manner designed below (figure2).

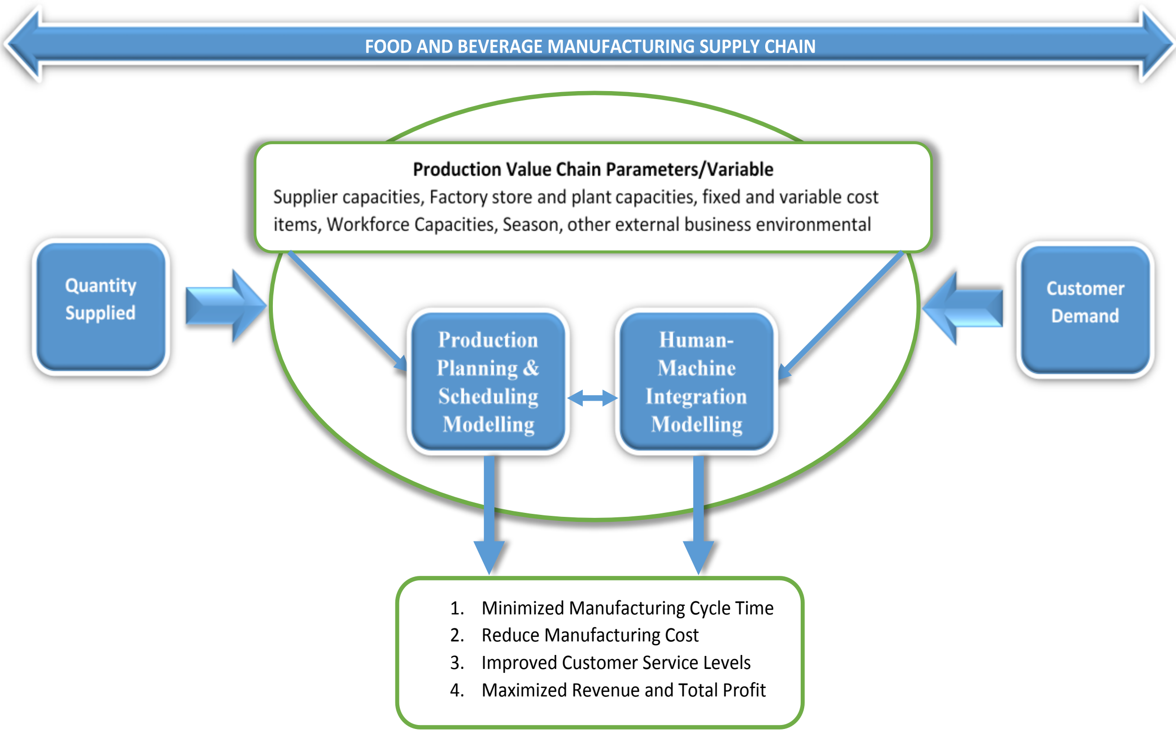

Figure 2. A proposed Enterprise Wide Analysis Tool for Production Scheduling Analysis in Food and Beverage Industry Firms in Ghana

Source: *Researchers Own Construct, 2020*

V. CONCLUSION

The food and beverage industry has remained a resilient one in many jurisdictions and has contributed massively to global economic growth. In this paper, production scheduling is explored in relation to the food and beverage industry in Ghana: the areas of human-machine interaction, production demand, production cycle time, and the production line of Kasapreko company Limited (KCL), Gihoc distilleries, and Healthi-Life Ghana limited all of whom are big wigs in Ghana's food and beverage industry are explored to understand the dynamics. The research reveals a growing demand for the products of these firms as they have been able to study the market and segment it accordingly. All of these companies have large production factories with large capacities. But it is noticed that the time taken for one production line to complete a task is often a bit too long and tasks also look not carefully scheduled. It therefor became palpable to design models for production scheduling optimization, Human-Machine integration optimization and Manufacturing cycle time optimization to fine-tune operations in the industry with demand. The queuing theory, Markov Chain model, task-artifact model, and the ant-colony optimization model formed the basis of the deduced models for this research. From the above insights from background to literature, and discussions, it can be justifiably said that the food and beverage industry in Ghana is on a verge of a massive breakthrough and international competition if these strategies will be applied critically. The conclusion is that, understanding production scheduling analysis and human-machine interaction can help increase production, reduce production cycle time, and increase profitability of food and beverage manufacturing firms in Ghana. Researchers and professionals should therefore focus on finding out the trends of production scheduling in specific segments of the industry to provide more precision is literature.

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