Simplifying Production Capacity and Workforce Planning for Firms in Ghana's Distillery Industry: A Simplex Linear Programming Illustration

Cherubin Yayra Kwasi Nunyuie

Alumnus, Department of Industrial Engineering, Hattiesburg, University of Southern Mississippi, U.S

Abstract

The convoluted operational nature of the distillery industry has left production managers battling with their planning needs. Meanwhile competition in the industry is nurtured around efficient and effective production facility and workforce configurations. Using a hypothetical dataset, this paper demonstrates how firms in Ghana's distillery industry can apply plant capacity utilization and efficiency measures, financial cost and volume analysis, and machine hour measuring techniques to plan their production configurations at optimal cost and profit levels. The paper also designs a workforce re-engineering model for firms using a Simplex Linear Programming (LP) Method. Firms are now assured of an effective strategy for decision-making on the type of production plant to install the quantity of products to produce in a particular period and the maximum cost and profit levels to produce at. In addition, firms can also determine labor-hours and overtime schedules that would be required for a particular production period accurately.

Keywords: Production Capacity, Production Planning, Workforce planning, Inventory, Strategy

1. Introduction

The manufacturing node of contemporary business value chain networks can be considered as the spinal cord of the world's economy. The manufacturing sector has gradually become the best strategic platform and planning unit for nations to gain infinite competitive and comparative edge over other competing nations. The United Nations Industrial Development Organization (UNIDO) (2017) revealed that manufacturing significantly contributes to global economic growth due to a much higher rate of manufacturing value added (MVA) growth in comparison with gross domestic product (GDP). One of the indicators selected for global monitoring on the progress of achieving the sustainable development goals (SDGs) refer to the ratio of MVA to GDP, which reiterates the importance of manufacturing activities in economic growth. Manufacturing growth in developing and emerging industrial economies, excluding China, increased to 2.5% in 2016. China's MVA dropped to 6.7% in 2016 from 7.1% in 2015 (UNIDO, 2017).

At the heart of all business operations lies cost reduction, customer focused service and profitability. Srivastava and Verma (2012) explained that firms are required to achieve sustainable competitive advantage in terms of cost savings and differentiation whiles creating value for shareholders and customers alike. A firm has competitive edge when it implements a strategy that creates superior value for customers, which competitors are unable to duplicate or find too costly to imitate (Hitt et al., 2014). Manufacturing operations in firms, particularly play a critical role in achieving and sustaining goals of businesses. Bhalla (2013) confirmed that inventory management and production scheduling are critical functions that have crucial bearing on the implementation of operational strategies. Per the innovative production and inventory control technologies and models developed over time, production planning and processes have become more accurate, cost efficient and optimal (Owusu-Mensah et al. (2020). Inventories offer the most important and fruitful area of cost reduction and increased profit, which encapsulate balancing ordering, holding, overstocking and understocking costs in order to minimize total cost (Bose, 2006). According to Piazola and Felderer (2016), the efficiency of a production company and its competitiveness is determined in large by the quality of planning.

Production capacity and workforce planning and engineering technologies are critical top-level decision-making tools that have direct and indirect repercussions on virtually all other plant processes along the production value chain. As identified by Gupta and Starr (2014), capacity management enquires about the existing production arrangement and whether any modification to it or other alternative configuration of resources might not provide superior profits at optimal costs. It was added that planning the workforce for a production period is strongly related to the output required, since it forms an integral part of demand forecast and control of inventories. Therefore, a meticulous installation and use of optimal production capacity resources, as well as an effective assignment and management of quality workforce is necessary for superior performance.

Companies in the distillery industry use raw ingredients, including grains, vegetables, fruits, and sugars, and manufacture them into spirits (Kaczanowska, 2012). Sutton and Kpentey (2012) vividly mapped the alcoholic beverage industry in Ghana. It is estimated that the annual per capita consumption of pure local alcohol in Ghana is approximately 1.54 liters. There are six large producers and a large number of medium sized and small firms who together produce over 200 brands. Ghana's alcoholic beverage industry is segmented into first, hard Liquors such as Whisky, Brandy, Schnapps, Gin and Rum. The second comprises Wines, Ciders and other mild alcoholic beverages. The third comprises Beer and Stout (Sutton & Kpentey, 2012, p.77) and finally, the industrially brewed drinks such as Pito (Prepared from millet), Akpeteshie (distilled from fermented palm sap) and Palm Wine (produced from sugary palm sap).
The manufacturing complexities inherent in the distillery industry only reemphasize the need for accurate decision-making tools especially for capacity and workforce planning and management (Owusu-Mensah et al., 2020). Associated with the high manufacturing complexities is the offer of a large product variety (Lang, 2009). In the words of Meier (2013), the planning of resources for industrial product-service delivery involves some challenges, which prevent the utilization of established methods for production planning and scheduling: demand forecasting is more difficult and unsecure, and the delivery times prof to be rather unstable.

Unfortunately, it is not uncommon to find production managers, particularly in developing countries, who rely solely on past production trends coupled with their experiences as the basis for making strategic, tactical and operational production control decisions. Gupta presented the challenges in production planning and controlling of a garment manufacturing firm as encompassing raw material sourcing and approval delays, sample approval delays, production delays, recording and communicating of wrong data,

and failure of final quality assurance inspections (Sarkar, 2015). Moreover, a high production system variability also results mainly from insufficient resources to perform the assigned tasks, insufficient capacity to handle the workload and insufficient time for planning and execution (Kutz, 2015). The elucidated problems above are replicated in Ghana's distillery industry.
Ultimately, the purpose of this paper to design a production capacity and workforce planning and management strategy for firms in Ghana's distillery industry using Kasapreko Company Limited (KCL) as case for application, in order to improve their production and inventory control efficiency for cost reduction, optimal operations and competitive edge.

The production capacity and workforce planning modelling and decision-making strategies proposed in this paper would benefit the world's distillery industry, as companies apply them in their operations. Again, the implementation of efficient production planning, workforce planning and inventory control operations by firms in Ghana's distillery industry translate into greater throughput, revenue generation, job creation and an expansion of Ghana's economy. Finally, the production cost of firms in the industry would be reduced mainly as a result of the minimization of idle labor and under-utilization of plants. The entire paper is organized in four main sections, with the remaining sections comprising the methodology, results and practical implementation of proposed models, and concluding remarks and directions for future research study.

1.1. Operationalizing key words in the study

The key terms used in this paper should be comprehended and interpreted as presented below. They include; Distillery, Production capacity, Inventory, Production planning and Strategy. The sub-section aims at placing the report into proper perspective for our readers as they understand the terms used herein. A Distillery is place where strong alcoholic liquors such as whisky, vodka and gin are made by distillation (Encarta Dictionaries, 2009). Distillation is the process of purifying a liquid by boiling the liquid and then condensing the vapors. Production capacity is often used interchangeably with production capacity. It is defined as the set of human resources and equipment that the company can use to produce goods or services to sell in the market (Matta & Semeraro, 2005). Sharma (1999) defined production planning as the art of making components and machines of specified quality on the planned production scale with the minimum consumption of materials and the maximum productivity of labor. Inventory is the goods that the organization keeps on hand for use in the production process. A company strategy is a set plans and policies by which a company tries to gain advantage over its competitors (Matta & Semeraro, 2005). It spans a wide scope of business functions and have long-term planning horizons (Sehgal, 2010).

1.2. Previous literature and novelty of current study

Previous literature on planning and managing production facility capacity and workforce is significantly limited for the distillery industry in developing countries let alone for individual companies. A chunk of existing production and inventory control literature tend to focus on efficient and effective operations management, enterprise resource planning, materials requirement planning and production cost analysis. However, few other works have applied mathematical models and software technologies to explaining the importance of optimal production capacity and workforce planning. This project fills the gaps in existing literature by employing mathematical models to assess the production capacity utilization and efficiency of a typical firm operating in the distillery industry in Ghana, in order to decide on what type and how much capacity to install in a regular production period, as well as on how and when to resize their workforce.

Nejad et al. (2022) proposed a data-driven model for analyzing energy consumption to achieve sustainable production system in a steel manufacturing industry. In a three-stage scenario analysis of consumption predictions, production scenarios and scenario-specific energy consumption prediction, it was found that Direct Reduced Iron (DRI), ladle age and scrap grade-3 most effectively predicted electricity consumption, whiles higher share DRI results in relatively high electricity consumption unlike input materials with high grade scrap share. Fireman et al. (2022) investigated the application of slack practices and resources for production planning and control in the construction industry based on observation, interviews and examining of documentation. The study showed 57 slack practice instantiations and 8 slack resources indicating a wide variety of coping mechanisms and the need to continually slack practices and resource interrelationships. In another study, a strategic model was designed for analyzing and planning cleaner production processes in the wood industry using analytical hierarchical process (AHP), towards improving energy consumption efficiency and minimizing pollution from Medium Density Fireboard (Khorshidi et al., 2021). In the same light, Benseman (2017) modeled the production planning system of the dairy industry in New Zealand using the time-staged Linear Programming Model. The modeled proved to be robust in modeling the seasonal availability and quality of wholemilk, guide decision-making on production input materials allocation, ensure timely response and adjustment of production schedules to market dynamics, and increase profitability.

Khanna (2015) espoused the significance of using modern advanced technology for production and operations management in the manufacturing sector. Innovative theories and applications; including material resource planning (MRP I & II) and Enterprise resource planning (ERP) were discussed. Guide JR et al. (2010) evaluated the capacity planning techniques practiced by the remanufacturing sector. Their study was revealed that the operational setting and dynamics of the remanufacturing industry required new capacity planning techniques developed in tandem with the standard techniques for the traditional new product manufacturing environment. Similarly, Geng and Jiang (2010) reviewed the existing solution to capacity planning that copes with the complexities associated with semiconductor manufacturing industry processes. Strategic capacity planning and design was therefore proposed to curtail the ramifications of the high capital investment cost, complex fabrication processes, high demand and capacity uncertainty, and rapid changes in technology. Das (2015) added a sustainability dimension to capacity planning of service businesses. It was identified that sustainability and the use of simulation and real options are emergent trends in capacity planning. For application purposes, methods to introduce sustainability in auto manufacturing in Sweden was examined. To that end, energy consumption and emission footprints were estimated for every capacity resources; simulation and virtual modeling cost effective tools were applied and real options approach was also applied to exercise the choices of stops, delay or expand capacity at different project time points.

In the area of workforce planning, Morecroft (2015) insightfully applied factory dynamic modelling and mathematical formulation to analyzing production workforce management. The model contained policies for forecasting, inventory control, production scheduling, workforce planning, hiring and departures as well as a production function depicting operating constraint of workforce on production. Moreover, Qin and Nembhard (2010) delved profoundly into the need for workforce agility in the rapidly changing production environment of current businesses. The lack of workforce agility was identified as the main hindrance to modern technology assimilation and market penetration. They therefore modeled the decision problem for workforce planning as a series of sequential investments in workforce capacity during the product life cycle. A real option valuation technique was used to optimize the design of workforce agility for maximum expected return in a stochastically diffused environment. Consequently, the sensitivity of production quality to market risks was reduced.

2. Materials and Methods

2.1. Data types and sources

A myriad of secondary data sources consisting of primary research findings were relied upon to make this study a success. Secondary data are extant data that may be useful to a current study but were collected for specific research objectives other than the study being currently conducted (Saunders et al., 2019). However, it is critical for researchers to evaluate available secondary data for their compatibility to current studies to ensure accurate, valid and generalizable research outcome (Cohen et al., 2017). In this study, documentary secondary data and survey-based data sources were used. These mainly include books, journals, magazine articles and newspapers particularly; the website of Kasapreko company limited (http://www.kasapreko.com), Sutton and Kpentey (2012), Mensah et al. (2014), Owusu-Mensah et al. (2020) and (Abubakari, 2015). Data reviewed encapsulated a brief overview of the establishment of Kasapreko Company Limited, their products and brands, marketing strategies, staff strength, revenue levels, main competitors and their supply and value chain processes.

Consequently, hypothetical datasets were derived based on the findings presented on the supply chain operations of Kasapreko Company Limited, in order to test the effectiveness of using the simplex linear programming and optimization models for production capacity and workforce planning. Several studies across varying discipline apply hypothetical data for modeling and analyzing phenomenon to inform decision-making (Jahanshahloo et al. 2005; Reed, 2009; Abdel-Maksoud & Saknidy, 2016; Gasior & Recchia, 2019; Wronski et al., 2021). The goal of ethics in research is to ensure that no one is harmed or suffers adverse consequences from research activities (Coldwell & Herbst, 2004). In this regard, the analysis and modelling would remain silent on private information and personal identification data.

2.2. Data analysis methods

First, a mathematical optimization model is used to analyze existing production capacity and to plan future capacities under current production plant operational conditions. Computation are based on design capacity, effective capacity and actual output parameters of the existing production facility capacities. Future capacity assessments require targeted annual demand, standard processing time per unit and the processing time needed during a production shift. Secondly, a Simplex-based Linear Programming (LP) method implemented in excel solvers was also used to formulate and solve workforce planning problems for Kasapreko Company Limited. The Simplex LP model is considered the most effective algorithm based decision-making tools that is useful solving complex relationships among variables to achieve optimal outcome (Azlan1 et al., 2017). Its application, spans across several aspects of operations management including resolving resource allocation and decision-making problems in labor, materials, machines, tools or capital, as well as for other optimization problems (Obot et al., 2016).

3. Results and Practical Application

3.1. Industry overview and background information of Kasapreko Company Limited

A brief background of KCL sets forth an explicit perspective for discussing its production planning and workforce planning processes and strategies. Emphasis is placed on the history, organizational culture and products.

Figure 1: Logo of KCL
Source: *http://www.kasapreko.com*

History

KCL was established in 1989 as a private enterprise with only five (5) workers by Dr. Kwabena Adjei at Nungua. The drive and passion to work coupled with the determination to respond to the growing demand for quality alcoholic drinks, fostered success. He started the business in a garage in Nungua, a suburb of Accra. Market penetration was quite a hurdle but was achieved by adopting a truly authentic approach; producing herbal-based products derived from rich herbs, locally sourced from Ghana's wealth of organic ingredients. KCL's vision differed from that of other alcoholic drink manufacturers in the country as it identified the increasing sophistication in the consumer: consistency in product taste, quality needs and attractive packaging. This meant the consumer was spending more on foreign imports and aspired for quality products. This was the mass niche that Kasapreko set out to serve, ensuring that it produced quality drinks at affordable prices for the ordinary Ghanaian (www.kasapreko.com).

Product Brands

Kasapreko has established a variety of brands in the bitters, whisky, gin, liqueur, brandy and wine drink categories, and continues to expand the range while expanding each brand's offerings. Our brands include *Kasapreko Alomo Bitters, Kasapreko London Dry Gin, Kalahari Bitters, Opeimu Herbal Bitters, Airforce Bitters, K20 Whisky, K20 Dry Gin, Kasapreko Barman Herbal Gin, Carnival Strawberry, VIP Irish Cream, Kasapreko Brandy, Tonic Wine, Kasavino Vermouth, Lime Cordial and Classic Margarita Lime* (www.kasapreko.com).

Figure 2: KCL's Brands

Source: http://www.kasapreko.com

Market Entry and Penetration

KCL has partnered qualified distributors to sell its products across Ghana as well as in Nigeria, Ivory Coast, Togo and South Africa. The company's best-selling product; *Alomo Bitters*, is also currently in high demand in Europe, America and Canada. In 2010, the company received the gold award for its export achievements and two years later, awarded the Exporter of the Year in 2012 (www.kasapreko.com)**.**

Employees

KCL currently employs over 600 regular and contract workers and over 2000 indirect workers.

Organizational culture and structure

The company's vision is to 'produce quality drink for all everywhere'. Its mission statement is 'to produce quality alcoholic and non-alcoholic beverages to satisfy consumers through the adoption of modern methods'. The company continually make use of research and development as well as the latest technology with local recipes in their production process. The company is also guided by a governance structure that encourages organizational effectiveness and motivates staff to achieve excellence (www.kasapreko.com)**.**

Market Type

KCL operates in an Oligopoly market structure.

Revenue

According to Mensah et al. (2014), the company achieved a steady growth rate in total sales and revenue from 2004 to 2006 ranging from GH¢ 1,539,138.00 to about GH¢2.5 million in 2006, but experienced a decline in 2007 with revenue of GH¢1,765,815.00. Another chain of growth is observed from 2007 to 2010 amounting to over 3 million Ghana cedis in revenue. Ghana contributes 50% of KCL's revenue, with Nigeria contributing 40% and the other 10% coming from other markets. The company made US$19.46 million in export revenues in 2012.

Headquarters and address

The company is located at D.T.D #64 off Sprintex Road, Baatsonaa, Accra.

Figure 3: KCL's Headquarters

Source: http://www.kasapreko.com

Main Competitors

GIHOC Distilleries Company Limited (GDCL), Baron Distilleries Limited (BARON), Agya Appiah Bitters (AGYA APPIAH), Joy Daddy Industries (JD), Kingdom Herbal and Guinness Ghana Breweries.

3.2. Logistics and supply chain processes of Kasapreko Company Limited

Procurement

According to Sutton and Kpentey (2012), KCL imports about 80% of inputs. Ethanol is imported from Brazil, India and Pakistan. Flavors are imported from Europe, bottles are imported from China and caps/corks from India. The inputs are sourced through brokers in Europe. Currently, the company has introduced its own proprietary custom-made bottles and caps as substitutes to those from India. Natural plants, potent parts and labels and boxes are sourced locally. The company has also recently procured holographic security seal on its products; Alomo Bitters and Alomo Silver form Germany and the United States of America. KCL has also acquired 40% share of a company in the Volta Region; Caltech Ventures Limited that process cassava into ethanol. This is aimed at reducing their import of ethanol by 50% and also reduce the impacts of the depreciated value of the Ghana Cedis of other international currencies.

Production

The aim of the production department is to satisfy all of their demand. The firm has always strategized to increase production capacity in order to meet surplus demand, consequently the introduction of new products in new markets have proved successful (Mensah et al., 2014). In 2012, the company expanded its automated factory by installed two liquor producing lines at a cost of US$30 million and a capacity to produce 40,000 plastic bottles per hour and 30,000 glass bottles per hour. The company uses over 25million litres of ethanol per annum. It also committed a total of about US$ 6.5 million to setting up a paper carton manufacturing subsidiary to feed its bottling lines at Spintex in Accra (Mensah et al., 2014). In 2015, the company increased capacity further in the quest to meet its increasing demand in the sub-Saharan Africa by installing a $70 million two high-speed production lines factory plants. These two lines produce water and non-alcoholic drinks with a combined capacity of 40,000 bottles per hour as well have a combined capacity to package 70,000 bottles in one hour in both glass and Polyethylene terephthalate (PET) formats. It also fills up 120,000 plastic sachets per shift.

Figure 4: KCL's FGs Warehouse and Newly Installed Production Plants (a, b, c)

(a)

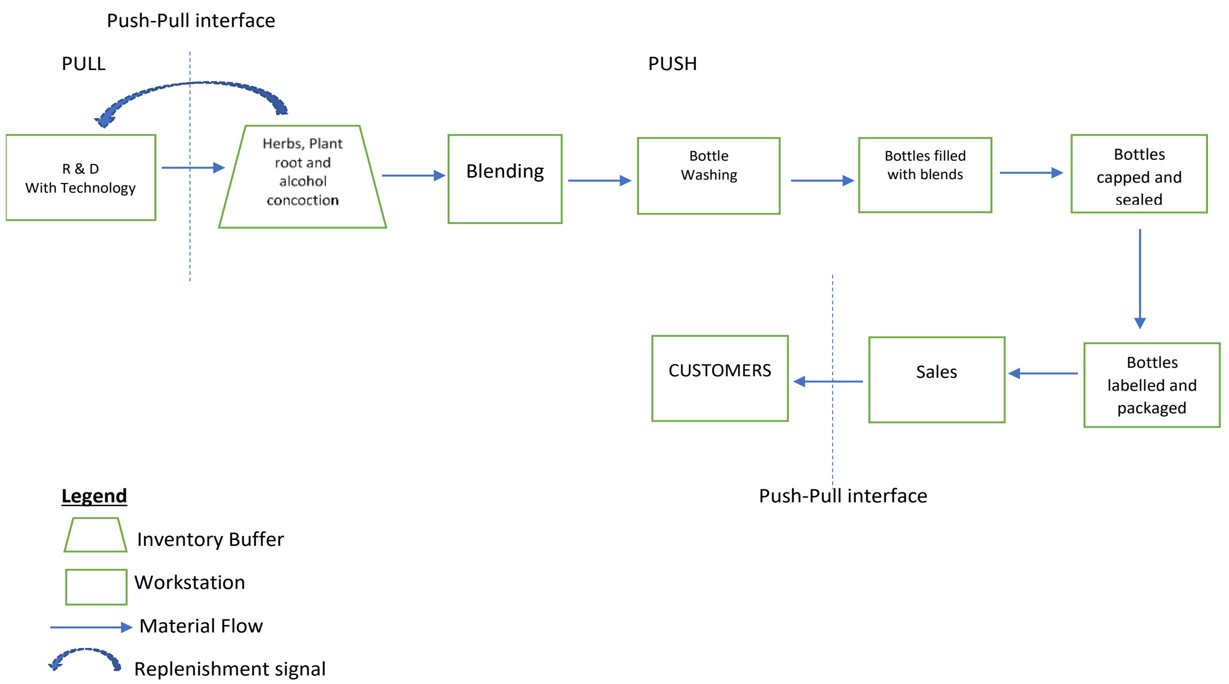
(b)

(c)

Source: http://www.kasapreko.com

KCL operates a hybrid production system: practice both push and pull systems. This system determines the point in the production process where the next job release is influenced either by customer factors or in-house production process factors (Figure 5). The production process is seamless due to the installed automated multi-product production plants. The company's Quality Control department collaborates with the Center for Scientific Research into Plant Medicine to supply the concentrate base for the production of products. Plant roots and herbs, alcohol and flavor concoctions are prepared about a week before the blending process takes place during production. At the first workstation, bottles are washed, then moved to the next workstation for it to be filled with various blends. At the next workstation, the bottles are capped, sealed and labeled. Finally, the products are packed into labelled cartons, sealed and lifted by forklifts to the warehouse.

Figure 5: Kasapreko Company Limited Production Line



Source: Researcher, 2023; Adapted from Hopp & Spearman, 2001

Warehousing and Distribution

KCL has recently opened a U$1.6million new ultra-modern warehouse in Kumasi in the Ashanti Region with a capacity of approximately 50,000 cartons of drinks. The company also have similar capacity warehouse in Accra. Key distributors of the company's products are located in all the regions of Ghana, about six (6) of them in Nigeria, some in South Africa, Togo, Benin, Cote d'Ivoire, Sierra Leone and Liberia. On the international market, they have Ghanaian expatriates who have some old brands in stock in the UK, USA, Belgium, Canada, Australia and Germany (Abubakari, 2015).

Figure 6: KCL's Product Distributors at the Loading Dock

Source: http://www.kasapreko.com

Marketing and Sales

KCL markets its products through sponsorships, award scheme, promotions, broadcasting commercials on both television and radio; billboards and parties, festivals and the like. Sales team conduct research about consumer taste and preference and also validate qualified potential distributors. The company also has key retail outlets in all countries it distributes its products.

3.3. Production Capacity Planning and Optimization Strategy for KCL

A strategic approach to production capacity planning and management engineering is one that considers the nitty gritty of ensuring an optimal profit as a result of using the available plant facilities or reconfiguring them to satisfy anticipated customer demand. Capacity planning and management strategies provide firms with the best accuracy and simple techniques to appreciate the optimal cost and profit outcomes that may result from various feasible plant set-up options within their resources. As couched by Das (2015), the goal of capacity planning is to minimize the discrepancy between demand and capacity in a cost effective, revenue effective, quality effective and safety effective manner. Thus, firms can decide on how much, when, where and what type of capacity to add in order to ensure sustained competitive manufacturing operations (Hopp & Spearman, 2001).

Kasapreko Company Limited has plans to penetrate its existing markets in the West African sub-region and also enter new markets in Europe. To be successful at satisfying future demands in the new markets, KCL must configure its capacities to supply those markets in an efficient and profitable manner. This section provides a strategic and holistic framework that would assist KCL in making its capacity requirement decisions in order to achieve optimal cost and profit. Existing capacities would be evaluated, future capacity requirements would be analyzed, financial cost and volume would also be analyzed.

3.3.1. Analyzing existing capacities of production facility

As explained in the method section of this paper, table 1 below shows a hypothetical data indicating the estimated design capacity, effective capacity and actual output of KCL's currently installed production plant in a typical production shift hour, as derived from the data collected from primary research surveys and cited as secondary data sources in the study.

Table 1: KCL's Production Plant Utilization and Efficiency Measure

Measure	Design Capacity	Effective Capacity	Actual Output
Quantity	73,000 cartons/day	55,000 cartons/day	52,000 cartons/day

The company operates an 8-hour shift per day. For the purposes of the computations in this study, we assume a single product production plant, where various products with different production lines and capacities are summed up.

Solution:

$\text{Design Capacity} = 73{,}000 \text{ cartons/day}$

$\text{Effective Capacity} = 55{,}000 \text{ cartons/day}$

$\text{Actual Capacity} = 52{,}000 \text{ cartons/day}$

$Where;$

$$\text{Efficiency} = \frac{\text{Actual Output}}{\text{Effective Capacity}} \qquad (1)$$

$$\text{Efficiency} = \frac{52{,}000}{55{,}000} \times 100$$

$$= \mathbf{94.5 \text{ or } 95\%}$$

$$\text{Utilization} = \frac{\text{Actual Output}}{\text{Design Capacity}} \qquad (2)$$

$$\text{Utilization} = \frac{52{,}000}{73{,}000} \times 100$$

$$= \mathbf{71.2 \text{ or } 71\%}$$

From the above calculated rates, it is recommended that KCL should improve its cycle time with aim to reduce idle hours of labor and machine.

3.3.2. Evaluating future capacities of production facilities

As presented earlier in the previous section, KCL has strategically positioned itself to take charge of planning and managing their production capacity requirements. However, a decision to make or buy in the context of planning capacities is considerable and worthy of taking a meticulous note of. This is specifically important to KCL since it plans to expand sales and its target markets. It would therefore be imperative for KCL to consider the available production capacity, the technical know-how of its workforce, the quality levels required by customers, the nature of the demand and market involved, an optimal cost and profit analysis and the risk involved with taking up such projects, before deciding on whether to buy or create capacities to satisfy anticipated demands.

First, we have to analyze the future processing requirements for KCL as it seeks to expand its market. Per the data estimated from respondents in the company, the production unit works for 8 hours per shift for 240 days in a year. See table 2 below for details.

Table 2: Future Annual Production Process Requirements for KCL

Products	Targeted Annual Demand (Cartons)	Standard Processing Time per Unit (hrs)	Processing Time Needed (hrs)
Alcoholic Beverage Production Plant	3,500,000	0.048	168,000
Non-Alcoholic Beverage Production Plant	2,000,000	0.050	100,000
TOTAL			**268,000**

Hence, anticipated annual capacity required = 8 hours × 240 days = **1,920 hours/machine**

The needed number of machine can be estimated as

$$\frac{268{,}000 \text{ hrs}}{1{,}920 \text{ hrs per machine}} = 139.6 \approx \mathbf{140\ machines\ needed}$$

Next, is to evaluate alternative capacity configurations that are available to KCL in order to decide on which capacity installations would meet the anticipated demand at an optimal operation cost and profit rates. The cost-volume analysis coupled with the break-even point functions were applied. As KCL aims at meeting its targeted estimated annual demand, the following data were generated. KCL may decide to add capacity by acquiring new production plants for $36 million dollars, with a variable cost pegged at $10 per carton and an estimated revenue of $30 per carton. How many cartons of products must be sold to break even? What profit or losses may be associated with future transactions that may result of particular capacity types? And what prices can be charged given a revenue and demand target? These questions would be answered in a moment.

Solution:

(a) Fixed Cost (FC) = $36,000,000 or $3,000,000 per month

Variable Cost (VC) = $10 per carton

Revenue (R) = $30 per carton

Therfore,

$$\text{Break even Quantity } (Q_{BEP}) = \frac{\text{Fixed Cost}}{\text{Revenue} - \text{Variable Cost}} \quad (3)$$

$$Q_{BEP} = \frac{3{,}000{,}000}{30 - 10}$$

$$Q_{BEP} = \frac{3{,}000{,}000}{20}$$

$= \mathbf{150,000\ cartons\ per\ month}$.

(b) Profit (P) = Q(R − VC) − FC (4)

Therefore, if KCL sells **200, 000** cartons every month, then

Q = Quantity produced and sold. = 200,000. Substituting this variable into the profit function,

= 200,000 (30 − 10) − 3,000,000

= 4,000,000 − 3,000,000

= $**1, 000, 000 per month.**

However, if KCL sells **100, 000** cartons every month, then

Q = 100,000. Substituting this variable into the profit function,

= 100,000 (30 − 10) − 3,000,000

= 2,000,000 − 3,000,000

$\mathbf{Loss = \$1,000,000\ per\ month}$.

(c) $\text{Profit (P)} = Q(R - VC) - FC$ (5)

However, if KCL targets aprofit level of $\mathbf{\$1,500,000}$ per month, but can only sell $\mathbf{200,000}$ cartons per month, then

$Q = 200{,}000$; $FC = \$3{,}000{,}000$ and

$VC = \$10$ per carton.

By substituting this variable into the profit function,

$1{,}500{,}000 = 200{,}000\ (R - 10) - 3{,}000{,}000$

$1{,}500{,}000 = 200{,}000R - 2{,}000{,}000 - 3{,}000{,}000$

$200{,}000R = 6{,}500{,}000$

$\mathbf{R = \$32.5\ per\ carton}$.

Hence, various figures according to company specific targets can be substituted for each variable in order to appreciate how different capacity configurations may turn out, as either profitable or losses.

3.4. Production Workforce Planning and Optimization Modeling Strategy for KCL

Planning and managing production workforce is equally critical as planning equipment capacities. The optimal performance of a production plant and equipment is engineered by an optimal assignment, sizing and overtime schedules for the available workforce. As KCL plan to enter and penetrate new markets, with its production targets, sales and revenues levels, it must also anticipate a workforce configuration that would assure the company of quality outputs at optimal production costs and profits. It must also be added that a workforce plan must be holistic enough to encompass both qualitative and quantitative labor force issues that are critical to production process configuration. This section presents a workforce planning and decision-making strategy for KCL using a linear programming model. According to Hopp and Spearman (2001), questions of how and when to resize the labor pool or whether to use overtime instead of workforce additions can be posed in the context of a linear programming formulation.

3.4.1. Workforce planning problem formulation and procedure

The LP model is by far the best and accurate optimization modelling techniques that is applied in the manufacturing industry, although with few discrepancies between real life problems and some assumptions of the model. Nonetheless, the model is flexible enough to incorporate diverse parameters and allow modifications to constraints. Per the estimated data gathered from KCL, a workforce plan for the next six (6) months can be modelled. The production plant works 8 hours a day and 160 hours a month. We assume that the only capacity constraints are those posed by labor, thus the required labor hours to produce one unit of the product using the single-product plant is given as 0.048 hours (equipment is highly automated). The projected demand from January, 2023 to June, 2023 are given as 250,000, 270,000, 275,000, 300,000, 350,000, and 400,000. Net revenue per unit is estimated at $25.00. Monthly inventory holding cost is pegged at $6.00 per unit. 10 workers are involved at the beginning of the planning horizon. Regular time labor cost is $30.00 per hour and overtime cost is half or regular time cost plus the cost of regular time labor, which is $45.00 per hour. The cost of hiring and training one labor is estimated at $2,000.00 and the cost of laying off a worker is estimated at $1,000.00.

3.4.2. Modeling and designing the workforce plan

Parameters introduced

Let j = an index of workstations, where j=1,……, n, so n represents the total number of workstations.
$\bar{t}$ = an index of periods, where t=1,……,$\bar{t}$, so $\bar{t}$ represents the planning horizon.
$\bar{d}_t$ = maximum demand in period t.
$\underline{d}_t$ = minimum sales allowed in period t.
a_j = time required on workstation j to produce one unit of product.
b = number of worker-hours required to produce one unit of product.
c_{jt} = capacity of workstation j in period t.
r = net profit per unit of product sold.
h = cost to hold one unit of product for one period.
l = cost of regular time in dollars per worker-hour.
l' = cost of overtime time in dollars per worker-hour.
e = cost to increase workforce by one worker-hour per period.
e' = cost to decrease workforce by one worker-hour per period.
X_t = amount produced in period t.
S_t = amount sold in period t.
I_t = inventory at the end of t (I_0 is given as data).
W_t = workforce in period t in worker-hours of regular time (W_0 is given as data)
H_t = increase (hires) in workforce from period $t – 1$ to t in worker-hours.
F_t = decrease (fires) in workforce from period $t – 1$ to t in worker-hours.
O_t = Overtime in period t in hours.

Solving for some parameters

t = {1, 2, 3, 4, 5, 6}
W_0 = The total number of labor hours available at the beginning of the planning horizon
$= 10\, workers \times 160 worker\ hrs\ per\ month = \mathbf{1600 \boldsymbol{hrs\ per\ month}}$.
I_0 = Inventory at the beginning of the period = **0 *units***
e = Hiring cost per worker hour = $\frac{\$\,2{,}000}{160\ hrs}$ = **\$12.5≈ \$13 per worker hour**
e' = Cost of firing a labor per worker hours = $\frac{\$\,1{,}000}{160\ hrs}$ = **\$6.25≈ \$6 / worker hour**
l' = Overtime cost = \$30 + \$15 = **\$45 per hour**
b = labor hours required to produce one unit of product (serving as the only capacity constraints, thus we can omit constraints (2) in our LP formulation) = **0.048 hours per unit produced**.
The objective function of the model is to maximize net profit, including labor, overtime, holding, and hiring/firing costs, subject to constraints on sales capacity. This is computed as the difference between net revenue and inventory carrying costs, wages; including regular and overtime, and workforce decrease or increase costs. This is formulated below;

$$\textbf{Maximize} = \sum_{t=1}^{\bar{t}} \{rS_t - hI_t - lW_t - l'O_t - eH_t - e'F_t\} \qquad (6)$$

Subject to:

1. Sales limit constraints for each month ($d_t \leq S_t \leq \bar{d}_t \quad \forall\ t$)
2. Capacity constraints for each work station ($a_j X_t \leq c_{jt} \quad \forall\ j, t$)
3. Inventory balance Constraints ($I_t = I_{t-1} + X_t - S_t \quad \forall\ t$)
4. The given size of workforce in a given period ($W_t = W_{t-1} + H_t - F_t \quad \forall\ t$)
5. Constraints on regular time and Overtime ($bX_t \leq W_t + O_t \quad \forall\ t$)
6. All decision variables must be integers ($X_t, S_t, I_t, O_t, W_t, H_t, F_t \geq 0 \quad \forall\ t$)

As we assume that all demands are met, we set $S_t = d_t$ to avoid separate sales variables and sales constraints.

Decision variables

X_t = amount that should be produced in each month.
I_t = inventory at the end of each month.
W_t = workforce worker-hours of regular time required in each month
H_t = increase (hires) in workforce worker-hours required in each month.
F_t = decrease (fires) in workforce worker-hours required in each month.
O_t = Overtime schedule hours required in each month.

Non-parametric LP formulation

$$\text{Maximize } Z = 25(d_1 + \cdots + d_6) - 6(I_1 + \cdots + I_6) - 30(W_1 + \cdots + W_6) - 45(O_1 + \cdots + O_6) - 13(H_1 + \cdots + H_6) - 6(F_1 + \cdots + F_6)$$

Subject to the following;

$I_1 - I_0 - X_1 = -d_1$
$I_2 - I_1 - X_2 = -d_2$
$I_3 - I_2 - X_3 = -d_3$
$I_4 - I_3 - X_4 = -d_4$
$I_5 - I_4 - X_5 = -d_5$
$I_6 - I_5 - X_6 = -d_6$
$W_1 - H_1 + F_1 = 1{,}600$
$W_2 - W_1 - H_2 + F_2 = 0$
$W_3 - W_2 - H_3 + F_3 = 0$
$W_4 - W_3 - H_4 + F_4 = 0$
$W_5 - W_4 - H_5 + F_5 = 0$
$W_6 - W_5 - H_6 + F_6 = 0$
$0.048X_1 - W_1 - O_1 \leq 0$
$0.048X_2 - W_2 - O_2 \leq 0$
$0.048X_3 - W_3 - O_3 \leq 0$
$0.048X_4 - W_4 - O_4 \leq 0$
$0.048X_5 - W_5 - O_5 \leq 0$
$0.048X_6 - W_6 - O_6 \leq 0$

By formulating the problem with Microsoft Excel Solvers, the following optimal solutions were obtained as presented in figure 7 and 8 below.

Figure 7: Workforce Planning Model for KCL (Initial LP Formulation)

Parameters						
r	25					
h	6					
l	30					
l'	45					
e	13					
e'	6					
b	0.048					
I_0	0					
w_0	1600					
t	**1**	**2**	**3**	**4**	**5**	**6**
d_t	250,000	270,000	275,000	300,000	350,000	400,000
Decision Variable						
t	**1**	**2**	**3**	**4**	**5**	**6**
Xt	0.00	0.00	0.00	0.00	0.00	0.00
Wt	0.00	0.00	0.00	0.00	0.00	0.00
Ht	0.00	0.00	0.00	0.00	0.00	0.00
Ft	0.00	0.00	0.00	0.00	0.00	0.00
It	0.00	0.00	0.00	0.00	0.00	0.00
Ot	0.00	0.00	0.00	0.00	0.00	0.00
Objective (Maximize Net Profit)	**$46,125,000.00**					
Constraints						
I1-I0-X1	0.00	=	-250000	*(-d_1)*		
I2-I1-X2	0.00	=	-270000	*(-d_2)*		
I3-I2-X3	0.00	=	-275000	*(-d_3)*		
I4-I3-X4	0.00	=	-300000	*(-d_4)*		
I5-I4-X5	0.00	=	-350000	*(-d_5)*		
I6-I5-X6	0.00	=	-400000	*(-d_6)*		
W1-W0-H1+F1	-1600.00	=	0			
W2-W1-H2+F2	0.00	=	0			
W3-W2-H3+F3	0.00	=	0			
W4-W3-H4+F4	0.00	=	0			
W5-W4-H5+F5	0.00	=	0			
W6-W5-H6+F6	0.00	=	0			
bX1-W1-O1	0.00	<=	0			
bX2-W2-O2	0.00	<=	0			
bX3-W3-O3	0.00	<=	0			
bX4-W4-O4	0.00	<=	0			
bX5-W5-O5	0.00	<=	0			
bX6-W6-O6	0.00	<=	0			
All decision variables must be >= 0						

Figure 8: Workforce Planning Model for KCL (Optimal Solution)

Parameters						
r	25					
h	6					
l	30					
l'	45					
e	13					
e'	6					
b	0.048					
I_0	0					
w_0	1600					
t	**1**	**2**	**3**	**4**	**5**	**6**
d_t	250,000	270,000	275,000	300,000	350,000	400,000
Decision Variable						
t	**1**	**2**	**3**	**4**	**5**	**6**
Xt	250000.00	270000.00	275000.00	300000.00	350000.00	400000.00
Wt	12000.00	12960.00	13200.00	14400.00	16800.00	19200.00
Ht	0.00	960.00	240.00	1200.00	2400.00	2400.00
Ft	13600.00	0.00	0.00	0.00	0.00	0.00
It	0.00	0.00	0.00	0.00	0.00	0.00
Ot	0.00	0.00	0.00	0.00	0.00	0.00
Objective (Maximize Net Profit)	**$43,293,000.00**					
Constraints						
I1-I0-X1	-250000.00	=	-250000	*(-d_1)*		
I2-I1-X2	-270000.00	=	-270000	*(-d_2)*		
I3-I2-X3	-275000.00	=	-275000	*(-d_3)*		
I4-I3-X4	-300000	=	-300000	*(-d_4)*		
I5-I4-X5	-350000	=	-350000	*(-d_5)*		
I6-I5-X6	-400000	=	-400000	*(-d_6)*		
W1-W0-H1+F1	0.00	=	0			
W2-W1-H2+F2	0.00	=	0			
W3-W2-H3+F3	0.00	=	0			
W4-W3-H4+F4	0.00	=	0			
W5-W4-H5+F5	0.00	=	0			
W6-W5-H6+F6	0.00	=	0			
bX1-W1-O1	0.00	<=	0			
bX2-W2-O2	0.00	<=	0			
bX3-W3-O3	0.00	<=	0			
bX4-W4-O4	0.00	<=	0			
bX5-W5-O5	0.00	<=	0			
bX6-W6-O6	0.00	<=	0			
	All decision variables must be >= 0					

3.4.3. Decision-making strategy for firms

From the above analysis and discussion, we can conclude that, the LP model is useful for making decisions on how much workforce size to hire or release, the period in which to hire or fire labor, how overtime hours to schedule, how much inventory is optimal hold and what quantity of goods to produce at the best cost possible. For KCL to achieve the maximum profit of **$43, 293,000.00** at an optimal cost within the first six month of 2023, given the constraints they set for themselves, they must not schedule for overtime work in the period. Again, the company may only fire labor in the first month but not in subsequent ones. Moreover, regular time working hours should be **12,000 hours in January, 12,960 hours in February, 13,200 hours in March, 14,400 hours in April, 16,800 hours in May and 19,200 in June.** Finally, no inventory must be held within the period.

4. Conclusion and Future Research Direction

Kasapreko Company Limited is competitive in the distillery industry mainly because of its production technology prowess. Per the projected capacity and workforce configurations, KCL is assured of huge revenue turnovers in this year and the beyond, only if the company would remain consistent with the constraints formulated. In as much as the company has enjoyed sales volume increases in the last few years and continue to expand their international markets base, they must as well strive to continually deploy appropriate capacity and workforce engineering tools in order to sustain optimal production cost and profits. It must be emphasized that an extended period of non-optimal production operations will cause KCL's competitive edge to deplete. The profound insight derived from applying the above discussed production capacity and workforce planning techniques and mathematical analytical tools is unequivocal. Firms in the Ghana's distillery industry are therefore assured of a more accurate and holistic approach to management decision making in planning their production and workforce capacities ahead of an anticipated demand.

Future researchers should work on how to fully capture and incorporate the dynamics of real world production processes into existing mathematical models and software. Again, various parameters and constraints within the model should be modified in order to simulate the various possible outcomes of the decision variables. For instance, the company can decide not to fire any worker ($F_t = 0$) within the period, which would display a different outcome of optimal solution.

Conflict of Interest

The author declares no competing interests.

Acknowledgement

I thank God for my life and as well grateful to my family and friends for their immeasurable support and motivation.

Author's Biography

I am an alumnus of the University of Southern Mississippi in the U.S, Department of Industrial Engineering, Hattiesburg (2019). I founded my own logistics and transport service firm in Ghana (Cherukyn Logistics Limited, Accra-Ghana) in July 2016. I am currently serving in the company as the Chief Executive Officer. In addition to the above position, I also serve as a Principal Disaster Control Officer at the Ho West District Office of the National Disaster Management Organization (NADMO) in Ghana. I have also attained a professional certification as a chattered member of the Chattered Institute of Logistics and Transport (Ghana & UK).

References

1. Abdel-Maksoud, B.M., Saknidy, S. "A New Approach for Training Needs Assessment." Journal of Human Resource and Sustainability Studies, , 4, (2016): 102-109. <http://dx.doi.org/10.4236/jhrss.2016.42012>.
2. Abubakari, S.A. Kasapreko to Expand its Market With More Products. 5 Nov 2015. <www.newsghana.com>.
3. Azlan,N.A.A.N., Saptari, A., & Mohamad, D E. "Augmentation of Simplex Algorithm for Linear Programming Problem to Enhance Computational Performance." Journal of Advanced Manufacturing Technology (2017).
4. Benseman, B.R. "Production Planning in the New Zealand Diary Industry." Journal of the Operational Research Society 37.8 (2017): 747-754. <https://doi.org/10.1057/jors.1986.135>.
5. Bhalla, V.K. International Business. New Delhi: S. Chand & Company Private Limited Publishing, 2013.
6. Bose, D.C. Inventory Management. New Delhi: PHI Learning Private Limited, 2006.
7. Cohen, L., Manion, L., & Morrison, K. "Using Secondary Data in Educational Research." Research Methods in Education. Routledge, 2017. 7.
8. Coldwell, D. & Herbst, F. Business Research. Cape Town: Juta and Company Limited, 2004.
9. Daft, R.L., Kendrick, M., & Vershinina, N. Management. UK: Cengage Learning. EMEA, 2010.
10. Das, A. An Introduction to Operations Management: The Joy of Operations. New York: Routledge, 2015.
11. Fireman, M.C.T., Saurin, T.A., Formoso, C.T., Koskela, L., & Tommelein, I.D. "Slack in Production Planning and Control: A Study in the Construction Industry." Construction Management and Economics (2022). <https://doi.org/10.1080/01446193.2022.2135749>.
12. Gasior, K., & Recchia, P. "The Use of Hypothetical Household Data for Policy Learning: Comparative Tax-Benefit Indicators Using EUROMOD HHoT." Journal of Comparative Policy Analysis: Research and Practice 22.2 (2019): 170-189. <https://doi.org/10.1080/13876988.2019.1609784>.
13. Geng, N.,& Jiang, Z. "A review on Strategic Capacity Planning for the Semiconductor Manufacturing Industry." International Journal of Production Research 47, 2009.13 (2010): 3639-3655.
14. Guide JR., V.D.R, Srivastava, R., & Spencer,M.S. "An Evaluation of Capacity Planning Techniques in a Remanufacturing Environment." International Journal of Production Research 35, 1997.1 (2010).

15. Gupta, S., & Starr, M. Production and Operations Management System. New York: CRC Press, 2014.

16. Gupta, S.K. The Routledge Companion to Production and Operations Management. New York: Taylor & Francis Group., 2017.

17. Hitt, M.A., Ireland, D. & Hoskisson, R.E. Strategic Management: Concepts; Competitiveness and Globalization. 11th. USA: Cengage Learning, 2014.

18. Hopp, W.J., & Spearman, M.L. Factory Physics: Foundation of Manufacturing Management. 2nd. New York: Irwin McGraw-Hill, 2001.

19. Jahanshahloo, G.R, Lofti, F.H., Shoja, N., Tohidi, G., & Razavyan, S. "Undesirable Inputs and Outputs in DEA Models." Applied Mathematical and Computation 169.2 (2005): 917-925.

20. Kaczanowska, A. "Distilleries in the US (IBIS Wolrd Industry Report 31214)." 2012. <http://0-client1.ibisworld.com>.

21. Khanna, R.B. Production and Operations Management. New Delhi: PHI Learning Private Limited, 2015.

22. Khorshidi, F.H., Azizi, M., Ray, C., Faezipour, M.M., & Hosseinabadi, H.Z. "An Analysis of Cleaner Production Planning by Applying Analytical Hierarchy Process: A Wood Industry Case Study." International Journal of Sustainable Engineering 14.3 (2021): 245-254. <https://doi.org/10.01080/19397038.2021.1924893>.

23. Kutz, M. Handbook of Measurement in Science and Engineering,. Vol. I. New Jersey: John Wiley & Sons Inc. Publication., 2015.

24. Lang, J.C. Production and Inventory Management with Substitutions. . New York: Springer Science & Business Media, 2009.

25. Matta, A., & Semeraro, Q. Design of Advanced Manufacturing Systems: Models for Capacity Planning in Advanced Manufacturing Systems. New York: Springer Science, 2005.

26. Meier, H. "Product Service Integration for Sustainable Solution." Proceeding of the 5th CIRP International Conference on Industrial Product-Service Sysytems, Bochum, Germany 14th -15th March. New York: Springer Science, 2013.

27. Mensah, C., Diyuoh, D., Oppong, D. "Assessment of Supply Chain Management Practices and It Effects on the Performance of Kasapreko Company Limited In Ghana." European Journal of Logistics Purchasing and Supply Chain Management 2.1 (2014): 1-16. <www.ea-journals.org>.

28. Morecroft, J.D.W. Straegic Modelling and Business Dynamics, + Website: A Feedback System Approach. UK: John Wiley & Sons., 2015.

29. Nejad, M.C., Hadavandi, E., Nakhostin, M.M., & Mehmanpazir, F. "A Data-driven Model for Energy Consumption Analysis along with Sustainable Production: A Case Study in the Steel

Industry." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 44.2 (2022): 3360-3380. <https://doi.org/10.1080/15567036.2022.2064943>.

30. Obot,A., Anthony , U. M., & Ozuomba, S. "A Novel Tabular Form of the Simplex Method for Solving Linear Programming Problems." International journal of Computer Science & Network Solutions 4.2 (2016).
31. Owusu-Mensah, D., Naifei, P.R., Lydia, B., Boateng, P., & Darkwah, W.K. "Analysis of Production System Management of Ghana's Food and Beverage Industry: Empirical evidence from Spare Parts Inventory Control, Production Quality and Maintenance Modeling." Journal of Food Industry 4.1 (2020). <http://dx.doi.org/10.5296/jfi.v4i1.16511>.
32. Piazola, F. & Felderer,M. Multidimesional Views on Enterprise Information Systems: Proceedings of ERP Future. Springer Science, 2016.
33. Qin, R., & Nembhard, D. "Workforce Agility for Stochastically diffused Conditions: A Real Option Perspective." International Journal of Production Economics 125.2 (2010): 324-334.
34. Reed, D.D. "Using Microsoft Office Excelh 2007 to Conduct Generalized Matching Analyses." Journal of Applied Behavior Analysis 42.4 (2009): 867–875.
35. Sarkar, P. Challenges in production planning and Control in Apparel Manufacturing. 2015. 14 November 2017. <www.onlineclothingstudy.com>.
36. Saunders, M., Lewis, P. and Thornhill, A. Research Methods for Business Students. 7th. England: Pearson Education Limited, 2019.
37. Seghal, V. Supply Chain As Strategic Asset: The Key To Reaching Business Goals. New Jersey: John Willey And Sons Inc, 2010.
38. Sharma, P.C. A Textbook of Production Engineering. New Delhi: S. Chand & Company Limited, 1999.
39. Srivastava, R.M. & Verma, S. Strategic Management Concepts, Skills and Practices. New Delhi: PHI Learning Private Limited, 2012.
40. Sutton, J.,& Kpentey, B. An Entreprise Map of Ghana. UK: International Growth Center (IGC), 2012.
41. United Nations Industrial Development Organization (UNIDO). International Yearbook of Industrial Statistics. Cheltonham, UK: Edward Elgar Publishing Limited, 2017.
42. Wronski, P., Wensing, M., Ghosh, S., Garttner, L., Muller, W., & Koetsenruijter, J. "Use of Quantitative Data Report in A Hypothetical Decision Scenario for Health Policymaking: A Computer-assisted Laboratory Study." BMC Medical Informatics and Decision Making (2021).