Aggregate Production Planning Framework in a Multi-Product Factory

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***Abstract*— The study investigates the best model of aggregate planning activity in a manufacturing operation. Trial and error method spread sheets were used to solve aggregate production planning problems. Linear programming model was introduced to optimize the aggregate production planning decisions. Case study application of the models in a furniture production firm was evaluated to demonstrate the effectiveness of the models.**

***Keywords*— aggregate production planning, trial and error, linear programming, furniture industry**

I. Introduction

Rapid change in global markets and international trade has affected the management of operations as it calls for competitive positioning in this arena. To this effect, the concept of production management has evolved beyond the scope of a single manufacturing location. Thus increased competition, coordination and control of production activities of factories spread across regions have become more important than ever [1].The aggregate plan contains targeted sales forecasts, production levels, inventory levels and customer order backlogs. In this regard, aggregate planning is an attempt to balance capacity and demand in such a way that costs are minimized.

Aggregate planning, being medium term in nature aims at bridging the gap between strategic planning and operational planning. Aggregate planning takes about 2 to 18 months [2]. During this period capacity can be managed by adding more resources, increasing working hours and reducing workforce. Other decisions to be taken may include changing the product mix and to some extent the layout. In this way the company is able to adapt to the dynamism of the market [3].

II. Justification

Local furniture industry has been facing challenges such as lack of technology, obsolete equipment, long turnover time and short product lifecycles. A solution approach to aggregate planning problem can be applied using optimization tools such as spreadsheets and linear programming to achieve an optimum solution. The furniture industry is a labor intensive industry with seasonal demand in most instances.

The application of aggregate production planning in the country is limited. The complexity of planning models is the reason why firms do not develop advanced production planning models. Most companies perform demand forecast, but due to changing customer patterns, production inefficiencies and nature of products the firms do not develop strategies to meet the changing demands. Ad hoc strategies to manage supply and demand are effected.

Explicit determination of the demand in terms of products in this era is difficult therefore it fails to give the projected load on the production facilities [4]. Aggregate production planning is therefore, an important aspect that determines demand in such a way as to give a clearer picture of the actual production load. To achieve this, the products are classified according to their size and type of operation. In this study several aggregate planning models will be developed to minimize cost [5]. Adjustments are made for monitoring and control of the industrial processes in order to respond to a changing environment to achieve optimum performance.

III. Overview of Production Planning(APP)

Manufacturing planning and control address decisions on the acquisition, utilization and allocation of production resources to satisfy customer requirements in the most efficient and effective way. Typical decisions include work force level, production lot sizes, assignment of overtime and sequencing of production runs. Optimization models are widely applicable for providing decision support in this context [5]. Management makes decisions in varying time scales and these affect overall company objectives based on the same models.

In a highly competitive and constantly changing market environment, it is even more important to have a high degree of coordination between all the planning activities. It is widely recognised that there is a great deal of potential for reducing costs in many areas if more efficient aggregate planning methods can be found which harmonise the system in its entirety[3]. The planning activity of an organisation is illustrated in Fig 1 below.

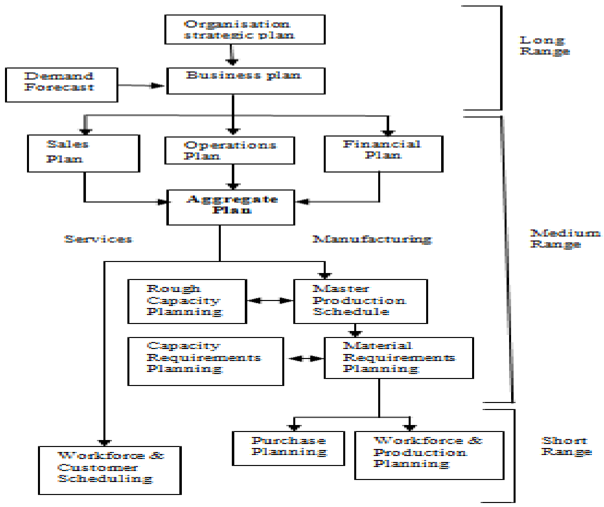

Fig 1.Operations planning hierarchy[3]

The business plan which is long term in nature yields the sales, operational and financial plan; these are key components of a functioning aggregate plan. A business plan elucidates management commitment and decision in the deployment of a company's resources. It sets the tone for a company's priorities and means of achieving them. Essentially it is a road map for business success. It highlights a well thought plan, the company needs to take to reach, maintain and grow revenue [5].

Capacity planning is the process of determining the production capacity needed by a manufacturing to meet changing demands. Capacity can be defined in two ways: design capacity and effective capacity. Design capacity is the capacity of a process or facility as it is calculated to be whilst effective capacity is the useful capacity of a process after maintenance, changeover, loading and other stoppages has been accounted for. The ratio of the actual output from a process or facility to its design capacity yields the utilisation of the firm [7].

$$\text{Utilisation} = \frac{\text{actual output}}{\text{design capacity}} \quad (1)$$

$$\text{Efficiency} = \frac{\text{actual output}}{\text{effective capacity}} \quad (2)$$

The identification of the relevant costs in aggregate production planning is an important issue. For production planning, firms typically need to determine the variable production costs, including setup-related costs, inventory holding costs, and the relevant resource acquisition costs. Costs associated with imperfect customer service, such as when demand is back ordered should be catered for. Planning problem always exists because there are limited production resources that cannot be stored from period to period. Choices must be made as to which resources to include and how to model their capacity and behavior, and their costs [5].

There is uncertainty associated with the production function, which are uncertain yields or lead times. It is preferable to include the most critical resource in the planning problem for instance, a bottleneck. Alternatively, when there is no dominant resource, then it becomes necessary to model the resources that could limit production.

There are two types of production functions. The first assumes a linear relationship between the production quantity and the resource consumption. The second assumes that there is a required fixed charge or setup to initiate production and then a linear relationship between the production quantity and resource usage. Related to these choices is the selection of the time period and planning horizon. The planning literature distinguishes between strategic and operational time periods [8]. For strategic issues, the planner has to worry about how to schedule or sequence the production runs assigned to any time period. The choice of planning horizon is dictated by the lead times to enact production and resource-related decisions, as well as the quality of knowledge about future demand.

A.Characteristics of aggregate planning [4]

In the broad sense of the definition, the aggregate-planning problem has the following characteristics:

- A time horizon of about 12 months, with updating of the plan on a periodic basis (conceivably monthly)
- An aggregate level of product demand consisting of one or a few categories of product – the demand is either fluctuating, uncertain or seasonal
- The possibility of changing both supply and demand variables
- A variety of management objectives which might include low inventories, good labor relations, low costs, flexibility to increase future output levels and good customer service
- Facilities are fixed and cannot be expanded

Aggregate planning is used in a manufacturing environment and determines not only the overall output levels planned but the corresponding input resources for the related products. Various alternatives exist for matching demand with capacity. Options which can be used to increase or decrease capacity to match current demand include:

Hiring and laying off workers - Hiring additional workers as needed or by laying off workers not currently required.

Overtime - This entails asking or requiring workers to work extra hours a day or an extra day per week, firms can create a temporary increase in capacity without the added expense of hiring additional workers.
Part-time or casual labour - By utilizing temporary workers or casual labour (workers who are considered permanent but only work when needed, on an on call basis, and typically without the benefits given to full time workers), companies reduce the salary bill significantly.
Inventory – Finished goods inventory can be built up in periods of slack demand and then used to fill demand during periods of high demand
Sub-contracting - Frequently firms choose to allow another manufacturer or service provider to provide the product or service to the subcontracting firm's customers.

Cross-training – Cross trained employees may be able to perform tasks in several operations, creating some flexibility when scheduling capacity.
Other methods **-** Among these options are sharing employees with counter cyclical companies and attempting to find interesting and meaningful projects for employees to do during slack times.

The furniture industry is a labour intensive sector thus the workforce variable in aggregate planning needs to be approached cautiously. Earlier studies suggested that worker transfer between production lines is more beneficial than hiring and firing. Worker flexibility has more impact in aggregate planning as it enhances worker learning and reduces labour attrition due to laying- off. Heterogeneous efficiency of transferred workers reduces costs associated with labour efficiency and throughput losses. Incentives, extend of planning and the manufacturing environment which is characterised by the tooling, work piece material, measurement instruments and part complexity has an effect on worker flexibility.

Demand management seeks to make demand smooth and less seasonal therefore it allows planning for constant production throughout the year. The strategy implies that demand be shifted from peak seasons to low seasons where most firms are operating below capacity. Aggregate Planning can be used to influence demand as well as supply.
Options exist for situations in which demand needs to be increased in order to match capacity (supply) include [10]:

- ***Pricing***. Vary prices to increase demand in periods when demand is less than peak.
- ***Promotion.*** Advertising, direct marketing, and other forms of promotion are used to shift demand.
- ***Back ordering***. By postponing delivery on current orders demand is shifted to period when capacity is not fully utilized.
- ***New demand creation***. A new, but complementary demand is created for a product or service.

Also manufacturers and their suppliers and customers can form partnerships in which demand information is shared and orders are placed in a more continuous fashion.

B. Aggregate Planning Strategies

The two pure planning strategies available to the aggregate planner are level strategy and a Chase strategy. Firms may choose to utilize one of the pure strategies in isolation, or they may opt for a strategy that combines the two [7].

i. Level Strategy-A level strategy seeks to produce an aggregate plan that maintains a steady production rate and steady employment level. As demand increases, the firm is able to continue a steady production rate, while allowing the inventory surplus to absorb the increased demand. A level strategy allows a firm to maintain a constant level of output and still meet demand. This is desirable from an employee relations point of view.
ii. Chase Strategy-A chase strategy implies matching demand and capacity period by period. This could result in a considerable amount of hiring, firing or laying-off of employees, increased inventory carrying costs and erratic utilization of plant and equipment. The major advantage of a chase strategy is that it allows inventory to be held to the lowest level possible, and for some companies this is a considerable savings. Most firms embracing the just in time production concept utilize a Chase strategy approach to aggregate planning [8].

iii. Hybrid strategy - In some instances a combination strategy can be found to better meet organizational goals and policies and achieve lower costs than either of the pure strategies used independently.

The role of aggregate planning may be described as establishing a regime of production situations that are achievable, controllable and utilizing available capacity. However capacity is more expensive than inventory. It is in capacity management that companies have the largest potential to gain competitive advantage. For this to occur companies need skill based competencies in aggregate production planning system design.

C. Production costs

The objective of the aggregate planning is to minimise the total cost of production within the planning horizon, hence need to investigate which costs affect the total cost of production on aggregate production and employment levels. The following costs are included [7]:

- Raw material cost
- Direct payroll cost
- Overtime cost
- Hiring / Firing cost
- Inventory / shortage cost

Direct payroll costs are calculated by taking the average wage of each worker and multiplying it with the number of workers employed during the period. Salaried staff and management costs are excluded, since they are considered to be relatively fixed during the planning horizon. Overtime costs are calculated by multiplying the total man-months of overtime by the regular pay and the overtime payment factor. Hiring costs include the cost of interview test, medical examination and training. Termination benefits, gratuities and negative impact on employees' morale all help determine the firing cost. Inventory costs are the sum of holding or storage cost, interest on tied capital and depreciation. Shortage costs are due to the potential loss of the customers and the negative effect on the reputation of the firm.

The complexity of models coupled with the lack of adequate data makes firms avoids using aggregate production planning (APP) models. The use of spread sheet modelling, and trial and error approach creates useful but simple solutions to APP models. Studies have suggested using the learning curve effect on the model where the user can find the least cost plan under different learning rates. In this study trial and error methods will be constructed and Lindo software will be used to solve a mixed integer linear programming problem [9].

IV. Research Design

Aggregate production planning (APP) determines the capacity a company needs to meet its demand over a certain period of time varying from two to eighteen months. During this time frame, it is not feasible to increase capacity by building new facilities or purchasing new equipment, however it is feasible to adjust employee level, add extra shifts, outsource, use overtime or change inventory levels.

A.Model development

The basic model to minimize the total cost is developed as shown below.
Minimize:

Total production cost over planning horizon
= Raw Material Cost + Payroll cost + Hiring cost + Firing cost + Overtime cost + Inventory cost + Shortage cost

B. Aggregate planning techniques

The techniques range from simplistic, graphical methods to the highly sophisticated linear decision rule and the parametric production-planning method. The most sophisticated techniques can be considered as optimizing, search, heuristic and dynamic methods. Within each of these categories are numerous alternative approaches, resulting in an abundance of theoretical solution procedures. Table I gives some of the common techniques used [3].

TABLE I
AGGREGATE PLANNING TECHNIQUES

Classification	Type of Method	Type of Cost Structure
Feasible Solution Methods	Barter	General/not explicit
	Graphic/tabular	Linear/discrete
Mathematically Optimal Methods	Linear programming models	Linear/continuous
	Transportation models	Linear/continuous
	Linear decision rules	Linear/quadratic/continuous
Heuristic decision procedures	Simulation search procedures	General/explicit
	Management coefficients	Not explicit
	Projected capacity utilisation	Not explicit
	Parametric production planning	Quadratic/not specified

Informal techniques: These approaches consist of developing simple tables or graphs which enable planners to compare projected demand requirements visually with existing capacity, and this provides them with a basis for developing alternative plans for achieving intermediate-range goals.

Trial and error method [1]: It is used to solve aggregate production planning since this method is easy to understand and it is used to convey planning details without getting involved with mathematical detail. It is used to develop manufacturing plans, determine cost and feasibility of each plan and selection of the lowest cost plan among feasible alternatives. Trial and error methods follow the steps below:
-Prepare an initial aggregate plan on the basis of forecasted demand and establish guidelines
-Determine if the plan is within capacity constraints. If not revise until it is.
-Determine the costs of the plan
-Transform the production plan to lower costs.
-Continue the process until a satisfactory plan is developed
-Perform sensitivity analysis to evaluate the effect of changes in such parameters as the carrying cost rate, the costs of hiring and firing and demand
-Track the plan (compare actual results to the planned results)

Two extreme plans i.e. the level production and the Chase strategy are developed first. Compromises within these extremes are then developed and evaluated for suitability.

Linear programming (LP): It is concerned with maximisation and minimisation of a field of a linear objective function in many variables subject to equality and inequality constraints for instance the function may seek to minimise the cost of hiring/firing workers, and holding inventory. The problem consists of selecting the values for several non-negative variables so as to minimize a linear function (the total relevant costs) of these variables subject to several linear constraints on the variables. An important benefit of a linear programming model is the potential use of the dual solution to obtain the implicit costs of constraints such as the maximum allowable inventory level. An algorithm called the simplex method was developed to find an optimal solution to linear programming models [5]. The optimal solution must be a vertex of the feasible region. All that is needed is to find the vertices with the most favourable value of the objective function in order to identify all optimal solutions.

The selection of aggregate production planning strategy depends on several factors like demand distribution, competitive position of the company, the product cost structure and the product line. In this thesis quantitative techniques will be used to aid the decision making.

V. Furniture Company overview

Spring Master Company is a wood furniture manufacturing company located in Harare with two factories in two different operating sites. The main plant deals with hardwoods like teak, oak and mahogany, while the second plant mainly manufactures pine furniture. The areas of analysis were the production sections namely: the breakdown section, machine shop, sub-assemblies, carving, and upholstery section, assembly section, finishing section, final fitting section and the warehouse. The company manufactures furniture for the office, bedroom, lounge, dining and occasional. The other items include chest of drawers, TV stands, TV cabinets, wine racks, hall tables and mirrors among other things. It supplies the local (93%) and export(7%) markets but the bulk of their products satisfies the local market. The firm supplies individual customers, government departments, retail shops, companies among a host of its clientele base.

VI. Research Findings

The production performance for the plant from January 2006 to December 2011 is given in Fig 2

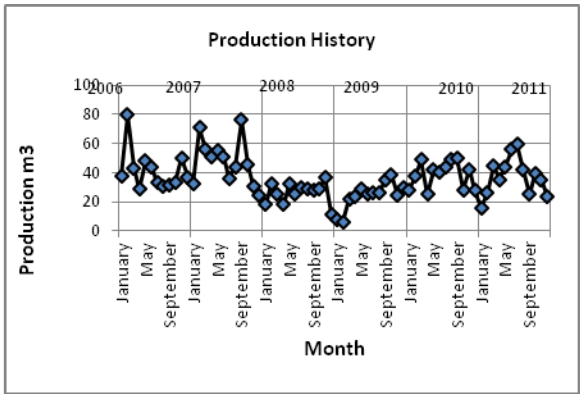

Fig 2.Production history

The pre-2008 era has the highest production figures this being attributed to prevailing disposable incomes, stable employment rates and sound capital equipment. Thereafter post dollarization era posed a range of challenges in equipment capitalisation, job redundancy and cost minimisation in addition to depressed macro and micro economic environments. The low activity in December and January of every year can be attributed to the short production and selling time as it is annual festive season break and maintenance shutdown period.

A. Demand forecast

The plant at its peak used to handle a capacity of 80m^3 per month but this has since been reduced due to aging equipment, depressed market conditions and employee turnover. In this study the maximum plant capacity was estimated at 60m^3 per month. The data was analysed for seasonality in a year and the monthly contribution to production was noted. The graph below shows the monthly contribution towards production from January 2006 to December 2011.

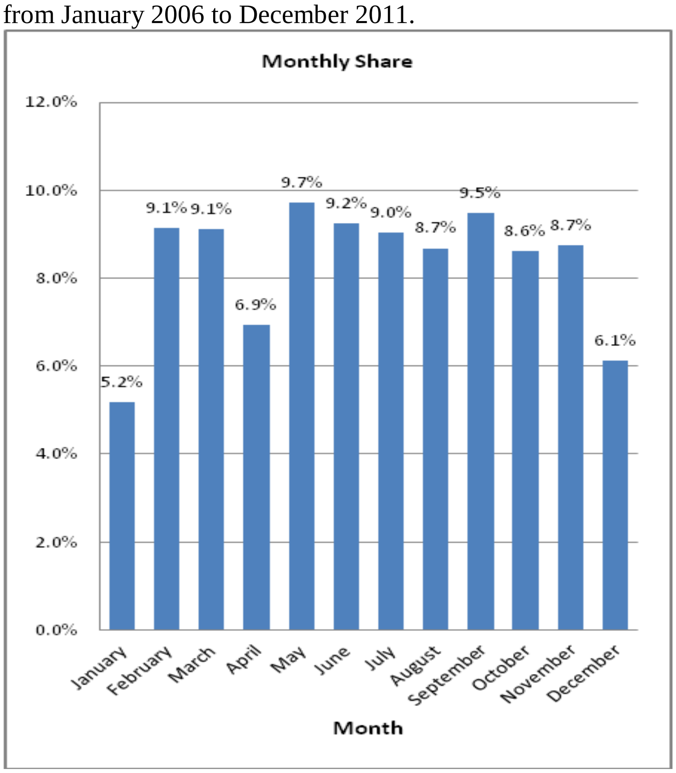

Fig 3.Average monthly contributions towards annual production

The monthly share was used to estimate the production for the month. For analysis it was usual to note that the January and December had the lowest figures. This can be attributed to the short operating times. It was also seen that April and August had significant drops in production (6.9% and 8.7% respectively). Possible justification for this might include significant holiday breaks and hence a decline in the output. The demand forecast for the months is shown graphically below.

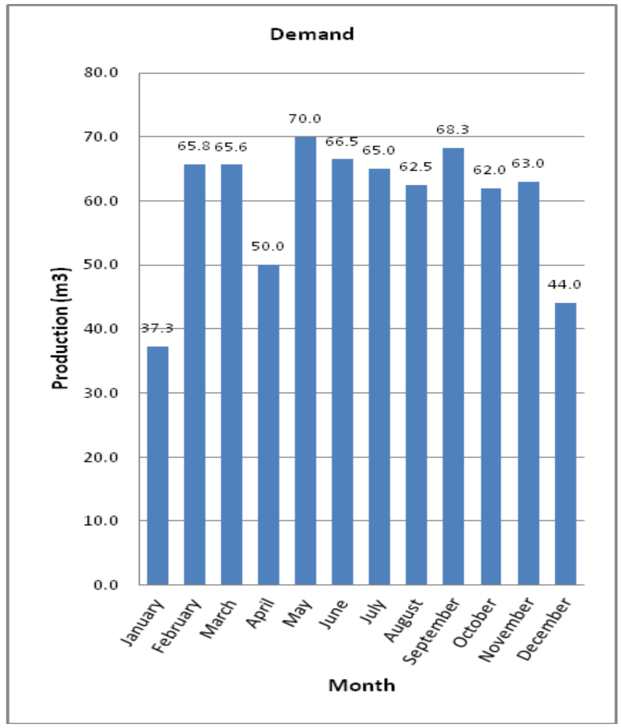

Fig 4.Demand

B. Aggregate production planning model

The model to be developed aims at reducing production costs. It will also analyse Chase and level demand strategies. The strategies will be used to come up with a hybrid strategy that reduces the costs even further. The results will be compared against computed results from the linear programming model. The linear programming model will be used to develop a model to enhance the decision making process for management.

Assumptions

-All furniture will be grouped under the five product families office, bedroom, dining, lounge and occasional

-Demand is in USD terms and the company aims at achieving 60m^3 of production. 42% being office, 18% dining, 16% occasional, 12% lounge, 12% bedroom. (from past financial records)

-Capacity of the firm is 60m^3 per month.

-Beginning inventories are estimated to be are one fourth of the capacities of the firm

-Beginning backorder value is zero

-Inventory level changes at the beginning of every month by the amount that is transferred from the previous month

Data

Demand -The demand for a given month is calculated from the annual target and multiplied by the monthly contribution towards the target based on 5 year analysis.

Working days -Working days per month vary in months with long holidays and breaks (January, April, August and December). On average they are assumed to be 22.

Working hours per day: 9.5

Regular wage: The minimum wage according to the National Employment Council (NEC) ruling in the furniture industry will equal $265.

Overtime limitation: There is a limit of four weekends per employee for overtime which amounts to 8 days per month

Overtime wage: According to the Labor law the wage payable for each hour of overtime paid by increase the amount overtime is paid increasing the amount of normal work wage per hour by fifty percent

Hiring cost: According to the World Bank Reports Doing Business the average hiring cost per worker is equal to 6% the gross salary (nationmasters.com)

Firing cost: According to the same report, the firing cost can be estimated to be 29.3 weeks of wages. However the cost actually depends on the amount of time a worker has been employed. In this study the firing cost will be calculated by multiplying the salary by 7.3.

Maximum Inventory: Maximum allowable inventory 50% of the capacity of the firm

Minimum Inventory: Minimum inventory level One tenth of the capacity of the firm

Inventory Holding Cost:The inventory holding cost is 2% of the market prices of the products per month.

Raw material cost are: 30% of the product cost

Capacity utilisation of the Spring Master Company factory is averaging 54% for 2011

Maximum number of workers: Although the workers vary with the chosen strategy but based on the company capacity of 80m^3 per month and the capacity of employee to be 0.3m^3 per month the number of shop floor workers required is 200. However since the capacity utilization is hovering at 54% the company will need at least 108 workers as the company will not function at full capacity every month.

Backorder cost: This cost arises when the demand cannot be met in the period it is supposed to be. It can be calculated as equal to 0.75 times the product cost.

Lost sales cost: Although it is difficult to quantify this cost can be quantified base on assumptions. This cost reflects the losses of sales revenue and goodwill when the producer is not able to fulfill demand and it is given as 1.4 times the product cost.

Subcontracting cost: Subcontracting cost should be treated as a necessity applied despite its unfavorable costs otherwise all companies would opt to subcontract instead of producing themselves. For this reason subcontracting cost will be higher than the total cost /unit but will be lower than the lost sales. Subcontracting cost is assumed to be cost 1.2 times the product cost.

B. Linear programming model

The following model is based on the Lindo Systems optimisation. Many LP models contain hundreds of constraints and decision variables. The objective of the model is to minimise all related costs in the setting up of an aggregate plan. Such costs include raw material cost, labour costs i.e. regular, overtime, hiring and firing costs, inventory costs, backorder, subcontracting and lost sales cost.

Model parameters

Products j: 1… N N =5

Periods t: 1… T T=12

N = 1 – dining furniture
2 – lounge
3 -- bedroom furniture
4 -- occasionals
5 -- office furniture

T= 1 -- January…………..T = 12 for December

Parameters

D_{tj} -- demand forecasted for product j in period t
m_{tj}-- hours required to produce 1m3 of product j in period t
$OTCAP_{tj}$ – overtime production hours for product j in period t
$WRCAPMAX_{tj}$ – maximum number of workers for product j in period t
$WRCAPMIN_{tj}$ – minimum number of workers for product j in period t
w_j – raw material cost per unit of product j
i_j- inventory carrying cost per unit of product j
b_j – backorder cost per unit of product j
l_j – lost sales cost per unit of product j
$MINI_j$ – minimum quantity of inventory per product j
$MAXI_j$ -- maximum quantity of inventory per product j
$MAXBO_j$ -- upper limit for the amount of product j that can be backordered
IB_j – initial value of inventory
BB_j – initial value of backorder
WH – number of regular per worker in period t

r- cost of man hour regular time
o- overtime cost per man hour
h- cost of hiring a worker
f-cost of firing a worker

Decision variables

X_{tj} – units of product j to be produced in period t

IN_{tj} – quantity of product j to be kept in inventory in period t

BO_{tj} – quantity of product j to be backordered in period t

LS_{tj} – quantity of product j which the firm loses in in sales in period t

OT_{tj} – man hours of overtime labour used in period t for product j

WR_{tj} – number of workers for product j in period t

RH_t -- regular man hours of product j in period t

HR_t – number of workers hired in period t

FR_t – number of workers fired in period t

Model

The objective of the company is to minimise total costs and the model can be constructed as follows

$$Min\ TC = \sum_{t=1}^{T}\sum_{j=1}^{N}(w_j X_{tj} + l_j LS_{tj} + b_j BO_{tj} + i_j IN_{tj} + rRH_{tj} + oOT_{tj}) + \sum_{t=1}^{T}(hHR_t + fFR_t) \qquad (1)$$

Constraints

$X_{tj} + IN_{t-1,j} - IN_{tj} + LS_{tj} + BO_{tj} - BO_{t-1,j} = D_{tj} \qquad \forall(t,j) \qquad (2)$

$\sum_{j=1}^{N} WR_{tj} - \sum_{j=1}^{N} WR_{t-1,j} - HR_t + FR_t = 0 \qquad \forall(t) \qquad (3)$

$m_{tj}X_{tj} - OT_{tj} - RH_{tj} \le 0 \qquad \forall(t,j) \qquad (4)$

$WR_{tj} \le WRCAPMAX_{tj} \qquad \forall(t,j) \qquad (5)$

$WR_{tj} \ge WRCAPMIN_{tj} \qquad \forall(t,j) \qquad (6)$

$RH_{tj} \le WH \times WR_{tj} \qquad \forall(t,j) \qquad (7)$

$OT_{tj} \le OTCAP_{tj} \times WR_{tj} \qquad \forall(t,j) \qquad (8)$

$IN_{tj} \ge MINI_j \qquad \forall(t,j) \qquad (9)$

$IN_{tj} \le MAXI_j \qquad \forall(t,j) \qquad (10)$

$X_{tj}, RH_{tj}, OT_{tj}, HR_{tj}, FR_t, WR_{tj} \ge 0 \qquad \forall(t,j) \qquad (11)$

$X_{tj}, BO_{tj}, LS_{tj}, HR_{tj}, FR_t, WR_{tj}, IN_{tj}$ are integer values

The LINGO 13.0 model was constructed and the results are given. Equation 2 is a constraint that ensures that the production quantities, backordered quantities and lost sales do not exceed the total demand quantity. Equation 3, 4 and 6 are constraints about the number of workers. Equation 4, 7 and 8 are constraints about regular and overtime working hours. Equation 9 and 10 are inventory limiting models.

C. Application of trial and error methods

Application for different strategies will be done with a view of comparing results. This was covered in conjunction with other evaluation methods.

D. Chase strategy

Chase strategies entail production at a rate in unison with demand. The strategies available include changing the workforce level. The strategy keeps the maximum workforce at 200 which is enough to meet maximum demand at the current production levels. The minimum required level of workforce is 93. The extra manpower is hired and laid off as and when necessary.

In this strategy a workforce size of 108 is needed at the current utilisation levels of around 54%. The minimum number of workers required is 93 and the cost of this strategy amounts to \$3 439 798. This can be attributed to the failure of this strategy to fully meet demand as can be seen by lost sales in all the months of year except January and December. There is a limit on the amount of production achieved by overtime as this equates to 8 days per month and in most cases these are of less working time than regular days. In the analysis 8 working hours were assumed.

Subcontracting is used where the companies resources cannot meet the expected demand and in this case in the months of February up to December. Subcontracting has the benefits that the company is able to let another company produce at a price lower at or at par with the company prices and there are significant benefits that may accrue like labour savings and storage of inventory. The costs of the different strategies are shown in the Table 2.

E. Level

The level strategy employed 200 workers producing $60m^3$ of products per month. The advantage of using this strategy for Furniture Company is that the first and last months of the year can be used to build stocks that might be used during periods of peak demand. The total cost for this strategy is \$ 2 095 254. Labour cost and inventory holding cost for this strategy are significant factors that contribute to the total product cost.

F. Mixed

Analysis of all strategies shows that the level strategy can be used to reduce costs even further by utilising the backordering process where delivery to customers is postponed until production can match demand yields reduced cost. The total cost for this strategy amounts to \$2 049 681. There is a significant backordering cost associated with this strategy in comparison with the level strategy.

G. Lingo solution

The total cost computed by the LINGO 13.0 model is \$1 878 384 which is a slightly better solution as compared to the trial and error methods. LP models can be practical and beneficial once models have been constructed. Constraints are easily applied to the formulated model.

According to the generated solution of the linear production model a workforce of 108 people is enough to cater for the whole year with variation in demand being met using inventory and over time. Most of the demand is met within the year so there is backordering and lost sales cost. Trial and error methods also give a good approximation of the production costs and cannot be totally ignored. However in real life situation many objectives have to be settled at once not just the cost aspect to it. For instance it might be necessary to reduce cost, reduce the hiring and firing rates and the cost limits. Linear programming can be modelled to cater for the underachievement or overachievement of certain goals like inventory levels, firing and hiring thresholds and the ceiling production cost targeted.

VII. Data Analysis

A. Comparison of strategies

TABLE II

COMPARISON OF STRATEGIES

Cost	Hire/Fire ($)	Overtime ($)	Subcontract ($)	Level ($)	Mixed ($)
Raw material	1 252 690	1 497 078	1252690	1 04 000	1 252 690
Labour	1 038 853	686 880	509 494	636 000	636 000
Backordering	0	0	4314	0	139 425
Lost sales	0	1245753	0	0	0
Inventory holding	10 087	10 087	10 087	65 142	21 66
Subcontracting	0	0	593 435	0	0
Total cost ($)	**2 301 630**	**3 439 798**	**2 370 021**	**2 095 254**	**2 049 681**

B. Cost analysis

The current cost analysis at Spring Master Company shows that the cost of sales for the 2011 trading year was $ 1 965 456 against a figure of $ 1 410 814 for 2010. However the total annual production for 2011 was 446 m^3 against a figure of 464m^3 for 2010. The cost of sales can be broken down into the following categories as depicted in the Table III.

TABLE III

COST OF SALES ANALYSIS

	2011	2010	Average Percentage Contribution
Cost of sales	$ 1 965 456	$ 1 410 814	
Direct material cost	49.8%	49.8%	49.8%
Direct staff costs	40.4%	41.8%	41.1%
Maintenance costs	6.8%	7.0%	6.9%
Direct Operating Expenses	7.3%	8.6%	8.0%
ISO and Quality Costs	0.3%	0.2%	0.3%
Direct overheads costs	-4.7%	-7.4%	-6.0%

From the above analysis and the fact that the computed results from the trial and error methods and the linear programming model exclude maintenance, quality and direct operating expenses. The cost of sales in the table can then be adjusted to exclude these costs to enable a fair comparison.

TABLE IV

COST COMPARISON

	Cost ($)	Quantity produced (m^3)	Number of employees
Current	1 786 389	446	194
Previous year (2010)	1 282 279	464	179
Trial and error	2 049 681	720	200
Linear programming	1 878 384	720	108

From Table 4 it can be appreciated that the cost of sales has gone up since the previous year i.e. 2010 this can be attributed to the increase in cost of raw materials, overheads and direct labour costs. An accurate assessment of the cost can be based on the parameter presented in Table V below

TABLE V

COST PER UNIT

	Cost per m^3 ($)
Current	4 005,35
Previous year (2010)	2 763,53
Trial and error	2 846,78
Linear programming	2 608,87

The cost per cubic metre is spiralling and it will balloon if left uncontrolled. It is crucial that Adam Bede ascertain a targeted cost of sales then work around it in monitoring and eliminating deviations. The analysis shows an average of $3 384,44 per cubic metre over the past two years. Adopting aggregate production planning process yields a cost reduction of 16% per m^3 on the spread sheet model and 23% on the use of linear programming models.

C. Throughput

The plant currently process 1.76 cubic metres of timber product into the warehouse every day. However with each man capable of 0.3m^3 per month this falls short of expectations. This will ultimately yield much lower production as reduced speeds; minor stoppages and plant unavailability weigh in. A target of 60m^3 per month which the proposed model assumes is realistic and achievable judging from past targets and production figures. The aggregate production planning strategies proffered are in agreement with this production target. The daily target becomes 2.73m^3 of timber/furniture into warehouse. This makes an increase of 0.97m^3. In the event of failure by employees to meet the daily demand it can be augmented by overtime after normal hours or during weekends.

VIII. Recommendations

Mathematical techniques have to be balanced with managerial judgment and experience. Whilst it might prove attractive mathematically for example in cases where firing employees makes sense, managerial experience might show decreasing productivity and worker attrition which models might fail to expose in each planning horizon. Managers act in a rational manner and will tend to make decisions that reduce exposure to risk; this makes strategies like hiring and firing or subcontracting difficult to effect even though theoretically they make business sense.

There is a tendency to blur the distinction between production planning and production scheduling. Planning precedes scheduling. Aggregate planning in particular is applied to a group of products and therefore does not yield detailed planning and scheduling information. It helps bridge the gap between strategic and operational planning.

The case study company, from analysis can tape into this strategy to realize full benefits that accrue if a systematic aggregate production planning model is utilized. From the models derived the following recommendations are suggested. Spring Master Company should adopt a hybrid system preferably that harness the benefits of level and chase demand strategies. The use of a steady workforce level that keeps production at a consistent rate should yield tangible benefits to the company. The trial and error method suggested offers a cost reduction of 16% per cubic metre and the linear programming model pushes it further to 22%. In periods of slack demand or reduced production e.g. in January, April and December the company can systematically utilise these months to send employees on vacation. A system of annualised working hours is also an attractive proposition as not all workers are needed in the first and last months of the year. Workers can also be reduced for months like April and August. In this regard workers who had worked overtime in periods of peak demand can be asked or required to work less during this period. The workers should not include skilled labour as this creates dissension and aid high employee turnover. Skilled workers tend to engage themselves in gainful activities outside the working environment; giving them periods of extended breaks might prove counterproductive.

Spring Master can shift from a make to order philosophy to a make to stock and harness the benefits that accrue due exploitation of delivery speed. This philosophy can be coupled with pro-activeness in managing the supply chain. Managing demand through promotions and advertising will ease production loading and smooth demand.

IX. Conclusion

Furniture industry is an industry where manufacturing companies do not prefer to use aggregate production planning techniques. The reasons for their poor usage in this particular sector include their complexity and time needed to develop and refine models. The use of models in some instances is synonymous with qualified engineers as it needs an extensive mathematical background. The Zimbabwean furniture industry is dominated by family owned businesses where decision making is highly centralised. The decisions from sales, production and accounting are mainly done by a few dominant figures with the rest assuming supervisory and policing roles.

In this work it was shown that trial and error methods provide a good approximate on its use and application in an industrial set-up. Cost savings of at least 16% per cubic metre were observed and throughput of 2.27m^3 per day was proffered as attainable. The Zimbabwean furniture industry lacks latest technology and these methods provide helpful production plans. Most developed software on the other hand provide easy to use solutions which can be more exact and accurate than trial and error methods proposed (cost savings of 22% were realised using the linear programming model). Furniture industry is a labour intensive sector, therefore not all proposed theoretical solutions such as hiring and firing and subcontracting are beneficial to the sector.

X. Further Research

The emergence of improved hierarchical production planning has proved to be popular in the field of aggregate planning. This phenomenon is providing useful insights in the production planning process. Aggregate production planning models are formulated analytically and this often results in large mathematical programming models. As computational models become excessive and large, it is impossible to develop optimal solutions. Decomposition techniques are one way of solving large scale models.

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