IOP Conf. Series: Materials Science and Engineering **212** (2017) 012020 doi:10.1088/1757-899X/212/1/012020

Finite Progressive Planning for the Assembly Process in Footwear

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Abstract. The scheduling of the operations of a manufacturing system is recognized for its efficiency in establishing a characteristic rate of production based on the forecasting of the ending date of an order. However, progressive planning focused on the footwear industries has not been studied in detail, since it is limited by the use of machines and supply according to the demand of the production line, whose development is based on just in time. The study proposes a finite progressive planning model in the area of footwear assembly that begins with analysis of the demand and identification of manufacturing constraints in order to establish an optimal ordering sequence. The results show manufacturing requirements through production orders that automatically determine production shifts per order, through experimentation of scenarios, the 25% increase in productivity indicators and a 31% improvement in efficiency are established. This improvement represents higher benefits for the industrial sector when establishing planning in the workplace.

1. Introduction

In this globalized world, companies have as priority to keep the customer satisfied, for this they seek to develop timely and quality products, trying to decrease production and storage costs, and that is where Fair Time Planning is born, i.e. JIT[1]. This implies that the manufacturing companies require radical changes to achieve the required quantity and quality of their productions and respond to market needs quickly, being essential a correct selection of the production planning and control system[2], especially for manufacturing plants that seek efficiency and effectiveness in their processes[3].

Programming production operations is known as Manufacturing Execution Systems (MES). A MES is an information system that schedules, dispatches, tracks, and controls the production of the plant. Production scheduling systems can be of infinite or finite load, infinite load occurs when the work is assigned to a work center according to what is needed over time and in a finite load approach is programmed Detail every resource in the preparation and run times for each order[4]. Developing a planning based on a JIT system can be considered a habitual problem, since engineers often do not have the time or the appropriate tools to make good production management[5], for this time dimension, the most common is progressive programming. Given that the footwear industry does not require very high production volumes[6], it is essential to consider the application of a progressive program that is developed under the JIT methodology, since any quantity that exceeds minimum required is considered a waste by investing effort and material in something that is not needed at that time[4].

By using a Just In Time system, it creates an advantage against competition and allows the entrepreneur to be more productive facilitating the response of the company to the needs of the demand, fulfilling the commitments acquired with the customer, delivering the products in the shortest possible time, thus increasing reliability in delivery,maximizing the new money generated by the company (throughput) and offering an optimal solution to small footwear companies[7].

Referring to the above, the Finite Progressive Planning, part from the need of companies to use optimization techniques to improve processes. Nowadays, many industries optimize process based on mixed-integer programming considering logistics at the same time [8]. This kind of programming presents obstacles since it exclusively depends on the effectiveness of the inventory management. These obstacles or issues are the lack of participation of workers and resistance to continuous improvement, cultural differences, high inventories levels, long term, market volatility, forecasting errors [9]. In the Indian industry, this programming is analyzed using performance indicators, such as cost reduction, productivity, reduction in the delivery time, variety of products, response and employee engagement [10].

Also, for other studies in this subject the uncertain random multilevel programming is proposed for problems involving production control [11].

Over the years, JIT production proposals have been developed whose approach takes place in such a way that all the company's capabilities can be aligned in a single production system, without neglecting the restrictions that are presented in such a system, given that effective management of these constraints is critical to reducing the uncertainties of a process and improving workflow, however, current approaches to the removal of constraints are fragmented and largely depart from human commitments[12], the timely control of these resources allows us to maximize resources and to have a minimum and adequate rotation of inventories, which is the objective of all cost systems[13], since it is a strategy that allows to improve the performance of companies, since all seek a continuous improvement controlling several aspects of the productive process in a collaborative way from the same supply chain until the control of the restrictions in the process[14], which through joint actions succeed.

One of the tools closely related to the JIT methodology refers to the pull production systems, whose objective is to let demand orient production and begin to manufacture the product after demand has reached the system[15]. This manufacturing principle allows companies to develop a program of operations that ensures that short- and medium-term decision-making is efficient, so that the analysis of constraints is essential in the optimization of results [16]. Hence, the need arises to consider a potential problem within production scheduling, which focuses on identifying and exploiting process constraints, so that organizational objectives can be achieved, as well as increased productivity and Competitiveness, improving costs and positioning the company in the market[17].

As a complement to the scheduling of operations, the scheduling of production is considered as a method to monitor the progress of a job and the load it produces on the manufacturing cell, maintaining as a limit the date of completion or delivery of the product Offered[18].

Studying and applying methods that allow scheduling production through Lean tools, reduces waste of time, work in process and raw materials, and can be projected in the future with large-scale studies of sustainable production as in the case of countries in Asia using appropriate sustainable business models and green supply chain management [19], this would imply the redesign of consumption patterns, which should not imply a decrease in the quality of life [20].The idea of a sustainable production and consumption is becoming a widely accepted social goal around the world [21].

The objective of this article is to show the experimentation of a model for progressive programming for the conventional footwear assembly area considering as demand variables and coordination of operations to produce weekly production schedules with a uniform workload. This influences the decision making about the use of resources and the pace of work conditioned by the delivery times of the finished product.

2. Methodology

This work uses an experimental methodology that describes a case study in the footwear sector regarding a progressive production system centered on the assembly area. The investigation frames its development in several leather shoe manufacturing organizations of the province of Tungurahua - Ecuador, from which a total of 32 footwear lines are obtained, of which a sample of 3 different models of the most produced in the Conventional assembly line the same as they are; Casual man, sporty woman and industrial safety. Each of these models represents different manufacturing lines.

The study begins with the analysis and identification of the activities and restrictions that take place in the assembly area of the companies, to establish a production of several models in the same working day, so as to avoid unnecessary stoppage of the process. Next, the sales forecast is generated, which allows a monthly and weekly production master plan to be applied, which facilitates the distribution of customer requirements through the demand curve, which describes the quantity of orders requested per order followed The actual production capacity is calculated, which interferes with the manufacturing time of each order and the quantity of human resources required for the manufacturing line, generating sequencing of production orders using a daily schedule that allows greater control over The reception times of sub-assemblies and delivery of finished product. Based on the information obtained, the calculation of indicators of productivity and efficiency of the system is developed by using it on two different production scenarios, one current and one proposed.

This research focused on the assembly area proposes a model of planning and sequencing of orders focused on the parameters and conditions of production of this process in a way that maximize the resources and limitations. The proposed model requires to develop a series of steps described below: Applying Restriction Theory (TOC) At this point, 3 of the 5 steps in TOC are developed, starting with the determination of all the restricted resources and bottlenecks in the assembly area, identifying the processes whose capacity is less than the required demand, and then deciding how to exploit the Constraints and subordinate the process to them[22]. Determining Sales Forecasting For the development of the forecast, the Winter Method[23] was used, where the systematic component of observed demand (Dt) has an estimate of the trend at the end of the period (Tt) and an estimated seasonal factor) And three smoothing constants for the level (α), trend (β) and for the seasonal factor (γ) with values ranging from 0 to 1. The forecast for future periods is given by:

$$Ft = (Lt - I + Tt - I)St \tag{1}$$

Observing the demand for period + 1, the estimates for the level, trend and seasonal factors are revised as follows:

$$Lt = \alpha(Dt + I * St) + (1 - \alpha)(Lt - I + Tt - I) \tag{2}$$

$$Tt = \beta(Lt + Lt - I) + (1 - \beta)Tt - I \tag{3}$$

$$St + p + I = \gamma(Dt + I)(Lt + I) + (1 - \gamma)St + I \tag{4}$$

Use of demand curves by footwear model the demand for footwear is concentrated according to the frequency distribution of the anatomical dimensions of the foot of the population according to the region that uses it, so it is concentrated differently in each size of footwear. By calculating and applying the demand curves by model, the quantity to be produced considering its individual demand for size is determined by applying Pull production concepts. This minimizes the inventories in process, final product and lost sales of the companies to maximize the availability of demanded products, as mentioned in Little Law proposed by Hopp and Spearman[24].

$$TH = WIP / CT \tag{5}$$

Where TH represents the Trougputh (Production Rate), WIP is the Inventory in process and TC refers to the cycle time. Develop the calculation of the weighted capacity considering the mix of models.

To develop a synchronized production in combination of models it is not enough to know the production capacity of each one, since it is necessary to obtain a real average value of production to schedule each shift of work of an efficient way in the whole installation. This value is defined as weighted production capacity, which depends directly on the number of models and order size of each. As a result, it has a real capacity that changes dynamically and adjusted to the reality of the constraints of the production plant.

Production Order Sequencing finally, to have a progressive production requires in footwear manufacture to have an inventory of molds that guarantees the constant flow of materials between all the processes in the production line and that this does not stop in some instant of time. At this point the production shifts are distributed for each model to be manufactured, considering the production limitation given the number of forms per model available for the process. Once defined the relevant points of the model proposed for the progressive programming of footwear is analyzed in detail each tool used, in order to establish the role they take within the hypothesis approach of the study and its contribution in the verification.

3. Results

Tungurahua, one of the main shoe producing provinces in Ecuador[25], offers a diversified set of shoe models, taking into account that most follow the same pattern in their production processes. This begins with the punching, where the pieces required for the model are cut, then sent to the trimming process which is responsible for making a subassembly by sewing the die pieces. In the assembly process, the trimmed cut takes the form of the foot by means of shoe molds (shapes) to later join the base of the product with the sole.

3.1. Identification of Constraints

By observing the productive process of the assembly area, two main resources are identified that limit the fulfillment of the requested orders, the first of them focuses on the quantity of shoes that exist by model, which given the small amount required Apply a combined production so that the production line is not stopped because of a lack of material resources and demand is satisfied without any inconvenience.

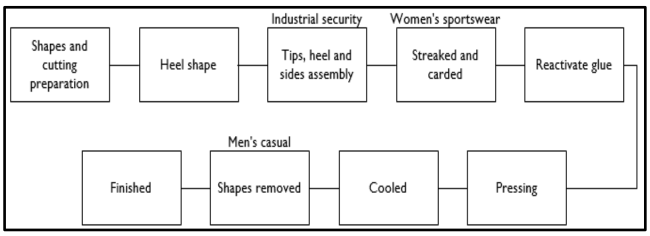

Figure 1. Capacity restricted by footwear model.

The second limitation focuses on the restricted capacity of the process, because not making decisions based on this resource can overload the bottleneck stopping production and causing unnecessary costs. Figure 1 shows the footwear assembly manufacturing sequence, which remains constant for the 3 models analyzed; However, each model has a different bottleneck that is used to develop production scheduling, thus, the restricted process of the casual model, the final drawing, For the sporty it is the process of scratching and grinding and the safety is limited by the assembly of points.

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3.2. Demand Analysis

The analysis of the sales made in the last years comprises a fundamental step for the investigation, because it is important to know the evolutionary evolution that has been registered of the models of footwear under study, with the aim of predicting the sales that could be generated in the medium term. Through the application of a forecast based on time series and due to the periodic fluctuations that are influenced by factors it is determined that the affectations of the past and that continue to disturb future time series.

Figure 2 shows the sales history of each model studied and the forecast calculated by framing in a box, from the information obtained the Winter time series method is applied in order to obtain the trend with adjusted seasonal values Of the group of models and considering the values of the constants α = 0,1; Β = 0.1; Υ = 0.1 corresponding to the revised estimate of the initial level, trend and seasonal factor respectively. Based on the straight line obtained, it is established that the safety model exceeds the base demand of pairs of footwear, while the sport model maintains a margin of variation closer to the tension line and the casual model presents a reduction the trend calculated.

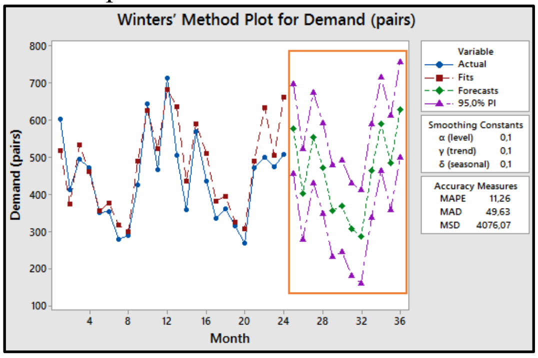

Figure 2. Sales history and forecast in Minitab software 17.

The main purpose of the analysis of the demand curve is to automatically represent the quantities required for each model by applying the percentage of sales sold in previous years. Figure 3 shows the demand curve formed by the points of intersection between two variables: model sizes and production requirements.

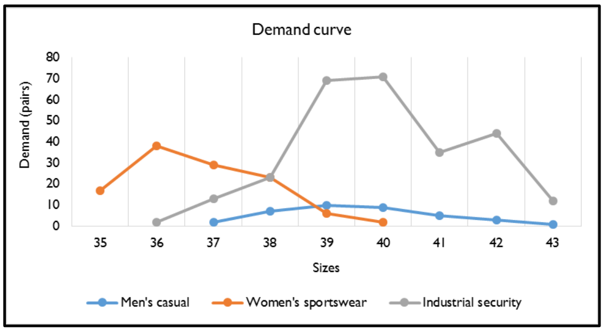

Figure 3. Demand curve by model studied.

Each model adopts a different curve, since the production requirements vary according to the market segment, whereas for the sports model there is a concentration between sizes 36 and 37; For the safety model the focus is on sizes 39 and 40; While the casual model presents an almost linear trend of production since the sizes 39 and 40 have a slight concentration with respect to the rest of sizes.

3.3. Aggregate Production Planning

For the assembly process, we have traditionally considered a series of aggregate production plans based on overtime, subcontracting, contracts and dismissals whose purpose is to adjust to the conditions in which the assembly process takes place; However, it is proposed to calculate the number of workers for the manufacturing cell based on the percentages of utilization of equipment and machinery, as shown in Figure 4. The results show a need for 12 workers obtained based on to the sum of the capacities.

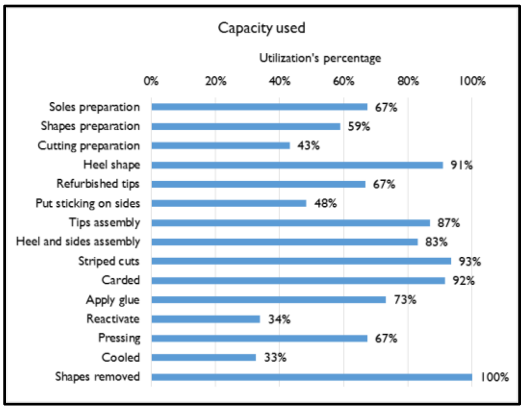

Figure 4. Utilization of machinery capacity

The proposed aggregate plan represents a variation of those already known and consists of producing on-demand with progressive programming, retaining the number of workers calculated and employing overtime when demand can't be satisfied with normal production capacity. In the case presented, the aggregate plan generates a saving of 16.06% over the traditional least-cost aggregate plan, which translates into a considerable direct cost reduction for the footwear producing sector. The proposed aggregate planning is characterized by distributing the high demands to the months in which the quantities required are less than the production capacity; While in some cases the use and coordination of ex-hours is required to meet the demand for future months, which avoids the increase of the labor load in the months with the highest demand and balances the production capacity to take advantage of the company resources.

3.4. Obtaining Production Orders

When considering a progressive production system, it is established that assembly sends the production requirements to the trimming and sub-assembling sub-assemblies through production orders that allow to synchronize and control the flow of work processes and loads. For the case under study, demand is calculated and calculated using demand curves, see Table 1.

Table1. Production Order.

MONTH 2													
WEEK 2													
CODE	MODEL	SIZES											TOTAL PRODUCTION (pairs)
		34	35	36	37	38	39	40	41	42	43	44	
CA873	MEN'S CASUAL				2	7	10	9	5	3	1		37
SK568	WOMEN'S SPORTSWEAR		17	38	29	23	6	2					115
S09	INDUSTRIAL SECURITY			2	13	23	69	71	35	44	12		269

3.5. Work shifts Calculation

The definition of work shifts involves the use of a couple of tools; The first so-called average monthly production capacity whose purpose is to allocate quantities to be drawn based on the relative importance of the models to each other. The second tool based on the calculation of the number of shifts required per order, for which we proceed to apply equation (1) on each model, establishing a relation between the weekly production capacity and the demand demanded in the same week Number of Shifts = Demand / (Weekly Capacity) (6) Since the value generated by equation (1) is obtained in weeks, there is a need to convert that time into days, as this facilitates the understanding and assignment of work schedules. The weighted production capacity is calculated by applying the Microsoft Excel "Search Target" tool with which the values of the actual capacity of each model are automatically distributed according to the standard and their quantity demanded by production order, which varies according to the Work shifts. This value is dynamic and changes at each shift, adjusting to demand.

3.6. Order Sequencing

Order sequencing allows the definition of the workload according to the production capacity per shift and the modeling scheduling according to the priority rules defined on the basis of the material constraints identified (number of shims of shoes by size and model). To start with the sequencing, it is necessary to elaborate a schedule of activities that establish the start and end date of the assembly sub-assemble by using Gantt diagrams to-command information of the production times of punching and trimming obtained in research independent.Table 2 gives the start of the production of footwear with the punching process, which takes a total of 6.2 hours to meet the demand established in the production order, followed by the trimming area with a time of 13.6 hours and Assembly with 19.8 hours. The example cited corresponds to an ordinary week of 5 days, whose production order is displayed in section 3.5.

Table2. Gantt diagram of production order footwear.

Process	Production hours	Monday	Tuesday	Wednesday	Thursday	Friday
Cutting	6,2					
Trimmed	13,6					
Assembly	19,8					

Figure 5 shows the sequencing of the models and sizes to be produced according to the order of production, taking into account that the days used correspond to those described in Table 2 by means of the Gantt chart. For this scenario the production time is two and a half days, starting production with a total of 80 pairs of shoes of the safety model combining several sizes due to the missing shoe sizes. The same rule of priority applies in the following day in which 49 pairs of the sports model are produced, followed by 13 pairs of casual and 108 pairs of safety footwear.

The scheduling of jobs for the assembly area depends directly on the number of shims per size and model so that those models with high demands complete several work cycles per shift, taking into account that the combination of models ensures the Return of logs to the beginning of the cellallowing to continue fulfilling the entered order, as indicated in the last day of work of Figure 5.

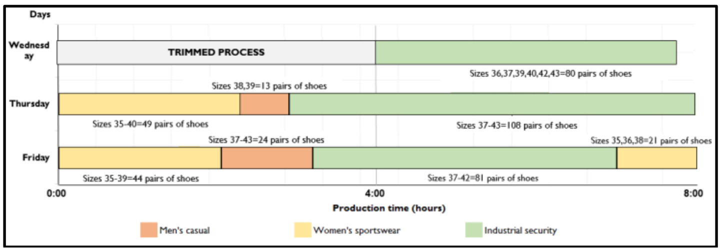

Figure 5. Sequencing production orders footwear.

4. Discussion

The analysis of two production scenarios, taking into account the variations in demand, current and proposed resources of companies, validates the optimization of the production system through the use of indicators of productivity and efficiency of the assembly area.

Figure 6 shows a comparison of production efficiency, for this it is established that the blue curve represents the current monthly capacity whose base is defined with 160 pairs / shift while the red curve represents the calculated monthly capacity that varies according to the demand per model required monthly.

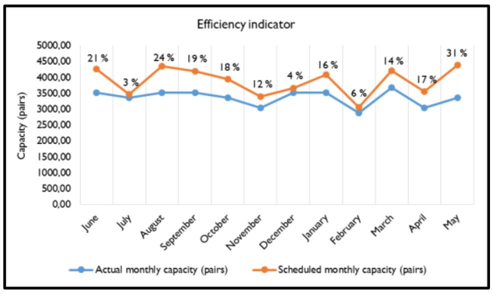

Figure 6. Efficiency variation current and proposed system.

Around the data shown in Figure 6, it is established that the research gives companies the possibility of improving their production by 3% and 31% through optimization of resource management and sequencing of activities. In addition, the calculation of partial productivity is developed, since the project does not consider a cost analysis, which evaluates the degree of utilization of the number of man-hours that affect the footwear assembly process. Figure 7 shows the productivity variation in a first scenario of demand related to the human resource that companies have. The initial number of workers was 15 and the pro- posed using the programming model were 12, resulting in an increase in productivity of this first scenario corresponding to 25% of current production.

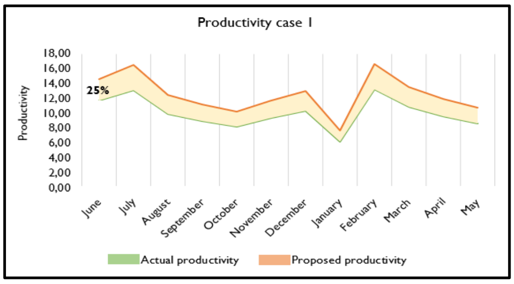

Figure 7. First stage productivity variation.

Under the consideration of the same human resources used for the previous case, a second production scenario is developed based on the forecast data obtained; Through this information is generated Figure 8, which also shows an increase in productivity that corresponds to 25% with respect to the current system of the company. Based on the two scenarios shown, it is established that for both cases the productivity is maintained a growth of 25%, a fact that undoubtedly creates a competitive advantage of the organizations compared to their competitors by reducing manufacturing costs in direct labor.

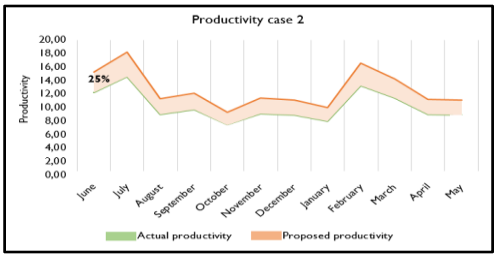

Figure 8. Productivity variation according to scenario.

5. Conclusions

The development of the daily sequencing of production that is part of the study influences the use of the working day and the use of material resources in each work cycle, which makes the progressive programming model proposed as an innovative tool for optimization of Operations for the conventional footwear assembly area by influencing the direct reduction of manufacturing times. One of the most important aspects of the programming model focuses on the application of OCD that alters its development perspective, taking into account the limited amount of resources available by shoe model leading to produce based on a mix of models, in order to avoid increases in production times or unnecessary stoppages of the production system. The planned planning model brings with it the maximization of benefits to footwear companies by increasing their production levels, represented by efficiency indicators that reach 31% of the current production standard of companies in the industrial sector. This fact supports the importance of opting for the proposed model as a method for improvement and decision making in the process. The application of the production planning and scheduling model satisfies the material flow needs of the footwear assembly process, since it is a novel method based on the proper use of JIT methodologies. The efficient allocation of human resources provides the opportunity to reduce direct manufacturing costs, maintaining a constant increase in productivity, taking a value of 25% in relation to the current productivity of companies. It is recommended that footwear companies opt for the use of the proposed product planning and sequencing model, since it represents a tool that adapts to the conditions of conventional assembly and allows the potential improvement of productivity through the program-progression of each footwear model considering the demand aspects and production constraints.

Acknowledgments

The authors thank the National Footwear Chamber of Ecuador and the Technical University of Ambato for the support provided during the execution of this work within the framework of the research project called “Operational optimization based on a lean dynamic system of alert of failures in the production processes for the footwear industry”.

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