Flexible Process Planning Design and Resource Optimization

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V. Thamaraiselvan
Scholar, Lean Operations and Systems
School of Business and Management,
Christ (Deemed to be University), Bangalore

N. Ramakrishnan
Associate Professor, Lean Operations and Systems
School of Business and Management
Christ (Deemed to be University), Bangalore

Abstract

Manufacturing processes undergo various transformations based on technological advancements and industry expectations. At initial times, during the period of first Industrial revolution, products were getting manufactured using human capabilities and skills. Then, electrically-driven motors, machines and conveyors were used. Now in the fourth Industrial revolution, Industries are equipped with automation, robots and cyber-physical systems. But adopting such technologies requires a high capital investment which cannot be accommodated by some start-ups. In this research paper, a case of a start-up which manufactures straws and vessel scrubbers in an eco-friendly manner as an initiative towards sustainability has been discussed. The key product of the company is biodegradable straws which are manufactured from coconut leaves through a set of processes. The scope of the research is to develop a labour-intensive process planning model. Managing contemporary issues is a big task for the company because of the dynamic nature of the environment. In this case, the demand for straws changes based on customer preference and accordingly, the manufacturing processes need to be revised. Hence, developing a rigid planning model is not an effective solution, so that, flexible manufacturing process needs to be developed. There is always a scope of improvement towards betterment and optimization in a manufacturing process. It is not necessary that the improvements should lead to drastic results. Japanese manufactures who bring the Toyota Production System (TPS) believe that small improvements in a continual basis will fetch better results in terms of quality, efficiency and lead time reduction. Once the model is developed, areas of improvement to optimize the resources are found out and iterations of process planning model were carried over to improve the efficiency. Through the study, it is found that the development of a flexible process plan is required to compete with the changing business scenarios.

Keywords: Sustainability, Biodegradable Straws, Coconut Leaves, Flexible Process Planning Model, Optimization and Efficiency

Introduction

The straw manufacturing process consists of series of steps starting from leaf collection, processing of leaves and convert the processed leaves into straws.

Figure 1.1: Process flow diagram of straw manufacturing

Each process requires human effort and some processes require the machine to perform the operation. Thetime taken for each process is calculated based on the video study and the optimum straws that can be produced in a day are determined through line balancing techniques. The objectives of this project are:

- To develop a flexible simulation model using MS excel where the process flow needs to be generated automatically when the inputs (demand and resources) are given
- To undergo iterations in the process planning model for optimum utilization of resources to increase efficiency and to maximize the output

Literature Review

Xu, Y., & Chen, M. (2016), developed a framework for JIT manufacturing using IoT where the specific challenges like real-time monitoring of resources and dynamic scheduling has been addressed. Availability of resources like machines, Tools and employees are ensured using RFID technology where RFID readers are installed on those resources which help to get real- time information on their availability.

According to Wagner, T., Herrmann, C., & Thiede, S. (2017), Industry is moving towards connected technologies called the Internet of Things. The vision to bring the organization as smart factors prevail across the industry. The term smart factory denotes the interconnection between people and things which is the core objective of Industry 4.0.

Schmidt, S., & Schmidt, B. S. (2019), states JIT was seen as only JIT delivery but now is got its view as JIT production. Zero-defect production, short setup times, small production sizes, multifunctionality was largely ignored. Apart from the 7 wastes, 8th waste was identified as the unused potential of resources which got its significance. Minimizing the waste should be the result, not a target. Beyond a certain point, waste minimization ceases and empowering the employees to bring the knowledge to the work stations will give optimized and sustainable practices.

According to Pinto, J. L. Q., Matias, J. C. O., Pimentel, C., Azevedo, S. G., & Govindan, K. (2018), JIT is a production system of manufacturing goods at the time when it is needed. Understanding JIT as a theory is easy but implementation is quite difficult as it involves reengineering of existing functional units and management of physical and information flows. Employee empowerment is a key in JIT implementation. JIT focuses on efficiency while lean focuses of using efficiency to add value to the customers

Liu, M. L., & Sahinidis, N. V. (1996), explained the development of process planning under uncertain conditions using stochastic programming. The model was developed by considering the problems involved in process planning and economics of the production plan

According to Reid, N. (2016), JIT a type of production system developed by Japanese manufacturer Toyota in the early 1940s. JIT aims to bring down the production cost, improves the product quality and increases the speed of product and process innovation. The ideology of JIT is that production starts only when the demand occurs. Hence, storing parts as inventory reduces, thereby decreases the storage and inventory cost.

Research Design and Methodology

The approach used in this project is line balancing techniques, where activities are done in a continuous manner to meet the demand. The company has a demand to produce 4500 8-inch straws per day. Hence process design is developed to achieve the demand

Process Design considerations for Model 1

- Demand – 4500/day
- Available human resources – 8
- Available time – 8 hours (includes break time of 1 hour and 15 minutes)
- No of leaves required – 4500
- Scraping machine – 1
- Width cutting machine – 1
- First layer rolling machine – 2
- Second layer rolling machine - 2

Capacity Calculation

Capacity of each process is calculated based on the time taken, resources availability and working time per day. In capacity calculation, efficiency factor is taken as 85% since all the activities involves human skills.

Capacity Calculation for Leaf Collection and Midrib Removal Process

- Time taken for the process/leaf = 3 seconds
- Output rate (leaves/min) = (60/3) *0.85 = 17 (considering 85% efficiency)
- No. of human resource(s) deployed = 8
- Total output rate (leaves/min) = 17*8 = 136
- Total time taken for the process = 4500/136 = 33.09 minutes

In a similar manner, capacity for each processis calculated. For scraping, width cutting and rolling operations capacity depends on number of machines used since it involves both manual and machine work content

Table 3.1: Capacity planning of process plan 1

Leaf collection and midrib removal

Time for processing one leaf (sec/leaf)	3
Output rate (leaves/min)	17
Max resource(s) deployed	8
Max output rate (leaves/min)	136
Total time taken for the process (mins)	33.09
Time (Hours: Minutes)	00:33

3 stage cleaning

Time for processing one leaf (sec/leaf)	6
Output rate (leaves/min)	8.5

Max resource(s) deployed	8
Max output rate (leaves/min)	68
Total time taken for the process (mins)	66.18
Time (Hours: Minutes)	01:06

Width cutting

Time for processing one leaf (sec/leaf)	8
Output rate (leaves/min)	24.225
Max resource(s) deployed	1
Max output rate (leaves/min)	24.225
Total time taken for the process (mins)	185.76
Time (Hours: Minutes)	03:05

Scraping

Time for processing one leaf (sec/leaf)	8
Output rate (leaves/min)	24.225
Max resource(s) deployed	1
Max output rate (leaves/min)	24.225
Total time taken for the process (mins)	185.76
Time (Hours: Minutes)	03:05

First layer rolling

Time for processing one leaf (sec/straw)	15
Output rate (straws/min)	3.4
Max resource(s) deployed	2
Max output rate (straws/min)	6.8
Total time taken for the process (mins)	220.59
Time (Hours: Minutes)	03:40

Second layer rolling (a)

Time for processing one leaf (sec/straw)	7.5
Output rate (straws/min)	6.8
Max resource(s) deployed	2
Max output rate (straws/min)	13.6
Total time taken for the process (mins)	110.29
Time (Hours: Minutes)	01:50

Straw cutting

Time for processing one leaf (sec/straw)	10
Output rate (straws/min)	5.1
Max resource(s) deployed	4

Max output rate (straws/min)	20.4
Total time taken for the process (mins)	75.53
Time (Hours: Minutes)	01:13

Second layer rolling (b)

Time for processing one leaf (sec/straw)	7.5
Output rate (straws/min)	6.8
Max resource(s) deployed	2
Max outputrate (straws/min)	13.6
Total time taken for the process (mins)	110.29
Time (Hours: Minutes)	01:50

Total time taken for completing the process when the processes are done in the sequence is 18 hours. Since the available time is only 8 hours activities have to process parallelly and on a continuous basis. Hence the continuous flow of the process is designed which is explained in the following step.

Developing Continuous Flow

- Midrib removal and 3 stage cleaning is completed first with all the human resources available
- Autoclave is a parallel process and addition of 10 minutes is given after the completion of 3 stage cleaning
- Scraping, width cutting, first layer rolling and second layer rolling operations are carried out in a sequential manner
- Processed leaves would be the output in width cutting, and straws would be the output in the rolling process
- At the end of second layer rolling, output will be the 24-inch straw, and this will be divided into three 8-inch straws in the straw cutting operation
- Human resources deployed in rolling operations areutilized for straw cutting operation
- Total output at each stage = Processing time * Resource(s) * Output rate

Table 3.2: Process planning model 1
3 stage cleaning

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
09:33 AM	10:39 AM	66	8	8.5	4488

Leaf collection and midrib removal

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
09:00 AM	09:33 AM	33	8	17	4488

Scraping

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
10:49 AM	01:54PM	185	1	24.225	4481.625

Width cutting

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
10:49 AM	01:54PM	185	1	24.225	4481.625

First layer rolling

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
10:49 AM	02:29 PM	220	2	3.4	1496

Straw cutting

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
02:29 PM	03:42 PM	73	4	5.1	4500

Second layer rolling

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
10:49 AM	02:29 PM	220	2	3.4	1496

With the above process plan, output of 4500 8-inch straws has been achieved within core working time of 6 hours and 45 minutes

Table 3.3: Time lapse of process plan 1

Process	Start time	End time	Time taken
Leaf collection and mid rib removal	09:00 AM	09:33 AM	00:33
3 stage cleaning	09:33 AM	10:39 AM	01:06
Autoclave	09:00 AM	10:49 AM	00:10
Scraping	10:49 AM	01:54 PM	03:05
Width cutting	10:49 AM	01:54 PM	03:05
First layer rolling	10:49 AM	02:29 PM	03:40
Second layer rolling	10:49 AM	02:29 PM	03:40
Straw cutting	02:29 PM	03:42 PM	01:13
Sterilization	02:29 PM	03:52 PM	01:23

Break	03:52 PM	05:07 PM	01:15
			08:07

Data Analysis and Interpretation

The process planning model provides the time taken for each processand the resources used. Analysis is done on how effective the resources they used, gaps in the existing process and finding the scope for improvement. Resource utilization is calculated by finding the ratio of working time to available time.

Table 4.1: Resource utilization of process plan 1

Human resource	Leaf collection & midrib removal	3 stage cleaning	Scraping	Width cutting	First layer rolling	Second layer rolling	Straw cutting	Total time (mins)	Available time (mins)	Idle time (mins)
1	33	66	185	0	0	0	0	284	405	121
2	33	66	0	185	0	0	0	284	405	121
3	33	66	0	0	220	0	73	392	405	13
4	33	66	0	0	220	0	73	392	405	13
5	33	66	0	0	0	220	73	392	405	13
6	33	66	0	0	0	220	73	392	405	13
7	33	66	0	0	0	0	0	99	405	306
8	33	66	0	0	0	0	0	99	405	306
Total time (mins)	264	528	185	185	440	440	292	2334	3240	906
									Resource Utili-zation percent	72.04

Inferences

- Out of 8 employees, only 4 employees are engaged fully with the work and have the least idle time of 13 minutes which is acceptable. The other 4 employees have significant idle time which reduces the overall efficiency of the process
- Since idle time is close to 15 hours (put together for all the employees) the resource utilization is around 70 %

Constraints in the Existing Process Planning Model

Layout Constraints

Midrib removal process and 3 stage cleaning process are designed in such a way, where 8 employees are working at the same time. Accordingly, the layout has to be planned, and huge space is required to carry out the process.

Process Constraints

The process is designed with an idle time of 15 hours. Process might be redesigned to reduce the idle time for improving the output and resource utilization percentage

Design considerations of Process Planning Model 2

- All 8 employees start working on all the processes parallelly. Complete elimination of batch production is achieved. Flow is made continuous from the start to the end of the process
- Idle resources are made to work on the bottleneck activity (3 stage cleaning) to reduce the idle time and increase the output
- Through iterations, demand is considered as 6000 8-inch straws and other aspects such as human resources, machines and time availability remains thesame as in process planning model 1

Capacity Calculation of Midrib removal and 3 Stage Cleaning

Table 4.2: Capacity calculation of process plan 2

Leaf collection and midrib removal

Time for processing one leaf (sec/leaf)	3
Output rate (leaves/min)	17
Max resource(s) deployed	1
Max output rate (leaves/min)	136
Total time taken for the process (mins)	352.94
Time (Hours: Minutes)	05:52

3 stage cleaning

Time for processing one leaf (sec/leaf)	6
Output rate (leaves/min)	8.5
Max resource(s) deployed	1
Max output rate (leaves/min)	68
Total time taken for the process (mins)	705.88
Time (Hours: Minutes)	11:45

Leaf collection and midrib removal

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/ res)	Total output
09:00 AM	02:52 PM	352	1	17	5984

Table 4.3: Process planning model 2

3 stage cleaning

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/ res)	Total output
09:10 AM	02:52 PM	342	1	8.5	2907
02:52 PM	03:42 PM	50	2	8.5	850
01:07 PM	03:42 PM	155	2	8.5	2635

Total of 6392 leaves can be processed in 3 stage cleaning

Scraping

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
09:00 AM	01:07 PM	247	1	24.225	5983.575

Width cutting

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
09:00 AM	01:07 PM	247	1	24.225	5983.575

First layer rolling

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
09:00 AM	01:54 PM	294	2	3.4	1999.2

Second layer rolling

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
09:00 AM	01:54 PM	294	2	3.4	1999.2

(leaves/min/res) Total output

Straw cutting

Start time	End time	Processing time (mins)	Resource(s) allocated	Output rate (leaves/min/res)	Total output
01:54 PM	03:32 PM	98	4	5.1	6000

Hence demand of 6000 8-inch straws can be met by redesigning the process and reducing the idle time

Table 4.4: Time lapse of process plan 2

Process	Start time	End time	Time taken
Leaf collection and mid rib removal	9:00 AM	2:52 PM	05:52
3 stage cleaning	9:10 AM	3:42 PM	06:32
Autoclave	9:10 AM	3:52 PM	00:10
Scraping	9:00 AM	1:07 PM	04:07
Width cutting	9:00 AM	1:07 PM	04:07
First layer rolling	9:00 AM	1:54 PM	04:54
Second layer rolling	9:00 AM	1:54 PM	04:54
Straw cutting	1:54 PM	3:32 PM	01:38

Sterilization	1:54 PM	3:42 PM	01:48
Break	3:52 PM	5:07 PM	01:15
			08:07

Table 4.5: Resource utilization of process plan 2

Human resource	Leaf collection & midrib removal	3 stage cleaning	Scraping	Width cutting	First layer rolling	Second layer rolling	Straw cutting	Total time (mins) Available time (mins)	Available time (mins)	Idle time (mins)
1	352	50	0	0	0	0	0	402	405	3
2	0	392	0	0	0	0	0	392	405	13
3	0	155	247	0	0	0	0	402	405	3
4	0	155	0	247	0	0	0	402	405	3
5	0	0	0	0	294	0	98	392	405	13
6	0	0	0	0	294	0	98	392	405	13
7	0	0	0	0	0	294	98	392	405	13
8	0	0	0	0	0	294	98	392	405	13
Total time (mins)	352	752	247	247	588	588	392	3166	3240	74
									Resource Utili-zation percent	97.72

Inferences

- All the human resources are engaged to the optimum time possible, and so the idle time is less
- Through redesigning of process plan and idle time reduction, resource utilization percent is increased from 72.04 % to 97.72 %

Findings

The process plan comparison is provided in the following table:

Table 5.1: Process plan comparison

Parameters	Model 1	Model 2
Demand (straws/day)	4500	6000
Human resources	8	8
Leaf collection and midrib removal	8	1
3 stage cleaning	8	1
Scraping machine	1	1
Width cutting machine	1	1
First layer rolling machine	2	2
Second layer rolling machine	2	2
Resource utilization	72.04 %	97.72 %
Total time taken (including break time)	08:07	08:07

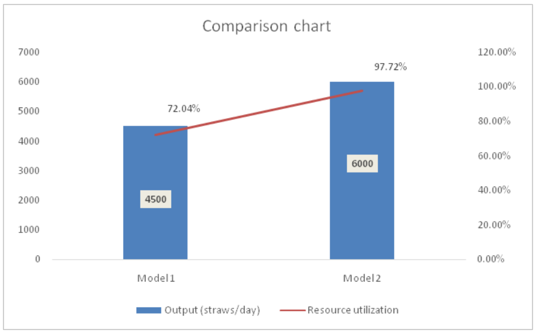

Figure 5.1: Comparison chart

Conclusion

The way the manufacturing processes are planned influences the output rate. To increase the output rate, it is not necessary to increase the resources, but existing resources could be utilized in an optimum manner. Achieving the demand alone should not be the target. The mode of achieving the target should be free from non-value-added activities. Manufacturing process design is not a single time job. Process planning needs to be reviewed periodically and improvements have to be done in a continuous manner to eliminate wastes in the process. Manufacturing process design should consider human limitations while designing. Processes involving human operations tend to introduce variations in producing the output as planned, and these aspects need to be considered in the process design. While designing the process, layout constraints, material flow and human resources flow needto be incorporated. Hence, process planning design should be practically feasible to implement in the production environment.

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