Construct Assembly Line Layout within Earliest Finish Time: A Case study on the Smart Shirts - Haragama

MT325 -GROUP 3

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Abstract

Apparel business applies different techniques to keep pace with the incremental competition conditions and changing consumer demands. The new design needs new analysis; new manufacturing techniques which will take much more time. There is no practice of scientific analysis to manufacture a new design garment. Critical path method (CPM) is one of the most effective techniques which is a systematic approach to identifying and reducing manufacturing time through the earliest start time and the earliest finish time and provides a scientific method for product manufacturing and whole production management. This study was carried out at a men's t-shirt producer. The current state of the production lines was analysed within the scope of the study. Then t-shirt production lines were organised with the CPM techniques. The main strategy of CPM was to estimate actual operation time by decreasing traditional manufacturing time. As a result, using the CPM in garment manufacturing less the lead time of production time as well as the whole manufacturing system gets a new approach and manufacturers can produce the product within minimum possible time and the apparel manufacturer will be able to fabricate contemporary fashion production projects.

Keywords: Apparel; Critical path method; Manufacturing; SVM; Process layout

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Chapter 1: Introduction

1.1 Introduction to Operations Research

Operations research (British English: operational research) (OR) is a discipline that deals with the application of advanced analytical methods to help make better decisions. Further, the term operational analysis is used in the British (and some British Commonwealth) military as an intrinsic part of capability development, management, and assurance. Operational analysis forms part of the Combined Operational Effectiveness and Investment Appraisals, which support British defence capability acquisition decision-making.

It is often considered to be a subfield of applied mathematics. The terms management science and decision science are sometimes used as synonyms.

Employing techniques from other mathematical sciences, such as mathematical modelling, statistical analysis, and mathematical optimization, operations research arrives at optimal or near-optimal solutions to complex decision-making problems. Because of its emphasis on human-technology interaction and because of its focus on practical applications, operations research has overlap with other disciplines, notably industrial engineering, and operations management, and draws on psychology and organisation science. Operations research is often concerned with determining the extreme values of some real-world objective: the maximum (of profit, performance, or yield) or minimum (of loss, risk, or cost). Originating in military efforts before World War II, its techniques have grown to concern problems in a variety of industries.

1.2 Introduction to the company

Smart shirt Ltd is a leading company in Sri Lanka which manufactures and exports the readymade garments (shirts and pants) to the world. Headquarter is in Hong Kong. And merged with Sunrise textile group. The garment plant operates in Hong Kong, China, Cambodia,Vietnam, Sri Lanka and a few other Asian countries. And also, the company owns 8 main manufacturing plants all over the in Sri Lanka.

Figure 1 - Sewing Department

- Company supplies more than 1000 employment opportunities with their required facilities with better satisfaction
- They produce the best products with iso standards with better satisfaction
- They assist High contribution for Dollar Income

Figure 2 - Main products

Products

Shirts

World-class quality shirts according to the customers' requirements (Ex: Stripes, Check, Contrast & Fancy shirts)

Pants

World-class quality pants according to the customers' requirements

Knits

World-class quality knits according to the customers' requirements

Vision and mission

The vision of the company is to outperform the leaders of the global apparel industry, by ensuring superior quality in all that they do. The factory which has been selected for the research is in Kandy district.

And the company started in 1992. In the present the plant operates with 960 head count of employees. From them 760 of machine operators are employed. The company produces the garments under the following brands. And develop partnerships with Spain, North America, Europe, and Asia

Polo

Ralph Lauren

Patagonia

Express

Dockers

Calvin Klein

Nordstrom

Club Monaco

Dillard’s

1.3 Production process of the company

Sewing department and process

Garment manufacturing is quite different from any other conventional manufacturing. Sewing section is one of the most important stages of apparel making. The sewing process is the attachment of different parts of the cut pieces. In this workplace. there are many operations who perform single operations. All the factors decide what parts of garment can be sewn at that station. Sewing section is the most important department in apparel industry.

Sewing quality Control

In the sewing section, the quality inspector checks the critical point and critical measurement according to the buyer's approval sample. If the quality is not OK, then take corrective action. Then they are lot audit and body ready for finishing. Generally, quality control of sewing is divided into 4/5 areas, they are front part, back part, garments assembly, waistband sewing/ Sleeve top stitch, and output garments inspection. If the sewing section quality is good in any department, then garments quality is good.

Machines used in the sewing section.

- Single needle lock stitch machine
- Double needle lock stitch machine
- Vertical needle lock stitch machine
- Single needle chain stitch machine
- Pointer
- Hallmark
- Overlock machine.
- Feed off the arm machine.
- Continuous fusing machine
- Kansai machine

Elements of sewing machine

- Sewing thread
- Needle
- Sewing machine

Sewing defects

- Needle damage
- Skip stitches
- Thread breakages
- Broken stitches
- Seam puckering
- Pleated seam
- Wrong stitch density
- Uneven stitch density
- Staggered stitch
- Improperly formed stitches.

SEWING SEQUENCE OF T-SHIRT MANUFACTURING PROCESS:

Number matching front 2 back part (back on part on upper side)

↓

Shoulder stitching (By over lock m/c)

↓

Neck rib truck (By plain m/c)

↓

Neck rib sewing by plain m/c

↓

Neck rib joins with body pant.

↓

Neck top sin

↓

Solder to solder back tip.

↓

Size label sewing

↓

Solder to solder back top sin.

↓

Sleeve marking and number matching with body parts.

↓

Sleeve tuck with body part (Sleeve mark point & solder mark point)

↓

Sleeve joint with the body part

↓

Side sewing and care label joint.

↓

Bottom hem tuck (at the end side)

↓

Bottom hem sewing

↓

Arm bottom hem joint

↓

Inspection

1.4 Problem Identification

Our project is based on real world application of Operations Research. First, we had different ideas when selecting a company, but as a team we discussed and concluded to visit Smart Shirts (Lanka) Ltd Haragama.

The reason for visiting this company is that the daily interactions are comparatively high, and we thought that we can get a better problem to apply OR for a larger area of raw materials or a production process.

As the next step we met the management of the company and discussed how to apply our theoretical knowledge in a larger practical field. And we found out that there are several problems occurring in the sewing department.

Current problems:

1. Machine breakdowns
2. Operator errors
3. Defects generation in sewing
4. Long line setting time
5. Frequent change in production planning
6. Production delays

By considering the above problems, it is noted that the sewing department takes more time for preparing and assembling the garment than using the traditional method of process flow. Hence study was focused on the assembly line process of the sewing department in depth and then we identified that there is no systematic way to create a production layout. Since the better production layout provides a better product within less time, we focused on introducing a new scientific approach for production. Therefore, this study was carried out to make the optimum assembly line layout of a t-shirt within the earliest finish time by using project management techniques.

1.5 Motivations

The project management techniques provide scientific methods for product manufacturing and whole production management.

The project management technique can be used to optimise the layout of an assembly line in a garment factory in several ways.

- Minimising production time - Identifying the critical path of the assembly line, which is the sequence of tasks that takes the longest time to complete these tasks, the overall production time can be reduced.
- Improving efficiency - Identifying bottlenecks in the assembly line, which are tasks that take longer than expected. By addressing these bottlenecks, the overall efficiency of the assembly line can be improved.
- Managing resources - Using project management techniques can determine the resources (e.g., personnel, equipment) needed for each task on the assembly line. This can help managers make more informed decisions about allocating resources and preventing over or underutilization.
- Identifying potential delays - Identifying tasks that are dependent on each other. If one task is delayed, it can affect the completion of other tasks. By identifying these dependencies, managers can anticipate and mitigate potential delays.
- Better tracking - track the progress of the assembly line, which can help managers identify issues early on and adjust as needed.
- Scheduling - Creating a schedule for the assembly line, which can help managers plan for and coordinate the use of resources and personnel.
- To reduce lead time - Reduce the lead time by reducing the time required to produce the garments and improve the production process.

Chapter 2: Methodology

2.1 Theory and Methodology

In here to solve the problem were discussed in chapter 1.4 can solve using CPM (Critical Path Method).

2.1.1 Critical Path

The critical path is the longest sequence of tasks that must be completed to complete a project. The tasks on the critical path are called critical activities because if they're delayed, the whole project completion will be delayed.

2.1.2 Critical Path Method

The Critical Path Method (CPM) is one of several related techniques for doing project planning which is the sequential activity from start to the end of a project, although many projects have only one critical path. CPM is for projects that are made up of several individual "activities." If some of the activities require other activities to finish before they can start, then the project becomes a complex web of activities. Some projects may have more than one critical path depending on the flow logic used in the project. If there is a delay in any of the activities under the critical path, there will be a delay with the project deliverables.

Key Steps in Critical Path Method

The process of using the critical path method in the project planning phase has six steps.

Step 1: Activity specification

Identify the activities involved in the project by using the Work Breakdown Structure (WBS). This is the main input for the critical path method.

Step 2: Activity sequence establishment

In this step, the correct activity sequence is established. For that, you need to ask three questions for each task on your list.

- Which tasks should take place before this task happens?
- Which tasks should be completed at the same time as this task?
- Which tasks should happen immediately after this task?

Step 3: Network diagram

Once the activity sequence is correctly identified, the network diagram can be drawn.

Step 4: Estimates of each activity.

This could be a direct input from the WBS based estimation sheet. We can use such estimation information for this step of the process. CPM assumes that the durations of the activities are determined.

Step 5: Identification of the critical path

For this, we need to determine four parameters of each activity of the network.

- Earliest start time (EST): The earliest time an activity can start once the previous dependent activities are over.
- Earliest finish time (EFT) = EST + activity duration.
- Latest finish time (LFT): The latest time an activity can finish without delaying the project.
- Latest start time (LST) = LFT - activity duration.

The float time for an activity is the time between the earliest (EST) and the latest (LST) start time or between the earliest (EFT) and latest (LFT) finish times. Float time is also called Slack time.

During the float time, an activity can be delayed without delaying the project finish date.

The critical path is the longest path of the network diagram. The activities in the critical path influence the deadline of the project. If an activity of this path is delayed, the project will be delayed. Here, **Slack Time = LSTi – ESTi** or **Slack Time = LFTi – EFTi**

Step 6: Critical path diagram to show project progress.

Critical path diagram is a live artefact. Therefore, this diagram should be updated with actual values once the task is completed.

This gives a more realistic figure for the deadline and the project management can know whether we are on track regarding the deliverables.

2.1.3 Types of Networks

Both AON (Activity-On-Node) and AOA (Activity-On-Arc) network diagrams are usually used in network planning formats, but they have different representations and characteristics, which has caused inconvenience for engineering technicians to learn and use network planning techniques.

Type 1: Activity on Node (AON) network design

▪ In this format Node represent activity

▪ Arcs represent precedence relationships between the activities**.**

Type 2: Activity on Arc (AOA) network design

▪ Arcs represent project activities

▪ Nodes represent the start and finish points for each activity.

In Activity on node format network usually there is a format to represent the node. The following figure shows the Node representation.

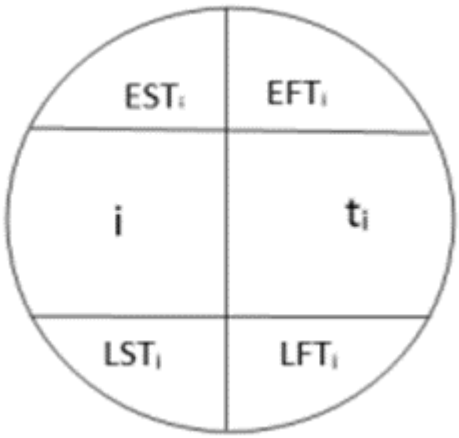


Figure 3 - Node Representation

t_i = time required to perform activity i

EST_i = earliest possible start time for activity i

EFT_i = earliest possible finish time for activity i

LST_i = latest possible start time for activity i

LFT_i = latest possible finish time for activity i

2.2 Description of the sample

2.2.1 Data collection methods

2.2.1.1 By field visit

2.2.1.2 By questionnaire

Questionnaire:

- Which tasks should take place before this task happens?
- Which tasks should be completed at the same time as this task?
- Which tasks should happen immediately after this task?

2.2.2 Description of the Data

- In application of traditional method, the Standard Allowed Minutes for a basic t-shirt is 637 seconds where the basic time is 490 seconds at 91% performance rating by using 10% of bundle, machine, and personal allowances (total 30%).

- Here the following Table 1 shows the Activity, Operation, M/C, Basic time without allowance(s) and Basic time with 30% allowance(s) each operation in the assembly line. Using the critical path method, solved and found the critical activities and found the best critical path to finish the project. And Table 2 shows the previous requirement of each activity.

Table 1 - Time Requirement

Activity	Operation	M/C	Basic time without allowance	Basic time with 30% allowance
A	Sleeve hem	F/L	40s	52s
B	Join the collar rib	SNL	14s	18.2s
C	Open the seam and tack	SNL	16s	20.8s
D	Jon shoulder	O/L	38s	49.4s
E	Attach the collar rib to body	O/L	48s	62.4s
F	Attach the main label	SNL	28s	36.4s
G	Attach tape to collar, fold & cut tap	SNL (Fldr.)	66s	85.8s
H	Close the neck tape	SNL	43s	55.9s
I	Attach sleeve	O/L	56s	72.8s
J	Side seam with care label	O/L	65s	84.5s
K	Bottom hemming	F/L	48s	62.4s
L	Tack sleeve	SNL	28s	36.4s
Total			490s	637s (637 SMV)

Here,

- OL – thread overlock.
- SNL – Single needle lock stitch
- FL – Flat lock m/c
- M/C – Machine

Table 2 - Previous requirement of operations

Activity	A	B	C	D	E	F	G	H	I	J	K	L
Immediate Predecessor	-	-	B	-	C, D	E	F	G	H, A	I	J	K
Time	52	18.2	20.8	49.4	62.4	36.4	85.8	55.9	72.8	84.5	62.4	36.4

2.2.3 SMV (Standard Minute Value)

In the apparel sector, SMV is used to calculate the process time.

SMV = Basic minutes + Bundle allowances + Machine allowances + personal fatigue allowances

Equation used for the solution.

SMV = Basic minutes + 30% allowances

- Bundle allowances 10%
- Machine allowances 10%
- Personal allowances 10%

2.2.4 Analysis of the Model

In the solution process since there are multiple initial points, we add dummy initial node as Start node with a time duration of 0 seconds. Here identified the immediate successor and immediate predecessor of each task. Following figure shows the Activity on node representation of above problem. Here there are three starting activities and then we must add a dummy start node.

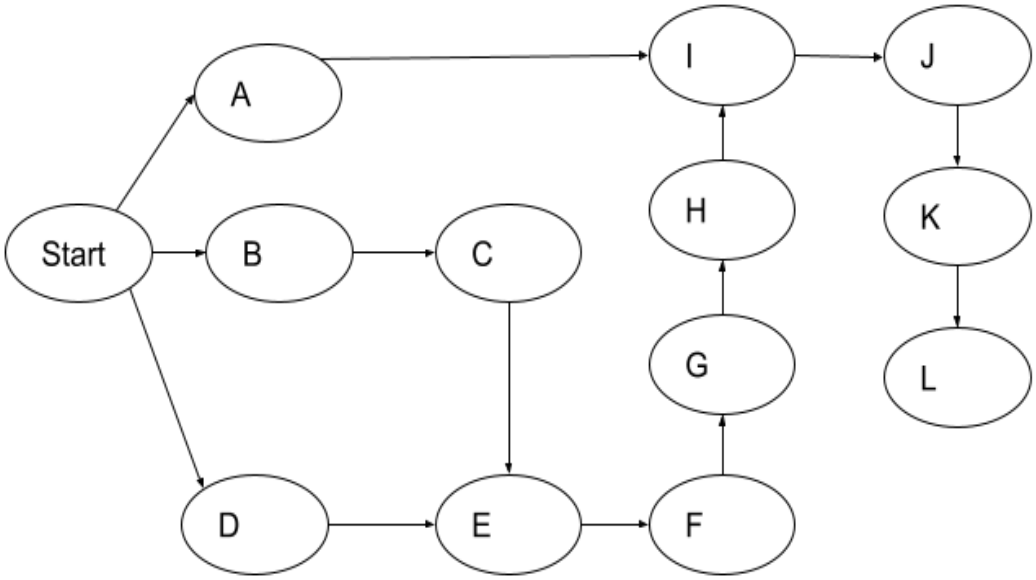


Figure 4 - AON graph representation

2.3 Mathematical Model

2.3.1 Earliest Start Time Linear Model

Decision Variables

$$T_i = EST_I = Earliest\ Start\ time\ of\ i^{th}\ Activity \quad i = A,B,C,D,\ldots,L$$

Objective Function

$$Min\ Z = T_A + T_B + T_C + T_D + T_F + T_G + T_H + T_I + T_J + T_K + T_L = \sum_{i=A}^{L} T_i$$

Constraints

$$S.T$$
$$T_I - T_A \geq 52$$
$$T_C - T_B \geq 18.2$$
$$T_E - T_D \geq 49.4$$
$$T_E - T_C \geq 20.8$$
$$T_F - T_E \geq 62.4$$
$$T_G - T_F \geq 36.4$$
$$T_H - T_G \geq 85.8$$
$$T_I - T_H \geq 55.9$$
$$T_J - T_I \geq 72.8$$
$$T_K - T_J \geq 84.5$$
$$T_L - T_K \geq 62.4$$

Non - negativity
$$T_i \geq 0$$

Chapter 3: Results and Discussion

Following Table 3 shows the result of the CPM method.

Table 3 - Results

Activity	Description	Time	EST	EFT	LST	LFT	Slack	
A	*Sleeve hem*	52	0	52	237.9	289.9	237.9	**null**
B	*Join the collar rib*	18.2	0	18.2	10.4	28.6	10.4	**null**
C	*Open the seam and tack*	20.8	18.2	39	28.6	49.4	10.4	**null**
D	*Join shoulder*	49.4	0	49.4	0	49.4	0	**
E	*Attach the collar rib to body*	62.4	49.4	111.8	49.4	111.8	0	**
F	*Attach the main label*	36.4	111.8	148.2	111.8	148.2	0	**
G	*Attach tape to collar,fold & cut lap*	85.8	148.2	234	148.2	234	0	**
H	*Close the neck tape*	55.9	234	289.9	234	289.9	0	**
I	*Attach sleeve*	72.8	289.9	362.7	289.9	362.7	0	**
J	*Side seam with care label*	84.5	362.7	447.2	362.7	447.2	0	**
K	*Bottom hemming*	62.4	447.2	509.6	447.2	509.6	0	**
L	*Tack sleeve*	36.4	509.6	546	509.6	546	0	**
		Note: ** denotes critical activities.						

According to the result of above table we can see Join shoulder, Attach the collar rib to body, Attach the main label, attach tape to collar fold & cut lap, Close the neck tape, attach sleeve, Side seam with care label, Bottom hemming and Tack sleeve are the Critical activities because their Slack values are zero. We must give more priority to finish the Critical activity first if any of those critical activities are delay then whole project delay. According to above table finally the project can finish within 546 seconds (9.1 minutes).

Following Figure 5 shows the critical path of the project.

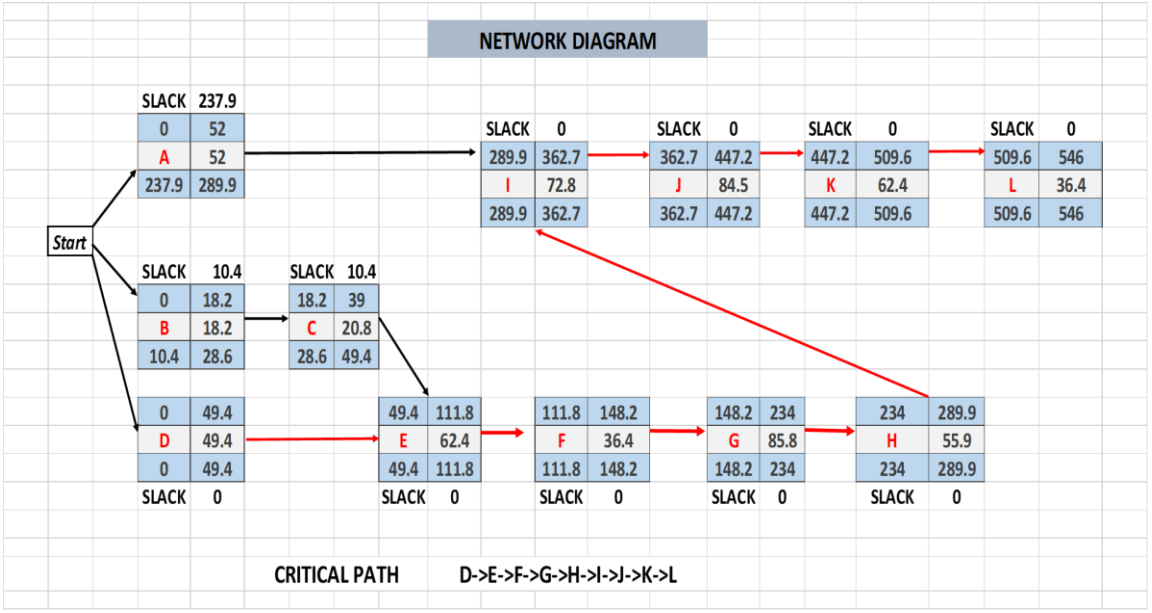


Figure 5 - Critical Path

Critical activities are,

- Join shoulder
- Attach the collar rib to body
- Attach the main label
- Attach tape to collar fold & cut lap
- Close the neck tape
- Attach sleeve
- Side seam with care label
- Bottom hemming and Tack sleeve

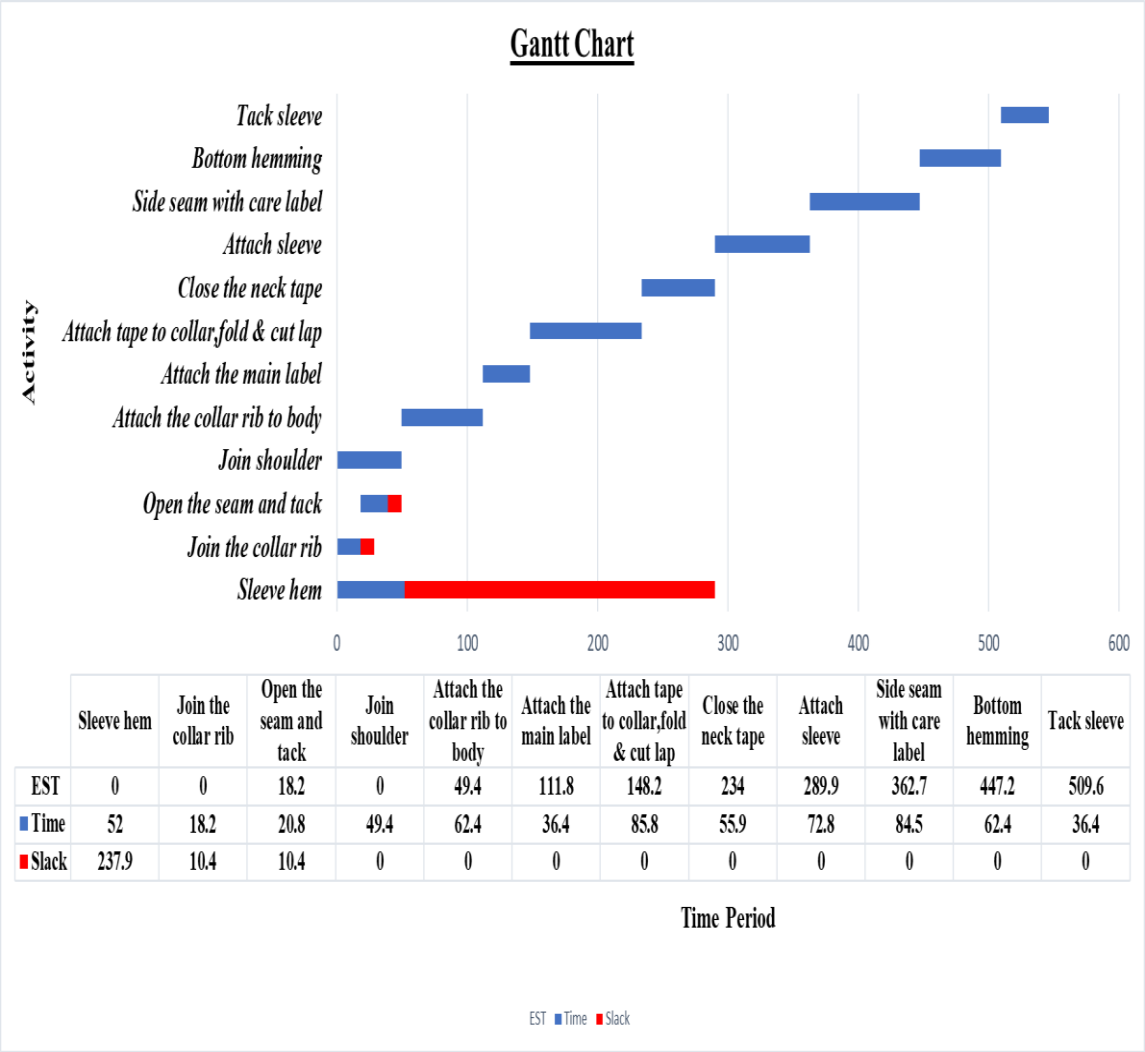
And critical path is,

Start -> D -> E -> F -> G -> H -> I -> J -> K -> L

Start -> Join shoulder -> Attach the collar rib to body -> Attach the main label -> Attach tape to collar fold & cut lap -> Close the neck tape -> Attach sleeve -> Side seam with care label -> Bottom hemming and Tack sleeve

3.1 Gantt chart

A Gantt chart is a type of bar chart that illustrates a project schedule. This chart lists the tasks (Activity) to be performed on the vertical axis, and time intervals (Time Period) on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity. Gantt charts illustrate the start and finish time of the terminal elements and summary elements of a project.



	Sleeve hem	Join the collar rib	Open the seam and tack	Join shoulder	Attach the collar rib to body	Attach the main label	Attach tape to collar,fold & cut lap	Close the neck tape	Attach sleeve	Side seam with care label	Bottom hemming	Tack sleeve
EST	0	0	18.2	0	49.4	111.8	148.2	234	289.9	362.7	447.2	509.6
Time	52	18.2	20.8	49.4	62.4	36.4	85.8	55.9	72.8	84.5	62.4	36.4
Slack	237.9	10.4	10.4	0	0	0	0	0	0	0	0	0

Figure 6 - Gantt Chart

Chapter 4: Conclusions and Future Directions

4.1 Introduction

The apparel manufacturer needs to capture the cycle where the fashion is changing in a week. The political issue, technological issue, social influences, and the economical influences change fashion. So, as early as possible it is needed to develop the production method by using a scientific approach where using technology consumes time for production. By examining the production department of Smart shirts Ltd, following major problems were detected.

- Long line setting time
- Frequent changing production planner
- Production delays

By considering the above problems, it is noted that the sewing department takes more time for preparing and assembling the garment than using the traditional method of process flow. Hence study was focused on the assembly line process of the sewing department in depth. Following are the key benefits expected by the assembly line in the apparel industry.

- Speed
- Accuracy
- Less Labour

Assembly line process mainly consist of critical activities and the time for each activity can be determined more accurately. Therefore, by examining all the factors, maximising the speed of the assembly line process by using the project management tool, Critical Path Method (CPM), can be considered as the best solution.

4.2 Challenges Occurred

Limitations of the CPM method

- Complexity: CPM can be a complex process, especially for large and complex projects. It requires a significant amount of time and resources to plan and schedule the assembly line.
- Assumptions: CPM is based on several assumptions about the project, such as task durations and resource availability, which may not always be accurate.
- Inflexibility: Once the CPM schedule is created, it can be difficult to make changes to the assembly line layout. This inflexibility can make it difficult to adapt to changes in production demands or customer requirements.
- Limited consideration of human factors: CPM may not take into account the human factors like skill of workers, ergonomics, working conditions and morale etc.
- Limited ability to handle uncertainty: CPM does not handle uncertainty well, and it may not be suitable for projects where the conditions are uncertain and are subject to change.
- Limited ability to handle non-critical paths: CPM does not handle non-critical paths well, and it may not be suitable for projects where the non-critical paths well, and it may not be suitable for projects where the non-critical paths are important.

Handling limitations of the CPM

- In our project, we have divided the whole shirt manufacturing process according to the respective departments and subprocesses and have focused on the most time-consuming process from the overall process.
- As CPM does not consider human resources, we have used the SMV (Standard Minute Value) for our time measurements which adds a respective percentage of time to the basic time by considering the working conditions and the morals. In addition to that the basic time is measured by using both trained and untrained workers.
- Our company, Smart shirts, has a fixed process cycle for a respective production item. So, the changes of conditions and the changes of assembly layout are minimal and rare.
- According to the reports, the company usually receives a fixed number of items per order, so the changes of production demands or customer requirements are also minimal and rare.
- According to the assembly line process used in the company, the majority of time-consuming tasks are critical tasks. Therefore, CPM is more appropriate.

Assumptions used for the solution.

- There would be no machine breakdowns in one production cycle.
- Task durations would not change due to the human factors.
- There would be no shortages of raw material during the production cycle.

4.3 Conclusion and future directions

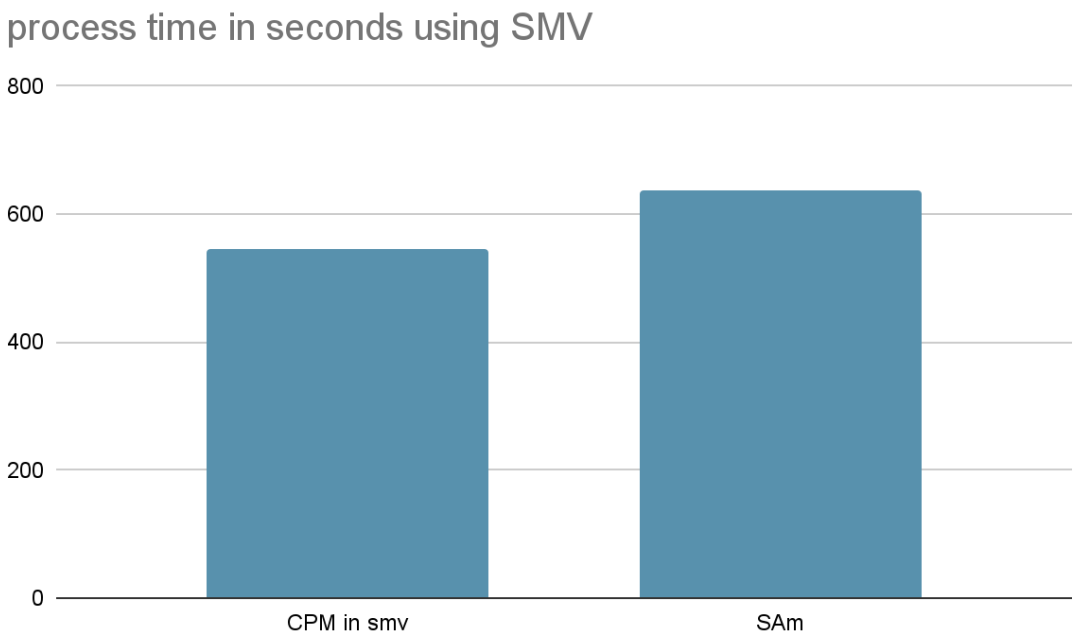


Figure 7 - Process Time CPM Vs Traditional

By analysing the results of the CPM method, we can identify two main incidents which enable saving time.

So, we can proceed with the tasks A, B and D concurrently.

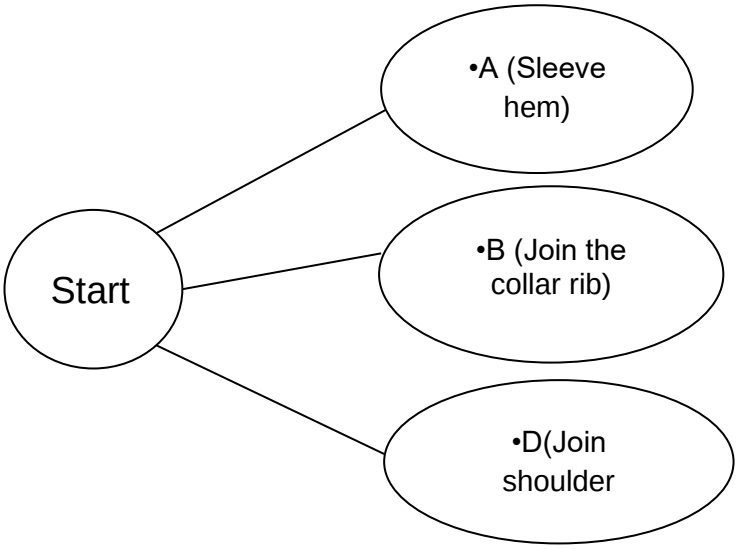


Figure 8 - Situation 1 of saving time of the proposed layout

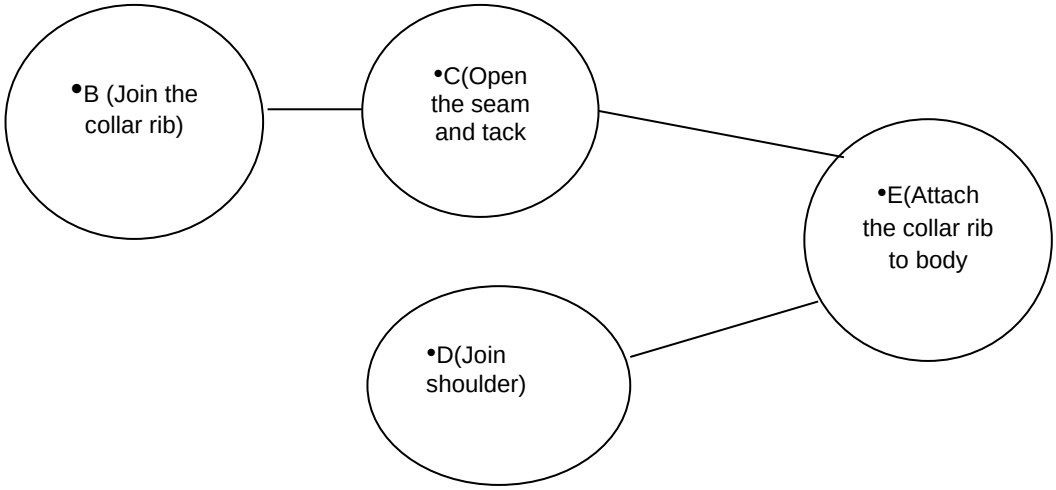


Figure 9 - Situation 2 of saving time of the proposed layout

It is possible to proceed with task C without completing task D as it is not a predecessor activity for task C. Hence, we can start task E early in CPM compared to the traditional method.

By using the CPM method, the manufacturing time can be reduced by 91 seconds compared to using the traditional method.

Target Production

When SMV decreases, target production increases.

$$\text{Target Production} = \frac{\text{Working hours (No of minutes) x No of manpower}}{\text{SMV}}$$

According to the above algorithm, target production could be increased by 14% by using the introduced assembly line process in CPM.

The earliest finished production time can produce all fashion by reducing traditional time as well as cost of the product. In our project we have mainly focused on the assembly line process. But when it comes to a production cycle, there are a number of process cycles such as cutting process, quality control process and labelling, ironing and packing processes involved. So, we can apply CPM to minimise the production time and gain more benefits to the company.

References

1. CPM scheduling and how the industry uses it by: Ms.PatriciaD. Galloway, PE.
2. A robust critical path in an environment with hybrid uncertainty by Sayed Jafar Sadjadi, Reza Pourmoayed, M. B. Aryanezhad
3. https://asana.com/resources/critical-path-method
4. https://textilesscholars.blogspot.com/2019/08/operation-breakdown-of-basic-t-shirt.html
5. https://ordnur.com/apparel/operation-breakdown-and-smv-of-t-shirt-of-knit-garments/
6. https://textilelearner.net/operation-of-sewing-section-process-breakdown-of-basic-shirt/
7. https://apparelresources.com/business-news/sourcing/industrial-engineering-in-apparel-manufacturing-viii/
8. https://www.onlineclothingstudy.com/2011/06/sewing-process-flow-chart-for-crew-neck.html