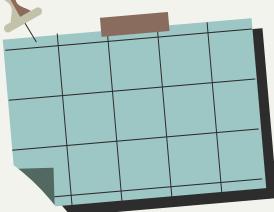




Group 06 – Final Presentation

Construct Assembly Line Layout with Earliest Finish Time



Group Members

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01. Introduction to the Company



- Leading multinational apparel export company

SMT Apparel Lanka Limited , Haragama

Workers

- Machine operators - 760
- Others - 200



SMT Apparel Lanka Limited



Vision

Outperform the leaders of the global apparel industry by ensuring superior quality in “ALL” what we do

Mission

- **To build**
Our corporate image by adhering to socially responsible practices.
- **To exceed**
Customer expectations by adopting superior technology to improve product quality and efficiency at the lowest cost.
- **To encourage**
the Commitment and excellence of our employees to promote teamwork within the organization.



Product Portfolio

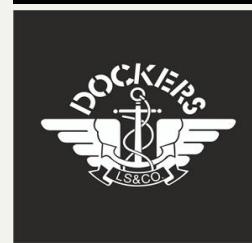
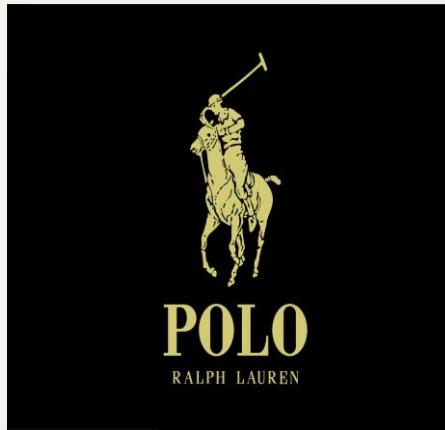
Products

- Shirts
- T-shirts
- Jeans
- Hoodies



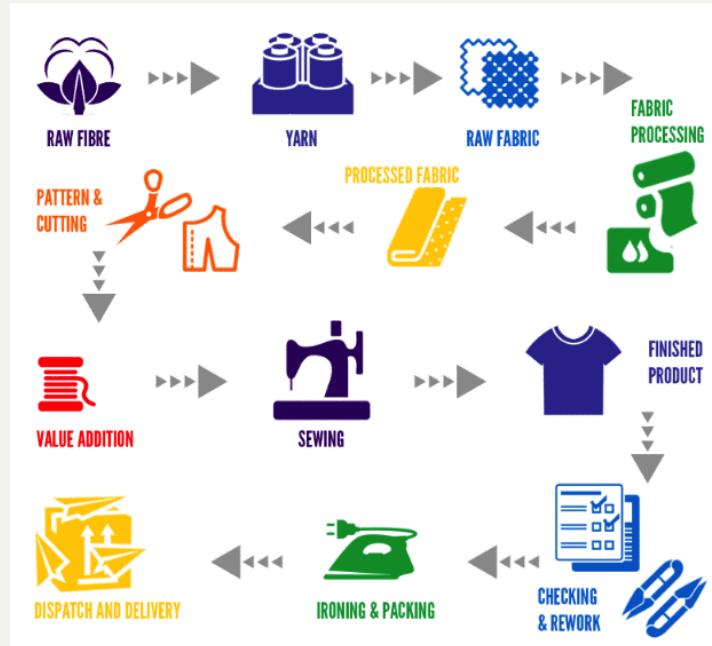
Product Portfolio (cont.)

Major customers



02. Production Process

Garment production involves a series of steps, from cutting fabric to finishing the final product. The process ensures that each garment is made with quality and efficiency.



Storing Cut Pieces

Sub-Store Organization

Cut pieces are stored for accessibility

5S Method

5S method ensures organized, accessible materials

Raw Material Storage

Accessories are organized and accessible



Numbering Cut Pieces

Order Identification

Bundles are uniquely numbered for identification

Ply Numbering Equipment

Specialized equipment ensures accurate and efficient numbering of cut pieces

Garment Component Identification

Accurate numbering of garment components is essential for correct assembly and final fit



Sewing

Parts Preparation

Garment components are aligned and prepared for accurate stitching

Marking Parts

Garment components are marked to guide accurate and consistent stitching

Part Folding & Pressing

Garment components are marked for precise and consistent stitching



Production Line Layout

Industrial Engineering

Industrial engineers design efficient production layouts

Product Specific Layout

Production line is customized for product complexity

Assembly Sequence

Operators assemble components in sequence for quality



Quality Control

Stitching Quality Check

Designated checkers ensure all seams meet standards

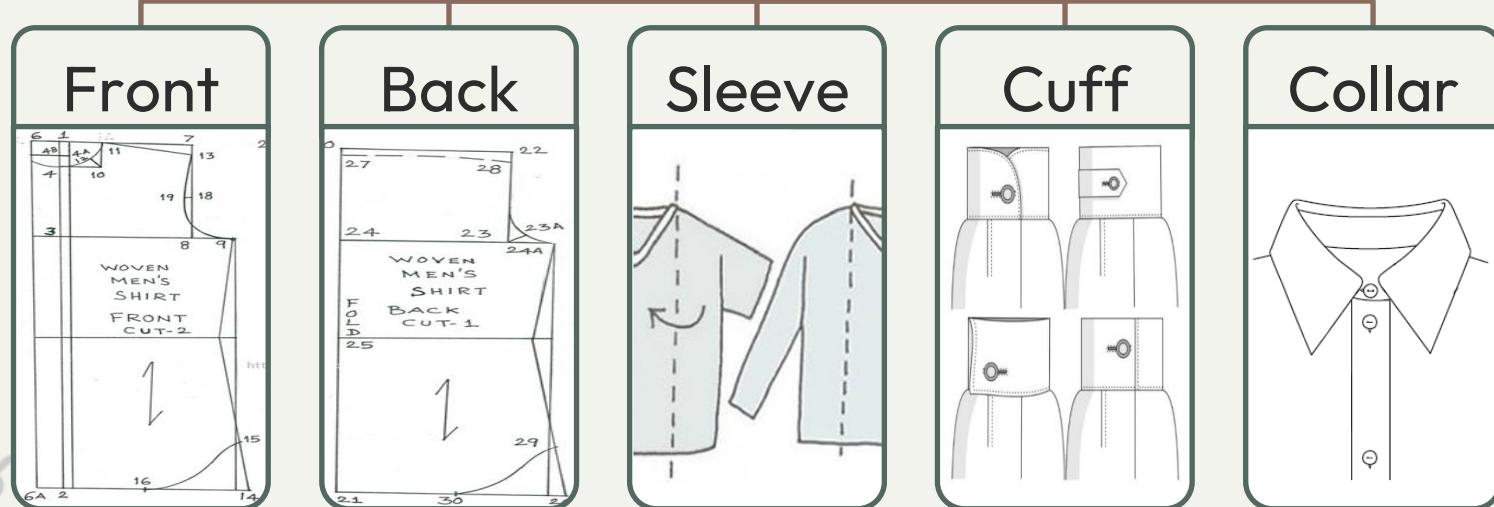
Fault Resolution

Checkers suggest solutions to correct stitching faults

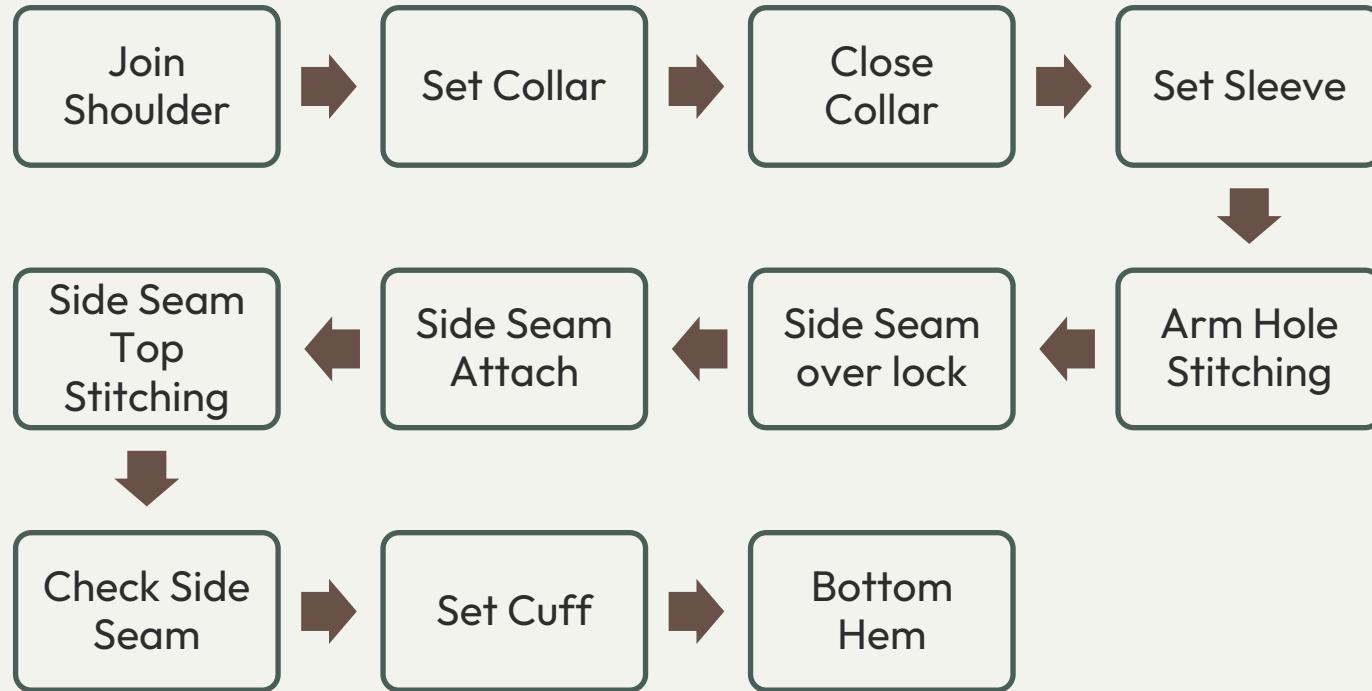


Detailed layout of the production process

Component Lay out for basic style



Assemble Line of Shirt



03.Identified Problems

- Machine Breakdowns
 - Operator Errors
 - Defects Generation in sewing
 - Production Delays



Solutions

Machine Breakdowns

- Real-Time Monitoring
- Training for Machine Operators
- Preventive Maintenance



Operator Errors

- Standard Operating Procedures (SOPs)
- Operator Training and Certification
- Quality Circles



Solutions (cont.)

Defects Generation in sewing

- In-line Inspection
- Assignment problem



Production Delays

- Start project with realistic deadlines
- Review employees' performance



04. Identifying the Problem & Solution

Problem : Production Delays

Solution : Construct Assembly Line Layout with Earliest Finish Time



Key Advantages

Increasing Production Efficiency

- Reducing Production Delays/Reducing time waste
- Minimizing Idle Time



Key Advantages (cont.)

Maximizing Output and Meeting Demand

- Increased Production Capacity
- Efficient Resource Utilization
- Scalability for Large Orders



05.Solving Method

Introduction to Project Management

- **Projects can be simple or complex**
- **Successfully completing a project requires**
 - Knowledge of the tasks involved
 - Accurate estimates of the time and resources required
 - Knowledge of physical and logical relations between the various tasks
- **Project Management Techniques**
 - Program Evaluation and Review Technique(PERT)
 - Critical Path Method(CPM)

Data Collection Process

The time taken for each activity in the production process was recorded daily over 180 days

This provided a

- Comprehensive dataset
- Capturing variations in process execution due to factors such as worker efficiency
- Machine performance
- External interruptions.

Data Collection Process

Day 01	Day 02	Day 03	Day 04	Day 05	Day 06	Day 07	Day 08	Day 09	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27
53.50	53.17	49.29	47.43	51.57	56.54	49.35	48.80	47.38	62.40	56.59	51.44	58.96	55.17	48.17	49.76	53.23	58.76	56.04	51.65	40.56	57.11	53.69	49.39	50.83	46.40	56
19.46	17.75	16.1	19.77	20.32	20.2	18.33	18.71	16.1	16.92	16.79	17.07	19.88	17.85	15.26	15.9	21.55	20.8	17.02	18.9	17.87	18.3	16.62	14.6	20.26	16.51	18
17.11	21.40	23.52	22.23	17.26	19.66	22.31	18.07	19.27	22.08	21.85	21.24	19.17	18.03	22.83	18.31	19.37	19.26	19.37	23.45	21.22	24.96	19.71	21.15	21.32	22.41	22
54.35	49.03	50.02	46.57	58.62	57.27	52.16	43.03	52.66	53.10	50.03	45.15	46.62	57.23	58.28	42.89	48.49	41.98	48.16	50.05	49.54	51.99	42.81	49.93	50.92	56.28	47
64.01	62.74	61.83	59.64	55.94	61.04	73.83	52.11	65.32	63.35	53.96	62.64	69.19	60.09	62.96	61.8	59.61	59.38	60.84	64.29	57.06	59.65	61.78	65.08	48.67	61.98	50
34.32	41.09	40.67	35.19	40.22	40.47	37.42	35.45	32.96	40.59	37.51	35.8	32.85	29.14	37.83	36.89	40.8	40.74	39.45	41.33	36.38	33.18	32.71	30.68	32.24	37.94	34
76.30	77.33	82.11	98.33	84.95	89.65	87.36	76.48	91.78	74.88	79.38	96.88	83.28	102.96	69.67	88.91	82.15	88.72	79.53	93.43	76.47	95.30	90.45	83.59	93.46	81.31	76
54.26	50.73	66.28	61.89	60.30	57.15	61.24	64.81	57.19	60.56	57.30	48.93	58.51	58.32	50.07	55.98	64.91	56.16	54.59	57.06	56.67	59.04	53.66	52.46	44.92	51.32	60
72.00	80.72	68.12	80.41	70.90	87.36	72.21	67.95	82.98	63.32	76.11	84.11	85.59	81.95	80.70	69.89	59.07	79.17	68.23	71.11	62.85	83.90	71.23	73.20	77.62	74.75	72
86.29	82.96	87.22	82.58	80.72	88.87	78.05	93.09	82.43	89.69	78.90	84.51	85.75	89.67	87.12	85.06	85.22	80.39	83.37	65.91	81.36	81.28	77.15	82.30	89.52	80.68	80
66.21	59.74	56.36	62.34	62.17	63.56	72.83	58.86	62.19	59.52	61.42	64.52	64.62	51.00	60.59	56.73	73.09	64.57	67.96	65.52	63.74	53.94	66.09	53.31	64.53	61.46	52
39.04	39.82	31.92	39.43	28.39	40.20	37.33	37.45	36.83	34.80	32.29	30.93	38.31	30.48	35.34	38.33	32.10	42.22	40.18	37.39	33.79	30.16	33.81	41.61	41.22	33.23	31

Day 157	Day 158	Day 159	Day 160	Day 161	Day 162	Day 163	Day 164	Day 165	Day 166	Day 167	Day 168	Day 169	Day 170	Day 171	Day 172	Day 173	Day 174	Day 175	Day 176	Day 177	Day 178	Day 179	Day 180
49.14	48.32	52.46	54.94	60.22	56.44	51.94	54.79	51.38	45.75	51.92	47.63	50.56	59.38	54.44	59.70	49.58	50.73	49.93	50.21	54.46	43.01	54.96	58.00
20.22	18.72	18.77	17.12	20.55	19.86	16.57	17.66	18.09	18.47	16.88	14.2	17.27	20.28	17.79	16.12	17.68	17.81	17.95	18.53	17.59	18.54	20.55	19.52
19.68	19.87	16.67	23.65	21.03	20.74	16.89	17.91	17.99	19.72	19.02	22.67	20.74	21.75	21.69	21.97	20.51	23.70	19.72	18.93	19.70	21.88	20.37	23.63
43.07	48.60	46.48	52.24	57.85	51.27	50.46	45.08	47.46	52.05	46.52	46.58	48.72	53.44	52.20	48.35	43.35	50.84	51.49	48.29	45.88	54.68	44.06	47.16
70.35	69.41	68.56	53.2	54.89	68.39	63.01	73.79	56.61	65.75	72.35	62.83	55.98	58.81	62.79	64.26	58.68	74.88	61.13	71.87	64.49	57.77	71.42	68.51
39.62	43.12	37.13	41.69	34.73	36.98	38.65	32.3	37.48	40.59	34.97	40.14	33.82	33.77	31.55	43.48	38.99	31.6	37.42	31.96	40.93	33.22	40.9	31.59
84.73	90.81	80.34	78.74	70.59	89.11	89.64	101.40	78.01	82.27	84.17	78.75	73.31	78.88	79.33	73.40	100.89	84.30	88.11	77.29	95.80	85.28	82.98	86.00
61.57	48.89	45.92	60.56	50.02	52.58	52.41	56.48	52.83	52.09	49.24	57.88	59.24	65.55	67.08	58.69	60.12	55.48	58.97	50.72	59.05	52.45	45.20	54.33
68.81	64.78	65.16	72.73	73.33	74.37	61.25	80.43	76.24	76.92	70.98	56.78	62.35	79.00	67.65	81.64	60.46	66.58	66.18	79.44	71.54	80.33	71.24	65.93
91.24	87.22	82.61	83.01	72.82	87.27	95.71	86.44	80.67	77.90	90.85	77.71	88.39	101.40	84.97	88.44	85.47	83.04	79.07	82.27	75.18	89.28	79.44	94.87
56.78	50.41	72.55	58.25	69.44	54.77	55.82	64.12	53.35	59.55	68.45	68.83	55.32	59.17	66.40	57.40	66.42	64.12	52.70	73.75	61.79	74.88	59.81	54.13
40.24	35.61	38.94	41.67	34.34	36.79	43.29	34.90	38.06	35.03	32.19	40.30	32.97	36.36	37.39	37.45	34.03	37.81	32.27	39.26	39.81	36.12	36.21	35.97

Summary of Activities

Activity	Operation/Description	Immediate Predecessor Activities
A	Sleeve hem	-
B	Join the collar rib	-
C	Open the seam and track	B
D	Join shoulder	-
E	Attach the collar rib to body	C,D
F	Attach the main label	E
G	Attach tape to collar, fold & cut tap	F
H	Close the neck tape	G
I	Attach sleeve	H,A
J	Side seam with care label	I
K	Bottom hemming	J
L	Track sleeve	K

PERT(Program Evaluate and Review Technique)

Considers multiple paths and probabilistic durations for activities

Time Estimates for PERT Analysis

Triangular Distribution for Activity Times:

Activity times are calculated using a triangular distribution based on three-time estimates:

- Optimistic Time (a_i)
- Most Likely Time (m_i)
- Pessimistic Time (b_i)

Activity	Optimistic time	Most Probable time	Pessimistic time	Activity	Min	Average	Max
A	40.56	52.00	62.40	A	40.56	52.00	62.40
B	14.20	18.20	21.84	B	14.20	18.20	21.84
C	16.22	20.80	24.96	C	16.22	20.80	24.96
D	38.53	49.40	59.28	D	38.53	49.40	59.28
E	48.67	62.40	74.88	E	48.67	62.40	74.88
F	28.39	36.40	43.68	F	28.39	36.40	43.81
G	66.92	85.80	102.96	G	66.92	85.80	102.96
H	43.60	55.90	67.08	H	43.60	55.90	67.08
I	56.78	72.80	87.36	I	56.78	72.80	87.36
J	65.91	84.50	101.40	J	65.91	84.50	101.40
K	48.67	62.40	74.88	K	48.67	62.40	74.88
L	28.39	36.40	43.68	L	28.39	36.40	43.68

These times were recorded in seconds

Time Estimates for PERT Analysis (cont.)

Earliest Start Time (EST): The soonest an activity can begin after its dependencies are completed.

Earliest Finish Time (EFT): Calculated as EST plus the activity duration.

Latest Finish Time (LFT): The latest an activity can conclude without impacting the project timeline.

Latest Start Time (LST): This is derived from LFT minus the activity duration.

Solve using Excel

Activities	Optimistic	Most Probable	Pessimistic	Activity time	EST	EFT	LST	LFT	Slack	
Start	0	0	0	0	0	0	0	0	0	**
A	40.56	52.00	62.40	54.24	0	54.24	242.67	296.91	242.67	
B	14.20	18.20	21.84	18.44	0	18.44	9.3	27.74	9.3	
C	16.22	20.80	24.96	19.81	18.44	38.25	27.74	47.55	9.3	
D	38.53	49.40	59.28	47.55	0	47.55	0	47.55	0	**
E	48.67	62.40	74.88	63.61	47.55	111.16	47.55	111.16	0	**
F	28.39	36.40	43.68	43.38	111.16	154.54	111.16	154.54	0	**
G	66.92	85.80	102.96	82.96	154.54	237.5	154.54	237.5	0	**
H	43.60	55.90	67.08	59.41	237.5	296.91	237.5	296.91	0	**
I	56.78	72.80	87.36	80.31	296.91	377.22	296.91	377.22	0	**
J	65.91	84.50	101.40	85.23	377.22	462.45	377.22	462.45	0	**
K	48.67	62.40	74.88	57.94	462.45	520.39	462.45	520.39	0	**
L	28.39	36.40	43.68	37.52	520.39	557.91	520.39	557.91	0	**

These times were recorded in seconds

*** denotes the critical activities

Solve using Excel (cont.)

Activities	Optimistic	Most Probable	Pessimistic	Activity time	EST	EFT	LST	LFT	Slack	
Start	0	0	0	0	0	0	0	0	0	**
A	40.56	52.00	62.40	51.09	0	51.09	236.62	287.71	236.62	
B	14.20	18.20	21.84	19.92	0	19.92	9.76	29.68	9.76	
C	16.22	20.80	24.96	17.68	19.92	37.6	29.68	47.36	9.76	
D	38.53	49.40	59.28	47.36	0	47.36	5.7E-14	47.36	5.68434E-14	
E	48.67	62.40	74.88	64.08	47.36	111.44	47.36	111.44	5.68434E-14	
F	28.39	36.40	43.68	41.13	111.44	152.57	111.44	152.57	0	**
G	66.92	85.80	102.96	80.67	152.57	233.24	152.57	233.24	0	**
H	43.60	55.90	67.08	54.47	233.24	287.71	233.24	287.71	0	**
I	56.78	72.80	87.36	63.81	287.71	351.52	287.71	351.52	0	**
J	65.91	84.50	101.40	94.04	351.52	445.56	351.52	445.56	0	**
K	48.67	62.40	74.88	69.73	445.56	515.29	445.56	515.29	0	**
L	28.39	36.40	43.68	36.75	515.29	552.04	515.29	552.04	0	**

These times were recorded in seconds

*** denotes the critical activities

Incorporating Randomness:

Random numbers are generated and applied within the triangular distribution framework.

This ensures that calculated activity times are dynamic and vary with each iteration.

Impact on Critical Path Identification:

Variability in activity times influences the identification of critical activities.

Changes in task durations may alter the critical path, leading to a dynamic set of critical activities.

Advantages of This Approach:

Provides a realistic representation of project scheduling.

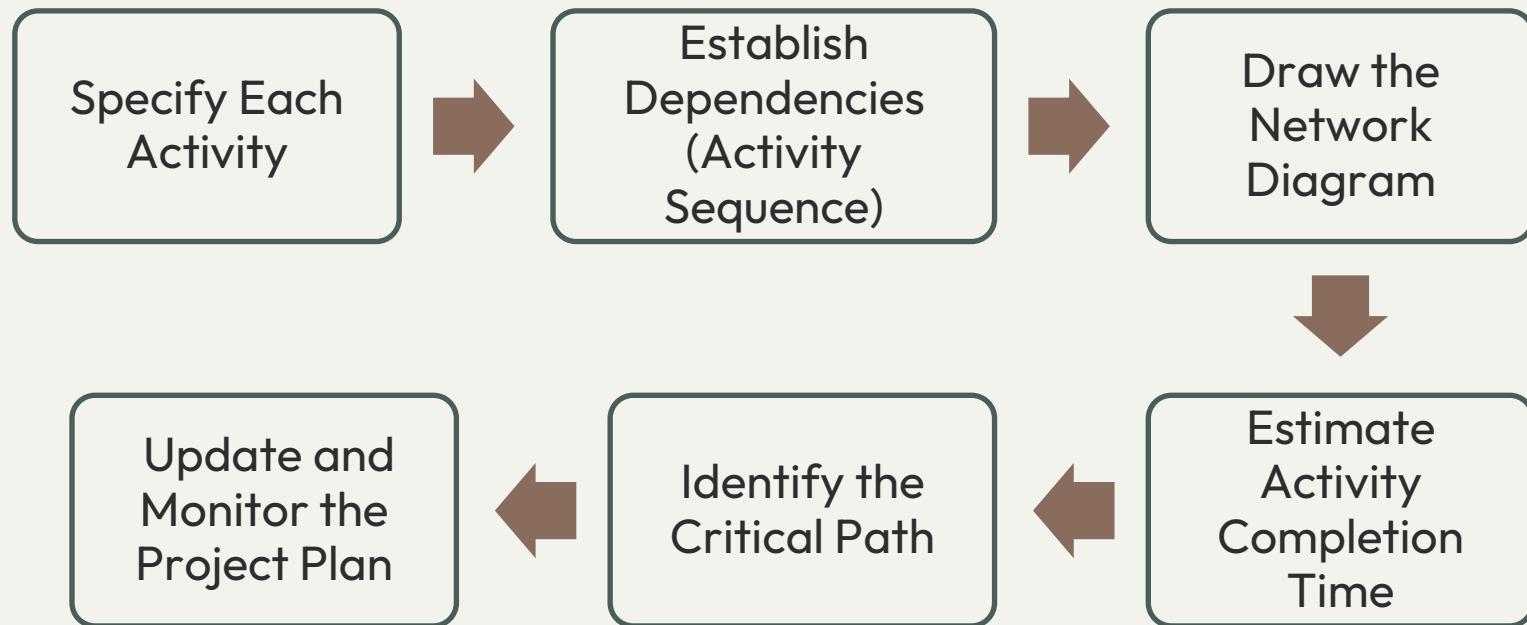
Accounts for uncertainties in task durations.

Allows flexibility in decision-making, enabling adaptive project management.

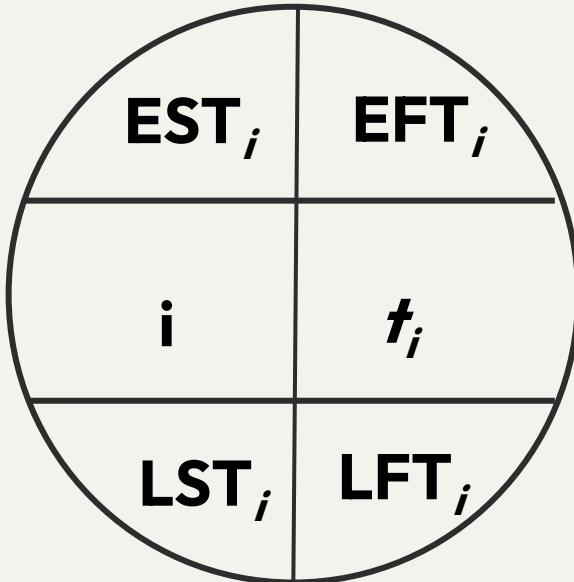
CPM(Critical Path Method)

Focuses on one well-defined critical path

Key Steps in the CPM



Information Recorded for Each Node



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

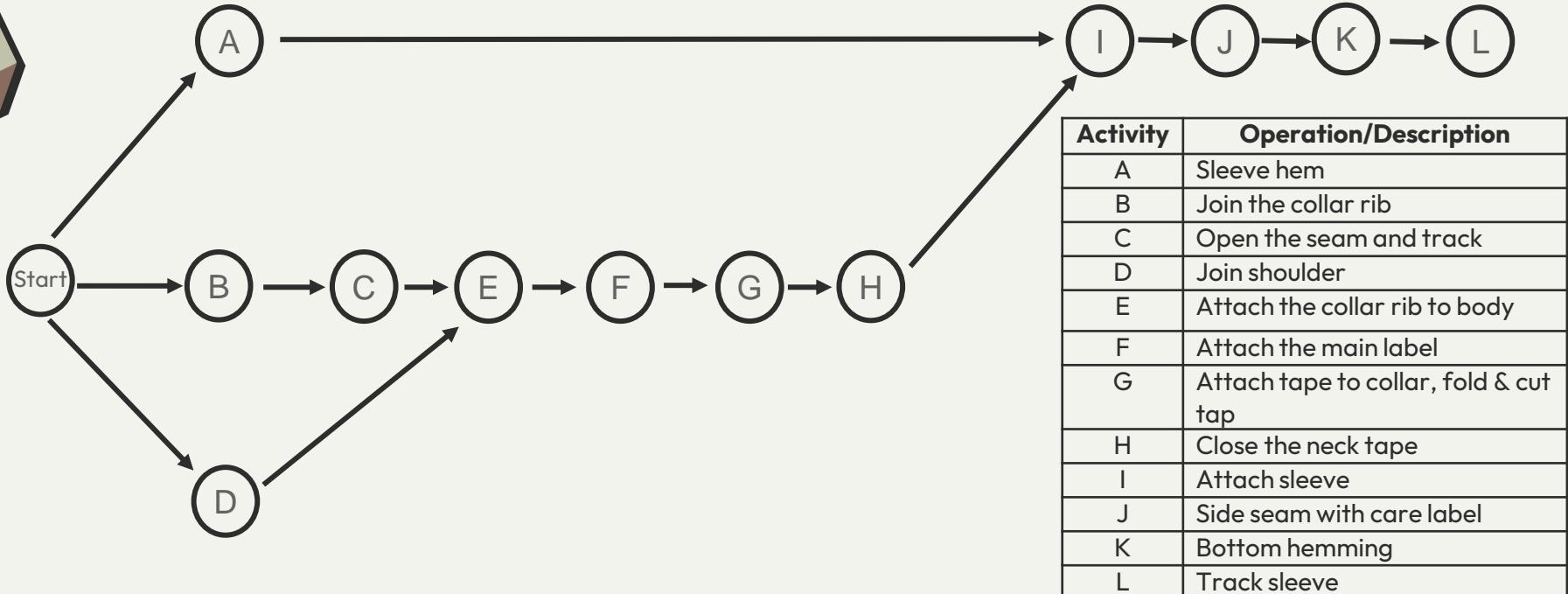
$$\text{Slack} = LST_i - EST_i \text{ or } LFT_i - EFT_i$$



Summary of Activities

Activity	Operation/Description	Time Required (in seconds)	Immediate Predecessor Activities
A	Sleeve hem	52	-
B	Join the collar rib	18.2	-
C	Open the seam and track	20.8	B
D	Join shoulder	49.4	-
E	Attach the collar rib to body	62.4	C,D
F	Attach the main label	36.4	E
G	Attach tape to collar, fold & cut tap	85.8	F
H	Close the neck tape	55.9	G
I	Attach sleeve	72.8	H,A
J	Side seam with care label	84.5	I
K	Bottom hemming	62.4	J
L	Track sleeve	36.4	K

An Activity - On - Node (AON) Network Representation



LP model for the Problem

EST

T_i = Earliest start time of activity i

$$\text{Min } Z = T_A + T_B + T_C + T_D + T_E + T_F + T_G + T_H + T_I + T_J + T_K + T_L + T_S$$

s.t;

$$T_A - T_S \geq t_S$$

$$T_G - T_F \geq t_F$$

$$T_B - T_S \geq t_S$$

$$T_H - T_G \geq t_G$$

$$T_D - T_S \geq t_S$$

$$T_I - T_H \geq t_H$$

$$T_C - T_B \geq t_B$$

$$T_I - T_A \geq t_A$$

$$T_E - T_D \geq t_D$$

$$T_J - T_I \geq t_I$$

$$T_E - T_C \geq t_C$$

$$T_K - T_J \geq t_J$$

$$T_F - T_E \geq t_E$$

$$T_L - T_K \geq t_K$$

$$T_i \geq 0; i=S, A, B, C, \dots, K$$

Linear Programming Model (EXCEL)

EST(Earliest start time)

Linear programming model for EST						
OBJECTIVE			Constraints			
Activities	Time	EST	From	To	Between Starts	minimum time Between Starts
S	0	0	S	A	0	0
A	52	0	S	B	0	0
B	18.2	0	S	D	0	0
C	20.8	18.2	E	F	62.4	62.4
D	49.4	0	B	C	18.2	18.2
E	62.4	49.4	C	E	31.2	20.8
F	36.4	111.8	D	E	49.4	49.4
G	85.8	148.2	A	I	289.9	52
H	55.9	234	F	G	36.4	36.4
I	72.8	289.9	G	H	85.8	85.8
J	84.5	362.7	H	I	55.9	55.9
K	62.4	447.2	I	J	72.8	72.8
L	36.4	509.6	J	K	84.5	84.5
	MinZ	2171	K	L	62.4	62.4

LP model for the Problem

LST

T'_i = Latest start time of activity I

$$\text{Min } Z = T'_A + T'_B + T'_C + T'_D + T'_E + T'_F + T'_G + T'_H + T'_I + T'_J + T'_K + T'_L + T'_S$$

s.t ;

$$T'_A - T'_S \geq t_S$$

$$T'_B - T'_S \geq t_S$$

$$T'_D - T'_S \geq t_S$$

$$T'_C - T'_B \geq t_B$$

$$T'_E - T'_D \geq t_D$$

$$T'_E - T'_C \geq t_C$$

$$T'_F - T'_E \geq t_E$$

$$T'_G - T'_F \geq t_F$$

$$T'_H - T'_G \geq t_G$$

$$T'_I - T'_H \geq t_H$$

$$T'_I - T'_A \geq t_A$$

$$T'_J - T'_I \geq t_I$$

$$T'_K - T'_J \geq t_J$$

$$T'_L - T'_K \geq t_K$$

$$T_i \geq 0; i=S, A, B, C, \dots, K$$

Linear Programming Model (EXCEL)

LST(Latest start time)

linear programming model for LST					
Objectives			Constraints		
Activities	Time	LST	From	To	Between Starts
S	0	0	S	A	237.9
A	52	237.9	S	B	10.4
B	18.2	10.4	S	D	0
C	20.8	28.6	E	F	62.4
D	49.4	0	B	C	18.2
E	62.4	49.4	C	E	20.8
F	36.4	111.8	D	E	49.4
G	85.8	148.2	A	I	52
H	55.9	234	F	G	36.4
I	72.8	289.9	G	H	85.8
J	84.5	362.7	H	I	55.9
K	62.4	447.2	I	J	72.8
L	36.4	509.6	J	K	84.5
Max Z		2429.7	K	L	62.4

Project Summary

Project Summary								
Activity	Description	Time	EST	EFT	LST	LFT	slack	
A	Sleeve hem	52	0	52	237.9	289.9	237.9	NOT
B	join the collar rib	18.2	0	18.2	10.4	28.6	10.4	NOT
C	Open the seam and track	20.8	18.2	39	28.6	49.4	10.4	NOT
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 tap	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	Track sleeve	36.4	509.6	546	509.6	546	0	**

** =>denotes SLACK Activity



Identifying Critical Path



Critical path :

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 →

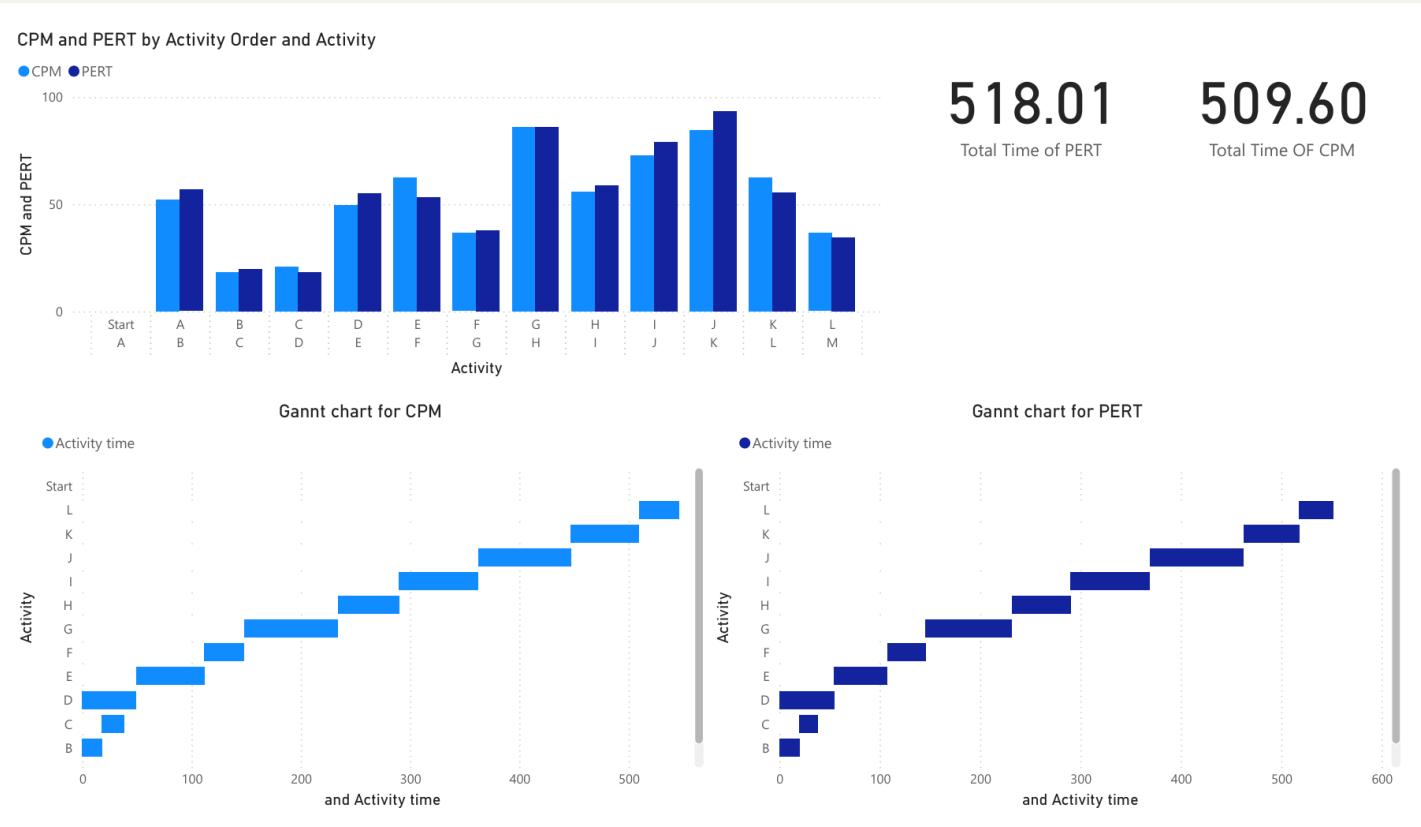
Side seam with care label → Bottom hemming and Tack sleeve.

06. Results & Discussion

Comparison: CPM vs. PERT

- Critical Activities: Identical for both (D, E, F, G, H, J, K, L)
- Slack Differences:
 - CPM: Deterministic durations → zero slack for critical activities.
 - PERT: Probabilistic durations → slight slack adjustments for non-critical activities.
- Completion Time

Power BI Dashboard Insights



Power BI Dashboard Insights

- **Bar Chart:** Highlights duration differences, especially for non-critical tasks.
- **Gantt Chart:** Shows dependencies and overlaps, aiding scheduling flexibility.

Effective Worker Reallocation

- **Scenario:** Worker absence in critical activities → potential production line halt.
- **Strategies:**
 - Reallocate within the same production line (analyze slack of A, B, C).
 - Reallocate from another production line if slack time is insufficient.

Challenges Identified

- Data Dependency: Accurate data collection was essential for both CPM and PERT. Inconsistent or incomplete data could lead to suboptimal results.
- Human Factors: Variability in worker efficiency and skill levels introduced deviations in task durations.
- Machine Reliability: Unanticipated breakdowns affected the accuracy of the projected timelines.

Despite these challenges, the combined use of CPM and PERT offers significant potential in optimizing the production process, making it more efficient, predictable, and adaptable.

Future Directions

1. Critical Path Determination (CPM):

Start → Join Shoulder → Attach Collar Rib to Body → Attach Main Label → Attach Tape to Collar → Close Neck Tape → Attach Sleeve → Side Seam with Care Label → Bottom Hemming → Tack Sleeve → End.

2. PERT Analysis:

Three time estimates for each activity were obtained from historical data over a 180-day period.

Random numbers were generated several times, identifying several critical activities.

Some critical activities were repeated multiple times, such as:

Attach Main Label, Attach Tape to Collar, Close Neck Tape, Attach Sleeve, Side Seam with Care Label, Bottom Hemming, Tack Sleeve

Disadvantages

- Timely Completion Importance.

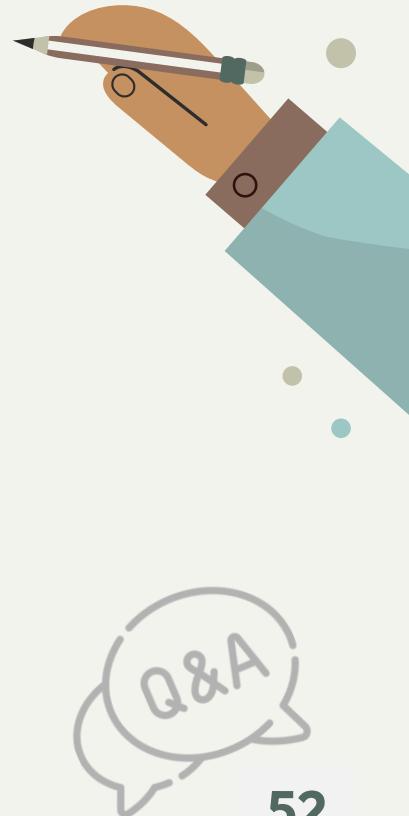
- Substitute Workers, Quality impact & Consequences

Conclusion

- Critical Path Method (CPM):
- Focuses on deterministic scheduling by identifying critical tasks.
- Aims to minimize delays through optimal resource allocation.

- Program Evaluation and Review Technique (PERT):
- Incorporates variability and uncertainty in task durations
- Enables better risk assessment and contingency planning

Q & A



Thank You!

