BD Factory
Production Plan for Barrel, Slide and Lower Frame

No	Student Name - Surname	What he/she did?	Contribution (%)
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2	Burak Yarımay	Data collection, factory visit, calculation of efficiency, preparation of R code for MST	%25
3	Şevval Ercoşgun	factory visit, preparation of process charts, preparation of R code for MST, preparation of presentation	%25
4	Ömer Faruk Özcan	calculation of time properties, preparation of the flow charts and preparation of the presentation.	%25
		Total	100%

Introduction

The project focused on improving the gun parts' production process, including slide, barrels, and lower receiver kits for BD Company. As mentioned, the company produces the whole production process for the 3 parts which are the slide, barrel, and lower receiver besides the heat treatment that needs a week to complete. Fortunately, the heating process allows the application of a higher number of batches that do not affect the process time needed to complete. Moreover, the company also works on putting the other parts together that complete the whole production process of a gun. Application of different algorithms including MST, process chart, and time study improving the production process of BD. The project scope examines the main production process including the production of barrels, magazines, and lower bodies. Under the performing of the algorithms, improving the process and layout, and providing recommendations depending on the results reached by using the methods.

Sequences of Machine Processes

Slide Production for 9x19mm

Start → OP10 Rough Processing (F7) → OP20 Inner Processing (F7) → OP30 Balancing (F1) → OP40 Channel Cutting (F7) → L10 Levelling (TT1) → V10 Vibration (V1) → SB10 Sandblasting (SB1) → OP50 Heat Treatment (-) → Finish

Slide Production for .45ACP

Start → OP10 Rough Processing (F7) → OP20 Inner Processing (F7) → OP30 Balancing (F1) → OP40 Channel Cutting (F7) → L10 Levelling (TT1) → V10 Vibration (V1) → SB10 Sandblasting (SB1) → OP50 Heat Treatment (-) → Finish

Barrel Production for 9x19mm

Start → OP10 Hole - Reamer (T1) → OP20 Rifle - Set (PRESS) → OP40 Outer Diameter Turning (T1) → OP50 Barrel Milling (F6) → OP60 T Channel - Hole (F6) → OP70 Shot Bed (T1) → L10 Levelling (TT1) → V10 Vibration (V1) → SB10 Sandblasting (SB1) → Finish

Barrel Production for .45ACP

Start → OP10 Hole - Reamer (T1) → OP20 Rifle - Set (PRESS) → OP40 Outer Diameter Turning (T1) → OP50 Barrel Milling (F6) → OP60 T Channel - Hole (F6) → OP70 Shot Bed (T1) → L10 Levelling (TT1) → V10 Vibration (V1) → SB10 Sandblasting (SB1) → Finish

Lower Body Production

Start → OP10 Rough Surface Trimming (F5) → OP20 Front Surface Trimming (F8) → OP30 Rear Surface Trimming (F4) → OP40 Before Wire (F4) → OP50 Magazine Discharge (F4) → L10 Levelling (TT1) → V10 Vibration (V1) → SB10 Sandblasting (SB1) → OP70 After Wire (F3) → OP80 Conversion (F3) → Finish

Process Chart of Barrel

Location: Balistic Defence	
Activity: Barrel Production	
Date: 04.12.2024	
Operator: Şevki	
Circle Apporiate Product and Type:	
Method: Present	
Type: Machine	

Summary			
Event	**Present**	**Proposed**	**Savings**
Operation	9		
Transport	8		
Inspection	1		
Delay	14		
Storage	1		
Time (min)	228.02		
Distance (m)	138.4		

Step #	Activity Description	Time (minutes)	Distance (meters)	Operation ○	Transport ⇨	Inspection □	Delay D	Storage ▽
1	Load Machine T1	4					x	
2	HOLE - REAMER	3		x				
3	Unload Machine T1	2					x	
4	Transportation of part from T1 to PRESS	1.07	2.7		x			
5	Load Machine PRESS	4					x	
6	RIFLE - SET	1		x				
7	Unload Machine PRESS	2					x	
8	Transportation of part from PRESS to T1	1.07	2.7		x			
9	Load Machine T1	4					x	
10	OUTER DIAMETER TURNING	5		x				
11	Unload T1	2					x	
12	Transportation of part from T1 to F6	1.06	21.64		x			
13	Load Machine F6	6.5					x	
14	BARREL MILLING	12		x				
15	T CHANNEL - HOLE	4		x				
16	Unload Machine F6	3.25					x	
17	Transport part from F6 to T1	1.06	21.64		x			
18	Load Machine T1	4					x	
19	SHOT BED	1.5		x				
20	Unload Machine T1	2					x	
21	Transportation of part from T1 to TT1	1.02	17.36		x			
22	Inspection of part	2.5				x		
23	Levelling	5		x				
24	Transport part from TT1 to V1	1.02	1		x			
25	Load Machine V1	3					x	
26	Vibration	135		x				
27	Unload Machine V1	1.5					x	
28	Transport part from V1 to SB1	1.47	21.36		x			
29	Load Machine SB1	4					x	
30	Sandblasting	1.5		x				
31	Unload Machine SB1	2					x	
32	Transport part from SB1 to Warehouse	5.5	50		x			
33	Storage							x

Process Chart of Lower Frame

Location: Balistic Defence	
Activity: Lower Frame Production	
Date: 04.12.2024	
Operator: Şevki	
Circle Apporiate Product and Type:	
Method: Present	
Type: Machine	

Summary			
Event	**Present**	**Proposed**	**Savings**
Operation	10		
Transport	7		
Inspection	1		
Delay	12		
Storage	1		
Time (min)	394.4		
Distance (m)	129.1		

Step #	Activity Description	Time (minutes)	Distance (meters)	Operation ○	Transport ⇨	Inspection □	Delay D	Storage ▽
1	Load Machine F5	3.5					x	
2	Rough Surface Trimming	5		x				
3	Unload Machine F5	1.75					x	
4	Transportation of part from F5 to F8	1.08	3.5		x			
5	Load Machine F8	4.25					x	
6	Front Surface Processing	43		x				
7	Unload Machine F8	2.13					x	
8	Transportation of part from F8 to F4	1.05	2.35		x			
9	Load Machine F4	4.3					x	
10	Rear Surface Processing	25		x				
11	Before Wire	45		x				
12	Magazine Discharge	43		x				
13	Unload F4	3.85					x	
14	Transportation of part from F4 to TT1	1.6	26.99		x			
15	Inspection of part	2.5				x		
16	Levelling	10.1		x				
17	Transport part from TT1 to V1	1.02	1		x			
18	Load Machine V1	3					x	
19	Vibration	135		x				
20	Unload Machine V1	1.5					x	
21	Transport part from V1 to SB1	1.47	21.36		x			
22	Load Machine SB1	4					x	
23	Sandblasting	1.5		x				
24	Unload Machine SB1	2					x	
25	Transport part from SB1 to F3	1.33	11.9		x			
26	Load Machine F3	4.3					x	
27	After Wire Operation	26		x				
28	Convertion	6		x				
29	Unload Machine F3	3.85					x	
30	Transport part from F3 to Warehouse	6.32	62		x			
31	Storage							x

Process Chart of Slide

Location: Balistic Defence	
Activity: Slide Production	
Date: 04.12.2024	
Operator: Şevki	
Circle Apporiate Product and Type:	
Method: Present	
Type: Machine	

Summary			
Event	**Present**	**Proposed**	**Savings**
Operation	7		
Transport	6		
Inspection	1		
Delay	10		
Storage	1		
Time (min)	316.8		
Distance (m)	109.19		

Step #	Activity Description	Time (minutes)	Distance (meters)	Operation ○	Transport ⇨	Inspection □	Delay D	Storage ▽
1	Load Machine F7	4.25					x	
2	Rough Operation	3		x				
3	INNER PROCESSING	53		x				
4	Unload Machine F7	2.13					x	
5	Transportation of part from F7 to F1	1.11	5.37		x			
6	Load Machine F1	6.5					x	
7	BALANCING	40		x				
8	Unload Machine F1	3.25					x	
9	Transportation of part from F1 to F7	1.11	5.37		x			
10	Load Machine F7	4.25					x	
11	SLIDE CHANNEL	17		x				
12	Unload F7	2.13					x	
13	Transportation of part from F7 to TT1	1.58	26.09		x			
14	Inspection of part	2.5				x		
15	Levelling	20		x				
16	Transportation of part from TT1 to V1	1.02	1		x			
17	Load Machine V1	3					x	
18	Vibration	135		x				
19	Unload Machine V1	1.5					x	
20	Transport part from V1 to SB1	1.47	21.36		x			
21	Load Machine SB1	4					x	
22	Sandblasting	1.5		x				
23	Unload SB1	2					x	
24	Transport part from SB1 to Warehouse	5.5	50		x			
25	Storage							x

By considering the Process Charts of the machines, a considerable number of delays caused by machine loadings can be observed. However, the high amount of time of the total time of process chart used for the operation process. Therefore, despite the many delays that occurred, the time is not wasted much due to these delays are mandatory and in a toleratable level. Moreover, the main reason long-distance transportation is needed between the machines is mainly caused by the structure of the factory building. Due occupied space between the machines does not allow us to reduce the transportation distance needed between the machines and this causes a high amount of transportation with heavy material.

The reason of inspection process is not very common between the production steps is, that almost all the production is operated directly by the machines which allows for reducing the allowance caused by the high needed effort. Also, using the machine in many steps allows us to reduce the number of inspections needed because as long as the machine works fine the error rate will be low.

Task Definiton

The task observed is the production process of 3 main gun parts. Slide, barrel, and Lower Receiver/Body/Frame production process from the beginning of production until the end of the assembly process of resulting in a fully working gun. However, the parts under consideration will be the production process of these three processes and their production steps completed inside the factory. The production of lower frame covers steps from rough surface trimming to conversion, for barrel production the requires steps from hole-reaver to sandblasting, and slide production needs rough to heat treatment steps to complete. For all these 3 products, an outsource provider will cover the heat treatment process. Therefore, the factory sends the products in higher batches than the machine capacity that the company has. Despite this, it seems like this process could cause a delay in the production process, the production management process that the factory using presently, the heat-treatment, and the connected processes are extremely high. Without an unusual delay, the workers inside of the factory, has almost zero delay effect due to the condition. Because of this reason, the project is focusing only to the production process of slide, barrel and lower frame parts considering the negative effect of the heat-treatment process as none.

Production process of the selected job(s) is provided as on the tables below:

Lower Body Production

Product Name	Operation No	Operation Definition	Stand Code	Process Time (sec)
Lower Body	OP10	Rough Surface Trimming	F5	300
Lower Body	OP20	Front Surface Trimming	F8	2582
Lower Body	OP30	Rear Surface Trimming	F4	1502
Lower Body	OP40	Before Wire	F4	2703
Lower Body	OP50	Magazine Discharge	F4	2583
Lower Body	L10	Levelling	TT1	603
Lower Body	V10	Vibration	V1	8099
Lower Body	SB10	Sandblasting	SB1	90
Lower Body	OP70	After Wire	F3	1562
Lower Body	OP80	Conversion	F3	360

9x19mm Barrel Production

Product Name	Operation No	Operation Definition	Stand Code	Process Time (sec)
Barrel 9x19 mm	OP10	Hole - Reamer	T1	180
Barrel 9x19 mm	OP20	Rifle - Set	PRESS	60
Barrel 9x19 mm	OP40	Outer Diameter Turning	T1	300
Barrel 9x19 mm	OP50	Barrel Milling	F6	720
Barrel 9x19 mm	OP60	T Channel - Hole	F6	240
Barrel 9x19 mm	OP70	Shot Bed	T1	90
Barrel 9x19 mm	L10	Levelling	TT1	300
Barrel 9x19 mm	V10	Vibration	V1	8100
Barrel 9x19 mm	SB10	Sandblasting	SB1	90

Production process of the selected job(s) is provided as on the tables below:

9x19mm Slide Production

Product Name	Operation No	Operation Definition	Stand Code	Process Time (sec)
Slide 9x19 mm	OP10	Rough	F7	180
Slide 9x19 mm	OP20	Inner Processing	F7	3180
Slide 9x19 mm	OP30	Balancing	F1	2400
Slide 9x19 mm	OP40	Slide Channel	F7	1020
Slide 9x19 mm	L10	Levelling	TT1	1200
Slide 9x19 mm	V10	Vibration	V1	8100
Slide 9x19 mm	SB10	Sandblasting	SB1	90
Slide 9x19 mm	OP50	Heat Treatment	-	-

.45 ACP Barrel Production

Product Name	Operation No	Operation Definition	Stand Code	Process Time (sec)
Barrel .45 ACP	OP10	Hole - Reamer	T1	180
Barrel .45 ACP	OP20	Rifle - Set	PRESS	60
Barrel .45 ACP	OP40	Outer Diameter Turning	T1	300
Barrel .45 ACP	OP50	Barrel Milling	F6	720
Barrel .45 ACP	OP60	T Channel - Hole	F6	240
Barrel .45 ACP	OP70	Shot Bed	T1	90
Barrel .45 ACP	L10	Levelling	TT1	300
Barrel .45 ACP	V10	Vibration	V1	8100
Barrel .45 ACP	SB10	Sandblasting	SB1	90

Production process of the selected job(s) is provided as on the tables below:

.45 ACP Slide Production

Product Name	Operation No	Operation Definition	Stand Code	Process Time (sec)
Barrel 9x19 mm	OP10	Rough	F7	180
Barrel 9x19 mm	OP20	Inner Processing	F7	3180
Barrel 9x19 mm	OP30	Balancing	F1	2400
Barrel 9x19 mm	OP40	Slide Channel	F7	1020
Barrel 9x19 mm	L10	Levelling	TT1	1200
Barrel 9x19 mm	V10	Vibration	V1	8100
Barrel 9x19 mm	SB10	Sandblasting	SB1	90
Barrel 9x19 mm	OP50	Heat Treatment	-	-

Due to heat treatment process is an outsource process which allows to send and collect higher batches than the production system of the factory, despite it takes a week to complete all procedures required to complete iti does not affect the production plan of the factory. Therefore, even the process if added to the whole production process charts and tables, there will be no information about the time needed or the table/stand for the process application to provide more accurate result on the time study calculation step.

Operation No	Observations (sec)	Average Duration (min)	Performance Rating
OP10	298, 302, 300, 299, 301, 297, 303, 300	5	1.05
OP20	2575, 2582, 2580, 2588, 2579, 2584, 2581, 2586	43.03133333	0.97
OP30	1498, 1502, 1500, 1508, 1501, 1499, 1505, 1504	25.0355	0.93
OP40	2698, 2704, 2702, 2706, 2700, 2710, 2705, 2701	45.05416667	0.98
OP50	2578, 2582, 2585, 2580, 2588, 2583, 2581, 2586	43.05216667	1.15
L10	601, 597, 603, 592, 610, 609, 606, 607	10.052	0.85
V10	8065, 8148, 8147, 8149, 8073, 8062, 8090, 8059	134.9853333	0.99
SB10	85, 85, 90, 92, 92, 92, 92, 95	1.506333333	0.92
OP70	1555, 1562, 1560, 1565, 1568, 1558, 1563, 1561	26.025	0.99
OP80	358, 362, 360, 359, 361, 364, 357, 360	6.002166667	0.93

In the provided table we can see the observed operations, performance ratings, and average duration generated by depending on the observation times for each operation.

By using these data and allowances, we will acquire the Standard Time, Normal Time and Required Sample Size data.

Operation No	Personal Allowance(%)	Delay Allowance (%)	Fatigue Allowance (%)	Total Allowance	
OP10	3.00	4	2	9.00%	• Due to repetitive tasks and occasional machine adjustments.
OP20	3.00	4	2	9.00%	• Due to repetitive tasks and occasional machine adjustments.
OP30	3.00	4	2	9.00%	• Due to repetitive tasks and occasional machine adjustments.
OP40	3.00	4	2	9.00%	• Due to repetitive tasks and occasional machine adjustments.
OP50	3.00	4	2	9.00%	• Due to repetitive tasks and occasional machine adjustments.
L10	3.00	5	8	16.00%	• High physical effort is needed for levelling tasks and delay due to manual insert for each product.
V10	3.00	5	2	10.00%	• Due to the minimal contribution of the operator and material handling processes.
SB10	3.00	5	7	15.00%	• High amount of physical strain and posture challenges and material handling processes.
OP70	3.00	4	2	9.00%	• Due to repetitive tasks and occasional machine adjustments.
OP80	3.00	4	2	9.00%	• Due to repetitive tasks and occasional machine adjustments.

By using the number of observations and average duration given in the table, Normal Time, Standard Time and required sample size values can be calculated. by using the formulas:

Normal Time = Observed Time × Performance Rating

Standard Time = Normal Time × (1+Allowance Factor)

Required Sample Size : $n = \left(\frac{z \times s}{e}\right)^2$

for α = 0.03 and h = 0.03

Normal Time	Standard Time(min)	Required Sample Size (n)
5.25	5.72	837.1377778
41.74039333	45.50	47.96249692
23.283015	25.38	93.68154263
44.15308333	48.13	37.41596814
49.50999167	53.97	30.92736501
8.5442	9.91	2003.33126
133.63548	147.00	495.7307374
1.385826667	1.59	29552.94995
25.76475	28.08	126.0834872
5.582015	6.08	722.221783

Layout Organization and Discussion

The determined layout type for the factory can be chosen as **Process Layout** by considering the given calculation and the structure of the building. Unfortunately, despite there are other layout options could fit better to the production plan of the factory, the building does not allow to apply any other layout algorithm from the more effective way. Therefore, we decided to apply process layout that allow us to get the highest efficiency under the given conditions.

After the application of process layout, we define the problem as minimizing the distance between the machines. To solve the provided problem, we decided to use a modified spanning tree algorithm which could give a suitable solution for the problem. To obtain a precise result for the problem, R programming language has been used. The R code of required calculations and visual representation of the modified spanning tree algorithm will be provided in the next slides.

R Code for the calculation of modified spaninning tree algorithm

```r

if (!requireNamespace("igraph", quietly = TRUE)) install.packages("igraph")
library(igraph)

# Distance Matrix
distance_matrix <- matrix(
  c(
    0, 3.5, 1, 30.86, 31.86, 14.87, 4.77, 16.37, 16.37, 13.01, 4.77, 13.01, 8.94,
    3.5, 0, 2.35, 26.86, 27.86, 7.7, 3.25, 10.2, 10.2, 9.01, 0.77, 9.01, 4.94,
    1, 2.35, 0, 26.99, 27.99, 11, 0.9, 12.5, 12.5, 9.14, 2.52, 9.14, 5.07,
    30.86, 26.86, 26.99, 0, 1, 20.36, 23.22, 17.36, 17.36, 16, 26.09, 16, 19.05,
    31.86, 27.86, 27.99, 1, 0, 21.36, 24.22, 18.36, 18.36, 17, 27.09, 17, 20.05,
    14.87, 7.7, 11, 20.36, 21.36, 0, 11.9, 3, 3, 20.14, 11.9, 20.14, 16.07,
    4.77, 3.25, 0.9, 23.22, 24.22, 11.9, 0, 9.9, 9.9, 5.37, 2.35, 5.37, 1.3,
    16.37, 10.2, 12.5, 17.36, 18.36, 3, 9.9, 0, 2.7, 21.64, 13.4, 21.64, 17.57,
    16.37, 10.2, 12.5, 17.36, 18.36, 3, 9.9, 2.7, 0, 21.64, 13.4, 21.64, 17.57,
    13.01, 9.01, 9.14, 16, 17, 20.14, 5.37, 21.64, 21.64, 0, 5.14, 0.7, 1.2,
    4.77, 0.77, 2.52, 26.09, 27.09, 11.9, 2.35, 13.4, 13.4, 5.14, 0, 5.37, 1.03,
    13.01, 9.01, 9.14, 16, 17, 20.14, 5.37, 21.64, 21.64, 0.7, 5.37, 0, 1.2,
    8.94, 4.94, 5.07, 19.05, 20.05, 16.07, 1.3, 17.57, 17.57, 1.2, 1.03, 1.2, 0
  ),
  nrow = 13, ncol = 13, byrow = TRUE
)

```

R Code for the calculation of modified spaninning tree algorithm

```r
# Flow Matrix
flow_matrix <- matrix(
  c(
    0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 1, 0, 140, 0, 0, 2, 0, 0, 2, 0, 0,
    0, 0, 0, 140, 0, 140, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 140, 0, 1, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 2, 0, 0, 0, 0, 4, 2, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 2, 0, 0,
    0, 0, 0, 2, 0, 0, 0, 0, 0, 2, 0, 3, 0,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 1,
    0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 9, 1, 0
  ),
  nrow = 13, ncol = 13, byrow = TRUE
)

# machine lengths
machine_lengths <- c(2, 3.1, 2.87, 4, 1, 0.6, 2.87, 1.65, 1.25, 1.85, 3.1, 1.85, 1.85)
names(machine_lengths) <- c("F5", "F8", "F4", "TT1", "V1", "SB1", "F3", "T1", "PRES", "F6", "F7", "F1", "F2")
```

R Code for the calculation of modified spaninning tree algorithm

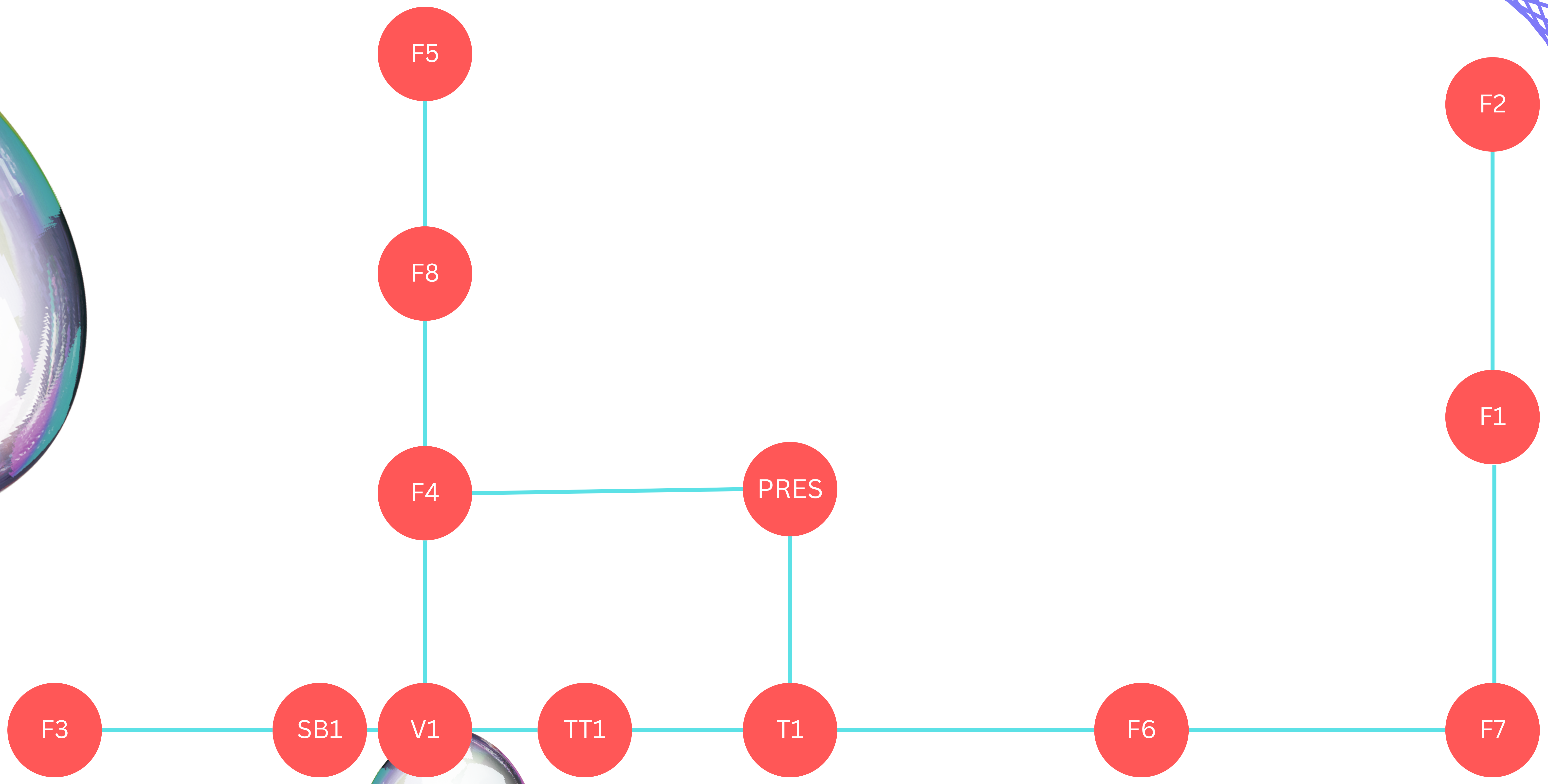
```r
#new weighted matrix
weighted_matrix <- matrix(0, nrow = 13, ncol = 13)
for (i in 1:nrow(distance_matrix)) {
  for (j in 1:ncol(distance_matrix)) {
    if (i != j) {
      weighted_matrix[i, j] <- flow_matrix[i, j] * (distance_matrix[i, j] + 0.5 * (machine_lengths[i] + machine_lengths[j]))
    }
  }
}

#Modified MST Graph
g <- graph_from_adjacency_matrix(weighted_matrix, mode = "undirected", weighted = TRUE, diag = FALSE)

# Modified Spanning Tree calculation
modified_tree <- mst(g, weights = E(g)$weight)

total_weight <- sum(E(modified_tree)$weight)
cat("Modified Spanning Tree'nin toplam ağırlığı: ", total_weight, "\n")

plot(
  modified_tree,
  vertex.label = names(machine_lengths),
  vertex.color = "skyblue",
  vertex.size = 30,
  edge.color = "darkgray",
  edge.width = 2,
  main = "Modified Spanning Tree"
)

```

Flow and Distance Matrix for Production Plan of the Company

FLOW CHART													
	F5	F8	F4	TT1	V1	SB1	F3	T1	PRES	F6	F7	F1	F2
F5	-	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F8	1.00	-	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F4	0.00	1.00	-	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TT1	0.00	0.00	1.00	-	140.00	0.00	0.00	2.00	0.00	0.00	2.00	0.00	0.00
V1	0.00	0.00	0.00	140.00	-	140.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB1	0.00	0.00	0.00	0.00	140.00	-	1.00	0.00	0.00	0.00	0.00	0.00	0.00
F3	0.00	0.00	0.00	0.00	0.00	1.00	-	0.00	0.00	0.00	0.00	0.00	0.00
T1	0.00	0.00	0.00	2.00	0.00	0.00	0.00	-	4.00	2.00	0.00	0.00	0.00
PRES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	-	0.00	0.00	0.00	0.00
F6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	-	2.00	0.00	0.00
F7	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	2.00	-	3.00	0.00
F1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	-	1.00
F2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00	1.00	-

DISTANCE MATRIX													
	F5	F8	F4	TT1	V1	SB1	F3	T1	PRES	F6	F7	F1	F2
F5	-	3.50	1.00	30.86	31.86	14.87	4.77	16.37	16.37	13.01	4.77	13.01	8.94
F8		-	2.35	26.86	27.86	7.70	3.25	10.20	10.20	9.01	0.77	9.01	4.94
F4			-	26.99	27.99	11.00	0.90	12.50	12.50	9.14	2.52	9.14	5.07
TT1				-	1.00	20.36	23.22	17.36	17.36	16.00	26.09	16.00	19.05
V1					-	21.36	24.22	18.36	18.36	17.00	27.09	17.00	20.05
SB1						-	11.90	3.00	3.00	20.14	11.90	20.14	16.07
F3							-	9.90	9.90	5.37	2.35	5.37	1.30
T1								-	2.70	21.64	13.40	21.64	17.57
PRES									-	21.64	13.40	21.64	17.57
F6										-	5.14	0.70	1.20
F7											-	5.37	1.03
F1												-	1.20
F2													-

Determined Layout Type for the provided method



Efficiency Calculation

Step 1: Calculating TMD for the Current Layout

- Determine the material handling distance (D_{ij}) and the material flow (F_{ij}) for each pair of machines (i, j).
- Formula:

$$TMD_{current} = \sum_{i=1}^{n} \sum_{j=1}^{n} F_{ij} \times D_{ij}^{current}$$

Step 2: Calculating TMD for the New Layout

- Calculate the material handling distance (D_{ij}) and the flow (F_{ij}) for the new layout in the same manner.
- Formula:

$$TMD_{new} = \sum_{i=1}^{n} \sum_{j=1}^{n} F_{ij} \times D_{ij}^{new}$$

Step 3: Calculating Efficiency Percentage

- Compare the total material handling distances of the current and new layouts to calculate the efficiency percentage:
- Formula:

$$Efficiency = \left(\frac{TMD_{current} - TMD_{new}}{TMD_{current}} \right) \times 100$$

	F5	F8	F4	TT1	V1	SB1	F3	T1	PRES	F6	F7	F1	F2
F5	-	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F8	1.00	-	2.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F4	0.00	1.00	-	26.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TT1	0.00	0.00	1.00	-	140.00	0.00	0.00	34.72	0.00	0.00	52.18	0.00	0.00
V1	0.00	0.00	0.00	140.00	-	2990.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB1	0.00	0.00	0.00	0.00	140.00	-	11.90	0.00	0.00	0.00	0.00	0.00	0.00
F3	0.00	0.00	0.00	0.00	0.00	1.00	-	0.00	0.00	0.00	0.00	0.00	0.00
T1	0.00	0.00	0.00	2.00	0.00	0.00	0.00	-	10.80	43.28	0.00	0.00	0.00
PRES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	-	0.00	0.00	0.00	0.00
F6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	-	10.28	0.00	0.00
F7	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	2.00	-	16.11	0.00
F1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	-	1.20
F2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00	1.00	-

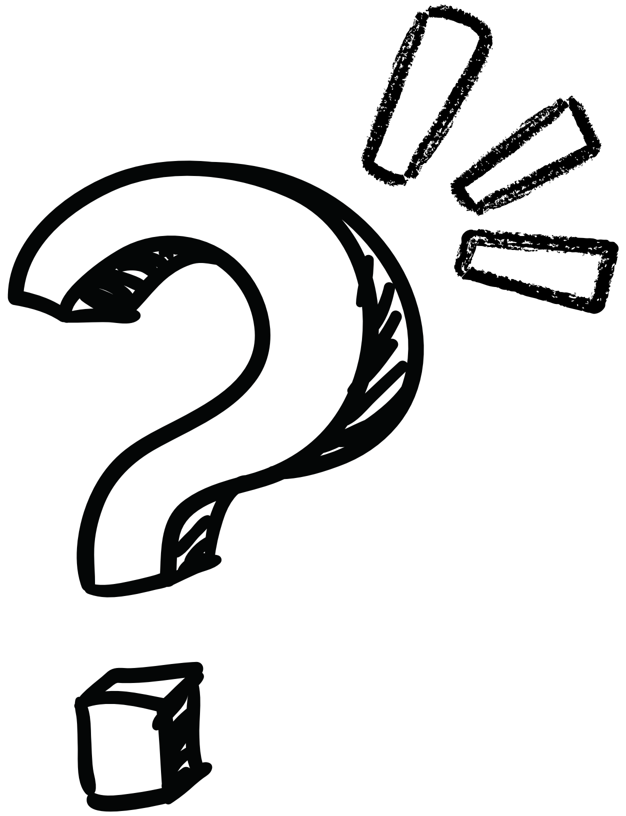
DISTANCE MATRIX													
	F5	F8	F4	TT1	V1	SB1	F3	T1	PRES	F6	F7	F1	F2
F5	-	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F8	1.00	-	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F4	0.00	1.00	-	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TT1	0.00	0.00	1.00	-	105.00	0.00	0.00	1.50	0.00	0.00	4.50	0.00	0.00
V1	0.00	0.00	0.00	140.00	-	105.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB1	0.00	0.00	0.00	0.00	140.00	-	0.75	0.00	0.00	0.00	0.00	0.00	0.00
F3	0.00	0.00	0.00	0.00	0.00	1.00	-	0.00	0.00	0.00	0.00	0.00	0.00
T1	0.00	0.00	0.00	2.00	0.00	0.00	0.00	-	3.00	1.50	0.00	0.00	0.00
PRES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	-	0.00	0.00	0.00	0.00
F6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	-	1.50	0.00	0.00
F7	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	2.00	-	2.25	0.00
F1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	-	0.75
F2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00	1.00	-

By using the given formula the old d_ij value 3652.71 and the new one is 537.75.

By using the given formula on the previous slide we can say that the efficiency rating is 85.28%

The reason for the efficiency percentage is too high for realistic values, mainly caused due to the factory has not much previous experiences for the application of any production planning method and also it is a new founded company. Therefore, several improvements can be applied to the factory production plan to get a better production. By considering these possibilities, the high level of efficiency calculation for the factory could be possible under the applied methods depending on the result provided.

Suggestions



- The machinery layout should be reorganized, and the factory arrangement restructured.
- To increase efficiency on the leveling bench, the number of operators should be increased.
- More efficient machines should be purchased to reduce the processing time of the vibration machine.
- To accelerate the workflow, the production line can be automated. This will also enable a reduction in the number of operators required for the machines.
- In addition to the methods used in the factory's efficiency analysis, data collection and monitoring systems can be implemented.
- Ergonomic adjustments can be made at workstations to reduce the physical strain on employees.