Budapest University of Technology and Economics
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Homework 1

Planning of Plant Logistics Systems

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Table of contents

1. Introduction

This homework focuses on determining the time required for operations and material handling in a production environment, specifically using the MTM (Methods-Time Measurement) and AIM (Anyagmozgatási Időszükséglet Meghatározása in Hungarin and Material Handling Time Determination in English) methods. The task involves analyzing a production line where a worker inspects and packs patterned badges, and the subsequent material handling operations required for transporting the packed units to their destination. By utilizing these methods, the goal is to assess the efficiency of the processes, optimize the number of employees and machines needed, and ensure that the production meets the daily weight requirements within an 8-hour shift.

In Task 1, the MTM method will be used to break down the operations into individual motions, calculating the cycle time for each activity and the required number of employees. Task 2 will then apply the AIM method to evaluate the material handling processes for transporting the pallet units from the packaging site to the unloading area, considering various combinations of handling equipment such as electric pallet trucks and forklifts.

This analysis will provide valuable insights into the overall efficiency of the production and transportation processes, allowing for improvements in labor allocation and equipment selection. The outcome of this work will inform decisions on process optimization, ensuring the maximum possible output with minimal resource usage while adhering to operational constraints.

2. Task 1: MTM

2.1 MTM Analysis of the Workflow

MTM (Methods-Time Measurement) is a predetermined motion time system used to analyze and measure the time required for a task based on the individual motions that make up the task. It is a technique used in industrial engineering to determine the standard time required to perform a task by breaking it down into basic motions (such as reaching, grasping, moving, positioning, etc.) and assigning specific time values to each motion. These time values are based on extensive studies of human performance and are used to calculate the total time needed to complete a task or process.

MTM helps in improving productivity, optimizing processes, and determining labor requirements by standardizing the time for tasks, reducing inefficiencies, and providing a foundation for time-based management and work measurement in various industries.

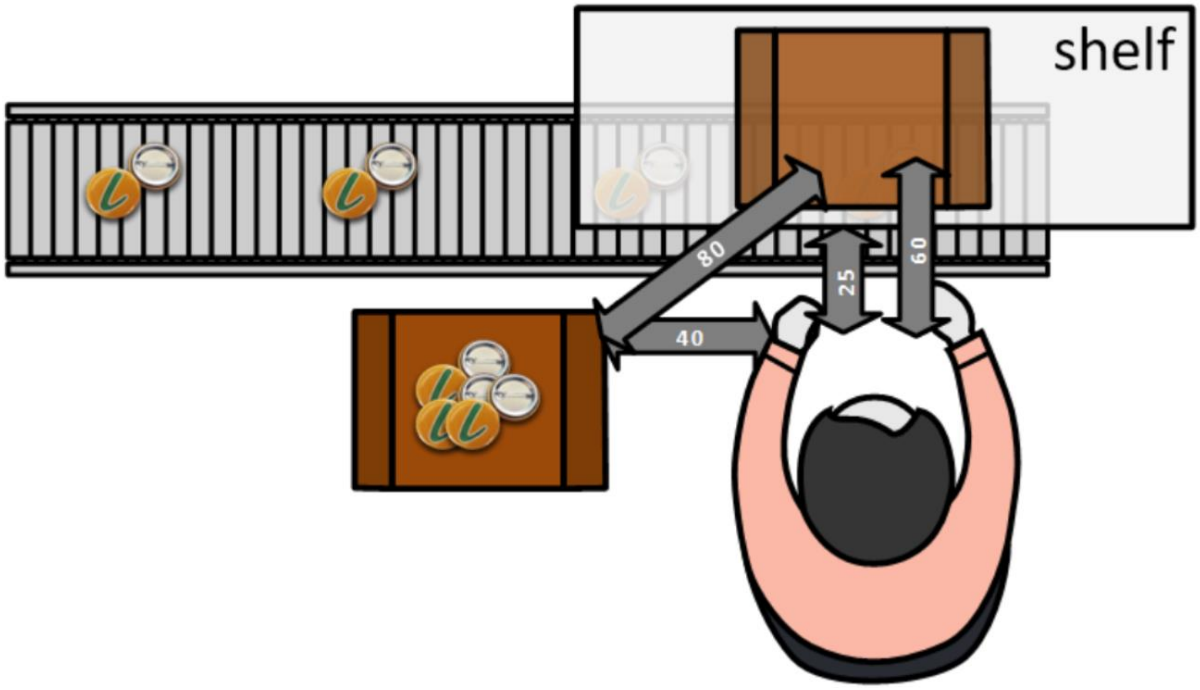

Figure 1: Packaging Workstation for MTM Analysis

In Figure 1, the packaging operation can be seen for the badges. This homework uses MTM methode to breakdown the operation in this process into motions that can be seen on Table 1.

Table 1: Motions for task 1

	Motion
For placing the badges in the box	Reaching for Badge
	Grasping the Badge
	Moving the badge back
	Eye focus
	Moving the Badge in Box
	Release
For Replacing the box	Standing Up
	Reaching for Empty Box
	Grasping the box
	Move Empty Box
	Positioning the box
	Release the box
	Sit down

2.2 MTM Time Values

As it can be seen before, the motions are divided into two steps. The first one is the For placing the badges in the box. The motions, along with TMU as well as the Value calculation chart for determining the exact value from the chart is given below:

Table 2: TMU for Placing the badges in the box

	Motion	Distance	Left Hand	Right Hand	TMU (Time Measurement Unit)
For placing the badges in the box	Reaching for Badge	25 cm	B	B	11.388
	Grasping the Badge	-	-	1A	2
	Moving the badge back	-	A	A	11.172
	Eye focus	-	-	-	7.3
	Moving the Badge in Box	40 cm	B	-	15.656
	Release				2

Not all the TMU are directly available in the charts given. So, they had to be determined using the value calculation chart below:

Table 3: Value Calculation Chart

	Motion	X1	Y1	X2	Y2	X3	Y3	Final TMU
For placing the badges in the box	Reaching for Badge	22.9	8.3	25.4	8.7	25	8.64	
	Grasping the Badge							
	Moving the badge back	22.9	10.5	25.4	11.3	25	11.17	11.17
	Eye focus							
	Moving the Badge in Box	35.6	16.9	40.6	18.7	40	18.48	18.48
	Release							
	Reaching Back to Waist (Move back)							
	Standing Up							
For Replacing the box	Reaching for Empty Box	55.9	14	61	14.9	60	14.72	
	Grasping the box							
	Move Empty Box							
	Positioning the box							
	Release the box							
	Sit down							

From the values from Table 2 and with the given charts for TMU values, the values of actual TMU from the given TMU in the charts was calculated by determining the Y3 in the below formula:

(1) $$\frac{(X3-X1)}{(X2-X1} = \frac{(Y3-Y1)}{(Y2-Y1)}$$

1. **Reaching for the badge:** At first the hand moved 25 cm to retrive the badge, so the distance here is 25 cm, The TMU of it can calculated from the given TMU charts for Reach. But since 25 cm does not exist on the chart, value was calculated using the value calculation chart.
2. **Grasping the Badge:** Case 1A was chosen, as the badge size is not given.
3. **Moving the badge back:** Case A was chosen.
4. **Eye focus:** Since inspection is done, Eye focus is chosen.
5. **Moving the Badge in Box: As** this moves the badge to the exact location. B is chosen.
6. **Release:** Here the release TMU is taken form the chart.
7. **Standing Up:** The time was taken from the chart
8. **Reaching for the empty box:** As the box is in a fixed location. A was used. The TMU is calculated in the value calculation chart.

9. **Grasping the Box:** Here 1A is used for the grasp function.
10. **Move Empty Box:** Here the C function is used from the chart. But as distance 80 is not available in the chart, it is calculated by the below formula:

    Moving Empty Box=((80-76.2)/2.54)*0.85+30.7
    Here, The Distance= 80
        Highest given distance in the chart= 76.2
        TMU at highest given point= 30.7
        Increase rate = .85
11. **Positioning the Box:** Here the value from Loose and Not Symmetrical was taken.
12. **Release the Box:** Here the release TMU is taken form the chart.
13. **Sit Down:** This value was also taken from the chart

The total time for putting 1 badge into the box and 30 badges into the box (as the box can contain 30 badges) can be found from table 4.

Table 4: Total time for placing the badges

	Motion	Distance	Left Hand	Right Hand	TMU (Time Measurement Unit)
For placing the badges in the box	**Reaching for Badge**	25 cm	B	B	11.388
	Grasping the Badge	-	-	1A	2
	Moving the badge back	-	A	A	11.172
	Eye focus	-	-	-	7.3
	Moving the Badge in Box	40 cm	B	-	15.656
	Release				2
				Total time for putting 1 badge	49.516
				Time for putting 30 badges	1485.48

And total time for replacing the box can be calulated from Table 5.

Table 5: Time for replacing the box

	Motion	Distance	Left Hand	Right Hand	TMU (Time Measurement Unit)
For Replacing the box	**Standing Up**				**43.4**
	Reaching for Empty Box	60 cm	Yes	Yes	14.72352941
	Grasping the box		1A	1A	2
	Move Empty Box	80 cm	Yes	YES	31.97165354
	Positioning the box				10.4
	Release the box				2
	Sit down				34.7
				Total TMU for replacing the box	139.195183
				Total TMU for 1 box	1624.675183

2.1.1. Total TMU For the Operation

Total TMU of the operation can be calculated by adding the Total TMU of replacing 1 box and the Total TMU for placing 40 badges in the box.

Here the Total TMU is= 1624.675183 TMU

Here,

Rest Factor= 0.15

Environmental Factor = 0.2

The actual cycle time was calculated by using the below formula:

Actual cycle time = Base time * (1 + EF + RF)

So, Actual cycle time = 1624.675183 *(1+.15+.2)= 2193.311497 TMU

We also know that ,

1 TMU= 0.036 Second

So, actual cycle time = 2193.311497 * 0.036= 78.95921389 Seconds

From the above info, Badges Packed per day and Boxes Packed per day by one operator can be determined by the below table:

Table 6: Boxes and Badges per day by one worker Calculation

Boxes and Badges per Day Calculation		
Rest Factor	0.15	
Environmental Factor	0.2	
Total Base Time for 1 Cycle	2193.311497	TMU
Total Base Time for 1 Cycle(Seconds)	78.95921389	Seconds
Shift per day	2	
Time per shift	8	Hours
Time per day (2*8*60*60)	57600	Seconds
Boxes per day	729	
Badges per day	21870	

Here , the Boxes per day is calculated by the below formula:

Boxes per day= Time per day/ Total Base Time for 1 Cycle

The answer is rounded down to find an integer number.

Here , the Badges per day by one worker is calculated by the below formula = Boxes Per Day* 30

2.1.2. Total Number of worker needed for packing the required amount of weight

Here, the required number of workers are shown in the below table:

Table 7: Number of workers needed

Weight needed to be packed	29364	KG
Weight needed to be packed	29364000	Gram
1 Worker can pack	21870	Badges
1 Worker can pack	1312200	Gram
Total Number of workers needed	22.37768633	
Actual Number of workers	23	

At first the total weight was turned into gram by multiplying the weight with 1000. Then from the previous calculations, the how much of the weight workers could pack in gram was calculated by the below formula:

Total Weight a Worker Can Pack= Number of Packed Badges* Weight of a single badge

Here, the weight of 1 badge is 60g. After that, the total number of workers needed was calculated by the below formula:

(2) $$Total\ Number\ of\ workers\ needed = \frac{Total\ Weight\ Needed\ to\ be\ Packed}{The\ weight\ one\ worker\ can\ pack}$$

This calculation gives us the number of workers in fraction. So, the value of the workers was rounded up.

2.1.2 Second operator

It is given that the second operator arranges the boxes as a EUR1 pallet (1200x800mm). The cycle time for this operation of 10 seconds per box, and consequently time to palletize 543 boxes: 543 * 10= 5430 Seconds

3. Stackbuilder

Using StackBuilder, inputs about dimensions of a badget and a pallet was given. Then the calculations was done like below steps:

Step 1: First the parameters of the box was put as input. Here , [length x width x height] [mm] (150 x 300 x 100). No inner dimensions are available.

Step 2: Then the weight of the box was calculated. The box weight here 0.4 kg and a box can contain 30 badges. A badge weights 60g. So the total weight of the box will be

(3) $Box\ Weight = Box\ Weight + (Number\ of\ Badges\ in\ the\ box * Weight\ of\ 1\ Badge$

(4) $$Box\ Weight = 0.4 + \frac{30*60}{1000} = .4 + 1.8 = 2.2\ Kg$$

Step 3: These values were put into Stackbuilder as per the below image:

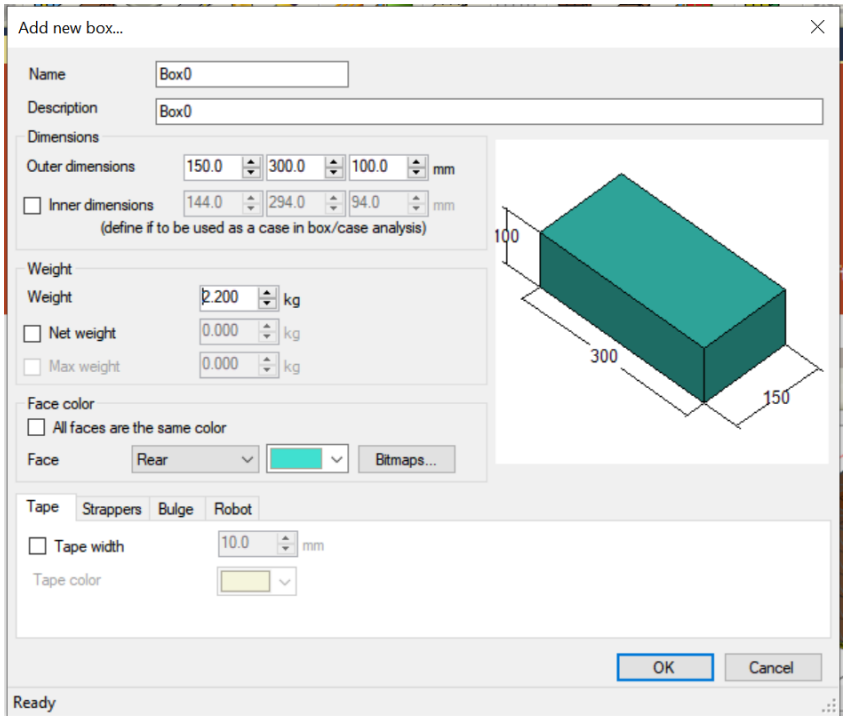

Figure 2: Generating Box in Stackbuilder

Step 4: Then Euro1 type pallet was chosen and analysis was one by below. Maximum pallet height was chosen as per the given data and the Maximum Weight was considered 1000 kg. Stackbuilder was instructed to give the best combination from the data.

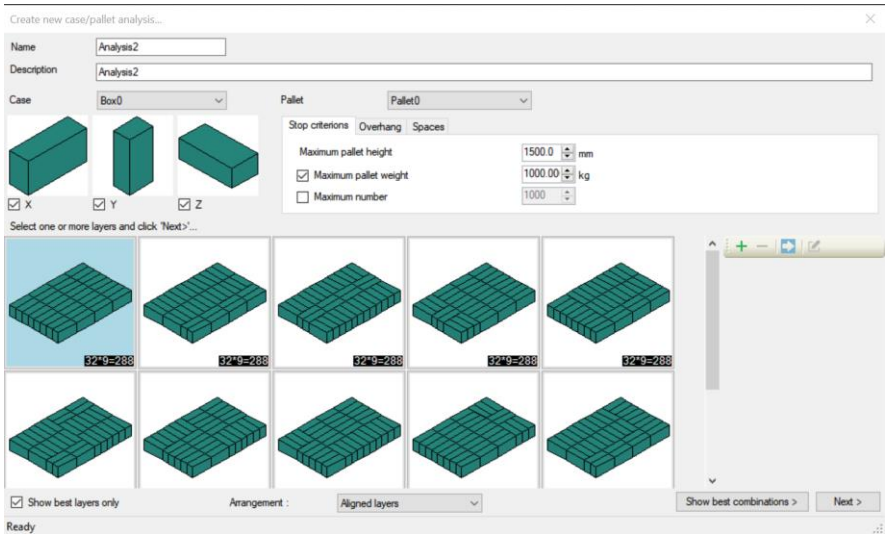

Figure 3: Analysis in Stackbuilder

After the analysis it gives output as per below:

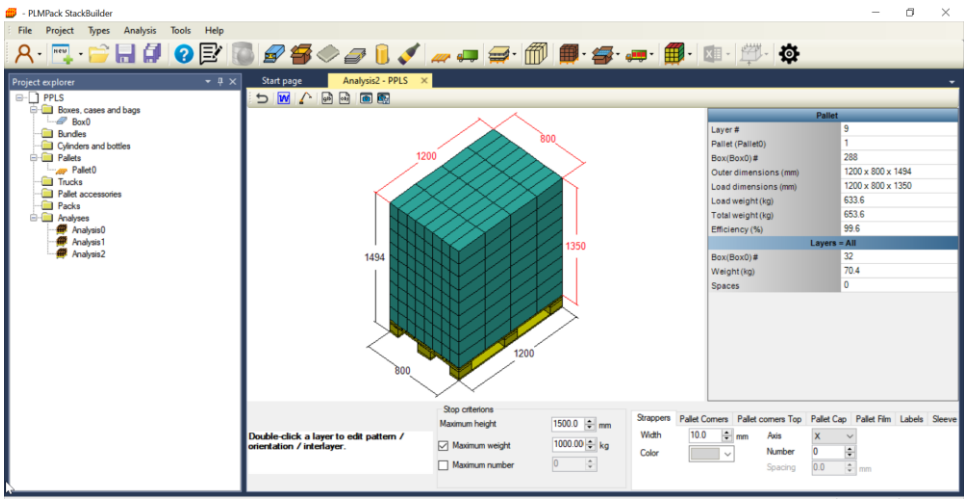

Figure 4: Results in Stackbuilder

So, 1 pallet can contain 288 Boxes, The load weight here is 633.6 kg and the Total weight here is 653.6 kg. The total efficiency here is 99.6%.

4. AIM Method

4.1. Basic data

Weight of badges to be packed and transported in a day = 29364 kg

The number of badges required in a day= $\frac{29364}{0.06}$= 489400 pcs

The number of boxes needed is= $\frac{489400}{30}$= 16313.33= 16314 Boxes

Now, 1 pallet contains 288 boxes.

So, total number of pallets needed are = $\frac{16314}{288}$ = 56.64= 57

Now, 10 seconds is needed for putting one box on the pallet.

So, total time needed for 1 pallet is = 288*10= 2880 Seconds

All the basic data needed determined so far can be seen on the below table:

Table 8: Basic Data for AIM

Basic Data	Values	Unit
Distance between packing positions and trailers/tow tractor (A)	10	meters
Distance between unloading position and trailers/tow tractor (B)	20	meters
Distance between A and B (D)	260	meters
Total weight to transport	29364	kg
The number of badges required in a day	489400	
Weight of a single badge	60	Grams
Badges per box	40	
Total weight of 1 full box	2.2	Kg
Box size	150 x 300 x 100	mm
Pallet size (EUR1)	1200 x 800	mm
Height of the pallet	1500	mm
Number of boxes per pallet	288	
The number of boxes needed is	16314	boxes
Total number of pallets needed are	57	
Total time needed for 1 pallet is	2880	Second

4.2. The process for M2 - EFT+TT2TR+EFT

For the trasportation of the goods trucks, tractors and trailers can be used. For that, there are a few notations used in this homework. Below are the notations:

- **EPT** - Electric pallet truck
- **HPT** - Hand pallet truck

- **EFT** - Electric forklift truck
- **TT** - Tow tractor
- **TR** – Trailer

4.2.1. Basic Time Calculation

Since here the process is EFT+TT2TR+EFT, it means that the operation has below processes:

1. An electric forklift truck (EFT) loads the Tow Tractor and the connected 2 trailers.
2. The TT2TR goes to location B.
3. EFT unloades the units.
4. The TT2TR comes back empty to position A.

For this, the Basic Time is shown in the below table:

Table 9: Basic Time Needed for AIM

EFT + TT2TR + EFT (Basic Time Needed)				
Operation	**Notation**	**Time (10^-2 min/m)**	**Actual Time**	**Unit**
Transporting time (loaded)	TT- L	0.8	0.48	Seconds/m
Transporting time (empty)	TT-WL	0.6	0.36	Seconds/m
Loading time (L)	L3	60	36	Seconds
Unloading time (U)	U3	65	39	Seconds
Starting and stopping (SS)	SS	16	9.6	Seconds
Changing direction (CD)	CD	36	21.6	Seconds

The explanation for the times are given below:

Transporting time (loaded): Here the pallets are moving with toq trucks, so moving with load value is picked in case of TT.

Transporting time Empty: Here the tow trucks go back empty to collect. So moving without load value was picked.

Loading time: Here the Pallets are empty before they ar loaded So, we pick the loaded value. But the height of the pallet with load is about 1500 mm which is 1.5 meters, so we chose the L3 empty value.

Unloading time: We are unloading but from a height and a pallet with a load, so L3 Loaded value was chosen.

Starting and Stopping: Here the value was taken from the AIM table and the value here counts both starting and stopping.

Changing Directions: Here, the value was taken from the AIM table and since the value accounts for both coming and going, we multiply this by 2.

4.2.2. Time for One Round Trip (A to B and back to A):

Table 10: Time for One Round Trip

Time for One Round Trip (A to B and back to A)		
Operation	**Time**	**Unit**
Moving Load to the Trailer and Tow Truck	14.4	Seconds
Load trailers at A	72	Seconds
Coming back to the loading site	7.2	Seconds
Loading Tow Truck	36	Seconds
Travel from A to B (260 m)	124.8	Seconds
Unloading of Tow Tractor	39	Seconds
Unloading 2 Trailers	78	Seconds
Travel from B to A (260 m)	93.6	Seconds
Start and stop	19.2	Seconds
Changing direction (CD)	43.2	Seconds
Total Time Needed	527.4	Seconds

The explanations are given below:

Moving Load to the Trailer and Tow Truck: Here the load is moved to the loading area. The Loaded Transport time is multiplied by 10 as the trailer and the tow truck is 10m away. It is also multiplied by 3 as it would have to move to the loading area 3 times. Here we consider that the one trip to the loading area from the packing area can load one trailer or one tow truck.

Loading: There are two kinds of loading here. One is the loading of the tow truck and the other is the loading of the trailers. Since there are two trailers, we multiply it by two.

Coming back to the packing area from the Trailers: Here the EFT comes back to the packing area. This is 10 meters away and the action happens two times. So, it is multiplied by 2 and 10.

Travel from A to B (260 m): This value is found by multiplying the distance with the transportation time (loaded).

Unloading Times: we find this time from the basic times. Since there are two trailers it has been multiplied by two for the trailers.

Travel from B to A (260 m): this is the distance multiplied by the transportation time (Empty). Here, it is considered that the unloading in the EFT happens simultaneously with this step.

Starting and Stopping: the value given was for starting and stopping for once. We multiply this by two to find the value for both point's start and stop time.

Changing direction (CD): Since there are two changes in changing directions it has been multiplied by two.

4.2.3. Environmental Factors and Rest Factor

Rest factor: For material handling with machines, the rest factor is 0.05

Environmental factor: Based on the illumination (120 lux), the environmental Rating is 2.

The road width is not limited. So, Rating score (R) = 1

So, total rating score for the environment= 2+1=3, this means 0.05

Total Factor= 1+.05+.05= 1.1

4.2.4. Actual Time Needed:

So, the actual time needed is = Base Time*(1+RF+EF)= 527.4*(1+.05+.05)= 580.14 Seconds

If the two truck can take 1 pallet and each of the trailer can take one pallet each, then this is the time for carrying 3 pallets.

So, total number of pallets is 57.

So, Time needed to transport 57 pallets is = 580.14 *(57/3)= 11022.66 Seconds

Number of Workers Needed= 11423.94/2880= 3.82= 4

4.3. The process for M1- EPT

4.3.1. Basic time for the M1-EPT Process

The basic times are given in the below chart:

Table 11: Basic Time for EPT

EPT (Basic Time Needed)				
Operation	**Notation**	**Time (10^-2 min/m)**	**Actual Time**	**Unit**
Transporting time (loaded)	EPT-L	1.5	0.9	Seconds/m
Transporting time (empty)	EPT-WL	1	0.6	Seconds/m
Loading time (L)	L	22	13.2	Seconds
Unloading time (U)	U	20	12	Seconds
Starting and stopping (SS)	SS	18	10.8	Seconds
Changing direction (CD)	CD	11	6.6	Seconds

The Explanations for these are given below:

Transporting time (loaded): Taken from AIM chart.

Transporting time (empty): Taken from AIM chart.

Loading time (L): Taken from AIM chart.

Unloading time (U): Taken from AIM chart.

Starting and stopping (SS): Taken from AIM chart.

Changing direction (CD): Taken from AIM chart.

4.3.2. Time for One Round Trip (A to B and back to A):

Below is the time taken for one round trip for moving a pallet from Packing Zone to the Unloading Zone.

Table 12: EPT- Time for One Round Trip (A to B and back to A)

Time for One Round Trip (A to B and back to A)		
Operation	**Time**	**Unit**
Load at Packing Zone	13.2	Seconds
Travel time (To point A, 10 m)	9	Seconds
Travel time (A to B, 260 m)	234	Seconds
Travel time (unloading position, 20 m)	18	Seconds
Unload time at Unloading Position	12	Seconds
Travel time (unloading position to B, 20 m)	12	Seconds
Travel time (B to A, 260 m)	156	Seconds
Travel Time (To the Packing Zone, 10m)	6	Seconds
Starting and Stopping	21.6	Seconds
Changing Direction	13.2	Seconds
Total Time Needed	495	Seconds

Explanations are given below:

Load at Packing Zone: Taken From AIM.

Travel time (To point A, 10 m): Loaded travel time multiplied with distance.

Travel time (A to B, 260 m): Loaded travel time multiplied with distance.

Travel time (unloading position, 20 m): Loaded travel time multiplied with distance.

Unload time at Unloading Position: Unloading Time.

Travel time (unloading position to B, 20 m): Unloaded travel time multiplied with distance.

Travel time (B to A, 260 m): Unloaded travel time multiplied with distance.

Travel Time (To the Packing Zone, 10m): Unloaded travel time multiplied with distance.

Starting and Stopping: This is done twice, so the value is multiplied by 2.

Changing Direction: This is done twice, so the value is multiplied by 2.

4.3.3. Environment Factor and Rest Factor

Rest factor: For material handling with machines, the rest factor is 0.05

Environmental factor: Based on the illumination (120 lux), the environmental Rating is 2.

The road width is not limited. So, Rating score (R) = 1

So, total rating score for the environment= 2+1=3, this means 0.05

Total Factor= 1+.05+.05= 1.1

4.3.4. Actual Time Calculation

So, the actual time needed is = Base Time*(1+RF+EF)= 495*(1+.05+.05)= 544.5 Seconds

This is the time it takes to transfer 1 pallet in EPT.

So, total number of pallets is 57.

So, Time needed to transport 57 pallets is = 544.5 *57= 31036.5 Seconds

Number of Workers Needed= 31036.5 /2880= 10.77= 11

4.4. Comparing the two material handling equipment combinations using the time results from the AIM method.

EPT: It needs 11 people to work per day, can transfer only 1 pallet in 544.5 Seconds

EFT + TT2TR + EFT: Need 4 people to work per day, can transfer 3 pallets in 580. Seconds.

It is evident from the above data that EFT + TT2TR + EFT is a better system.

4.5. Schematic diagram of the material handling route

Below are the Schematic diagrams of the material handling route:

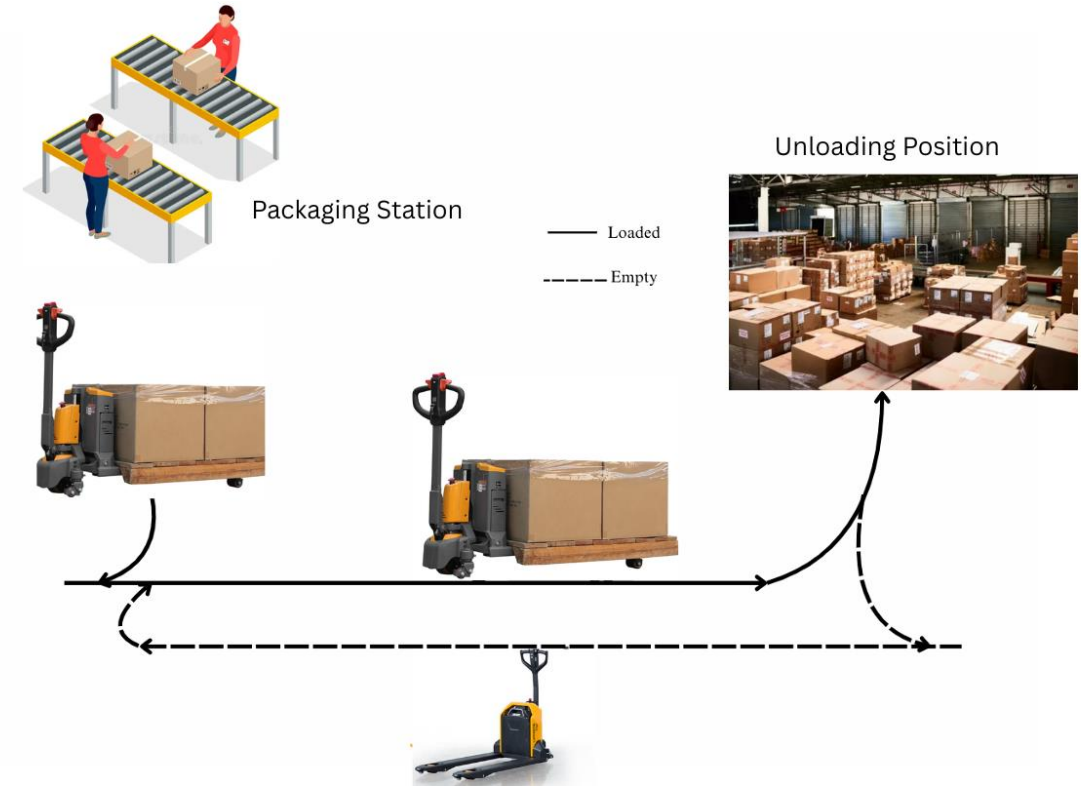

Figure 5: The process for M1- EPT

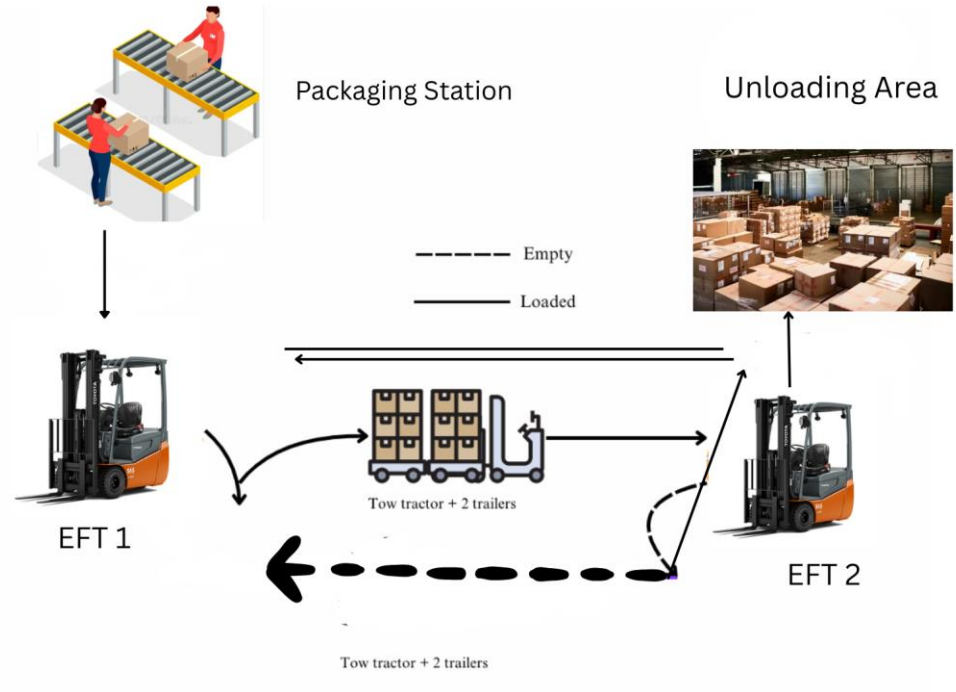

Figure 6: The process for M2 - EFT+TT2TR+EFT

5. A Development Proposal to Improve the Packaging Process

Consider implementing a rolling or sliding tray system that allows for the seamless and efficient replacement of full boxes with empty ones, effectively minimizing the need for workers to stand up. This system would facilitate a smoother workflow by reducing unnecessary movement, thereby enhancing overall productivity. Alternatively, a rotating table could be employed as another viable solution, ensuring that an empty box is automatically presented directly after a full one has been processed. This method would not only streamline the process but also contribute to a more organized and efficient working environment, ultimately optimizing the entire workflow.

So the new time of motion a box:

Table 13: Development Plan

	Motion	**Distance**	**Left Hand**	**Right Hand**	**TMU (Time Measurement Unit)**
For Replacing the box	Reaching for Empty Box	60 cm	Yes	Yes	14.72352941
	Grasping the box		1A	1A	2
	Move Empty Box	80 cm	Yes	YES	31.97165354
	Positioning the box				10.4
	Release the box				2
			Total TMU for replacing the box		61.09518296
			Previous TMU		139.195183
			Saved TMU		78.1

6. List of Figures

7. List of Tables