PoliTong Spring 2016

Fundamentals Of Industrial Plants

Feasibility Study Of A Facility To Produce Injection Molded Car Parts

Technical Report

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CONTENT

1. Introduction & Our Strategy

The mission of this plant is to manufacture injection molded car parts, in particular, dashboards for an international car manufacturer. The production request is to produce 2 different kinds of dashboards Dashboard A and Dashboard B, with production rate of 230,000 items per year for both of the dashboards. As informed clearly in the instruction, the dashboard consists of 8 main components (Body*1, Exterior Cover*1, Glove Compartment*1, Glove Compartment Bracket*2, Vent Frame [Central*(1*2), Side*(1*2)], Fin [Central*(6*2), Side*(4*2)], Shutter [Central*(1*2), Side*(1*2)], Control Wheel [Side*(1*2)], Instrument Frames [Display Frame*1, Radio Frame*1, Navigator*1]. All of these components undergo both injection molding presswork and assembly operations. The raw material we have to use in this project is the granules of thermoplastic material. In total there are 3 sorts of thermoplastic, High Density Polypropylene, Acrylonitrile-butadiene-styrene, and Polyamide, which we have to pay attention while making decisions on the material flow and the production process.

One of the first steps of this project was the strategy decision. It is an important choice, since it affects the whole facility design. Our main tasks were to obtain a simple and practical plant design (taking consideration of feasibility, efficiency of production, ergonomic and maximum satisfaction of employees and workers), meanwhile trying to keep low both the initial investment and the variable costs in order to maximize the profit.

2. Plant Layout Design

i. *Designation For Simplicity

According to our understanding on the type of mold and machine operations, we pay attention to separate the machines for producing Dashboard A and Dashboard B. In our report, we may prefer to use the following designation to make the description briefer and clearer.

Designation Of Machines And Assembly Stations

M1	Injection Molding – Body
M2	Injection Molding – Exterior Cover
M3	Injection Molding – Glove Compartment
M4	Injection Molding –Glove Compartment Bracket
M5	Injection Molding – Fin (Central, Side; Left, Right)
M6	Injection Molding – Shutter & Wheel (Central, Side; Left, Right)
M7	Injection Molding – Vent Frames (Central, Side; Left, Right)
M8	Injection Molding – Instrument Frames (Display & Radio; Navigator)
A0	Dashboard Final Assembly
A1	Sub-Assembly 1
A2	Sub-Assembly 2
A3	Air Vent Assembly

ii. Type of Layout Decision

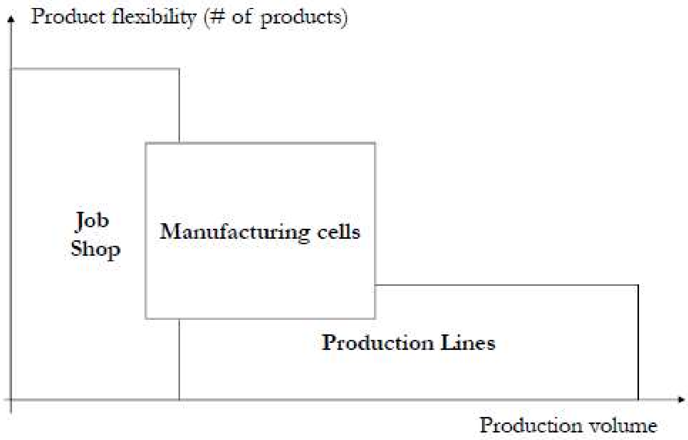
Based on what we learned from the class and the information that is given, we know that in this layout,

#of products = 2 (Dashboard A & Dashboard B) ➔ low #of products

production rate= 230,000 items/year for each kind

= 1000 items/day for each kind

= 67 items/hour for each kind ➔low production rate

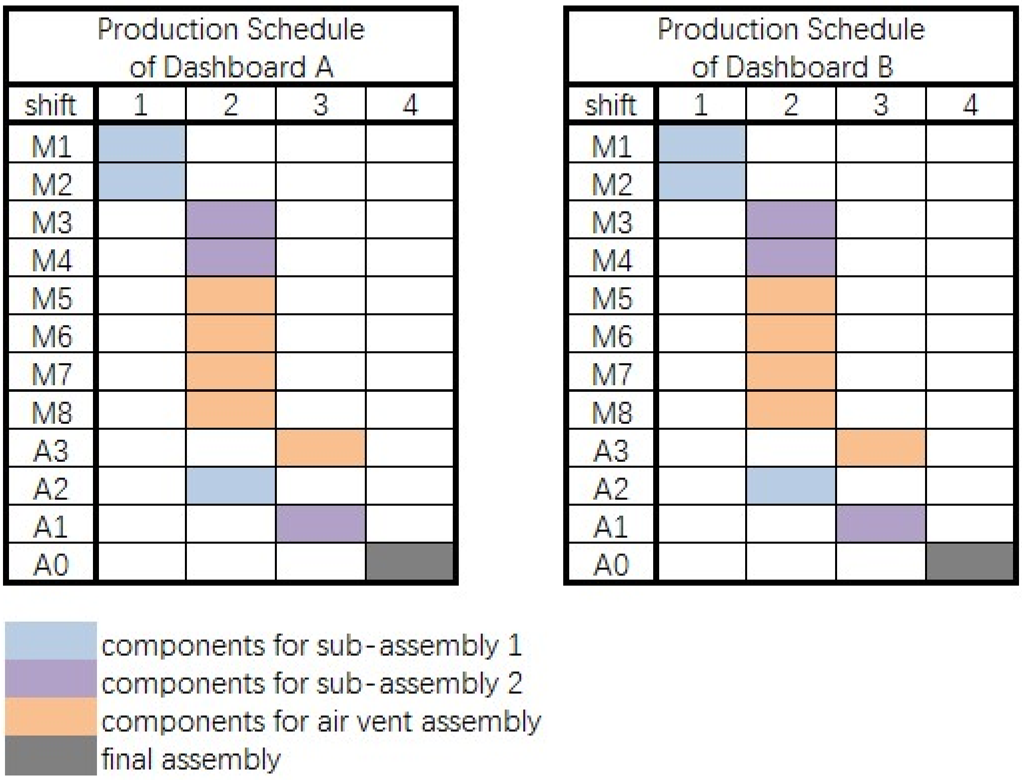


** the given working day per year is 230 days. Each day there are 2 working shift, 7.5 hours in each work shift, which are also given in the instruction.*

According to the ABC classification, it is quite easy to decide to choose a JOB SHOP layout (one department for each kind of operation, in total 12 departments).

On the fundamental of our decision to apply a JOB SHOP layout, we plan a rough production schedule. However at this point, noticing the set-up time for M1 & M2 is 450 minutes that is exactly one shift, which may be not sensible to plan producing body or exterior cover of both Dashboard A and B on the same machine [every day using one shift for setting up, changing the mold and the other shift working is not practical, also a kind of waste of time]. So we decide to start the calculation for number of machines with consideration on A & B respectively first.

Production Schedule For Dashboard A & B Seperatedly



iii. Number of Machines

According to all the information given, we first calculate the machines need in the job shop departments for **only one type of dashboard**, which means all the number of the machines to satisfy the demand of both type of dashboard should be doubled.

Effective time per shift = 7.5*60*90% = 405 minutes/shift

Calculation on the # of machine for producing the components of **one type dashboard**:

	Scrap %	#/unit	# Demand /shift	Time Standard(min /press)	# products have to be produced / shift	(int)# products to be produced / shift	TT(min/unit)	# machine	(int)# machine
A0	0.08	1	500	3	500.4003203	501	0.808383234	3.711111	4
A1	1	1	501	1	506.0606061	507	0.798816568	1.251852	2
A2	2	1	507	2.4	517.3469388	518	0.781853282	3.06963	4
A3	0.15	4	2004	1.2	2007.010516	2008	0.201693227	5.94963	6
M1	2	1	518	2.4	528.5714286	529	0.765595463	3.134815	4
M2	2	1	518	2.4	528.5714286	529	0.765595463	3.134815	4
M3	1	1	507	0.92	512.1212121	513	0.789473684	1.165333	2
M4	0.2	2	1014	0.33	1016.032064	1017	1.592920354	0.103583	1
M5	0.15	12	24096	0.24	24132.1983	24133	0.201383997	0.099313	1
M5	0.15	8	16064	0.24	16088.1322	16089	0.201379825	0.148972	1
M6	0.15	6	12048	0.17	12066.09915	12067	0.201375653	0.140699	1
M7	0.15	4	8032	0.24	8044.066099	8045	0.201367309	0.297963	1
M8	0.15	2	1002	0.6	1003.505258	1004	0.806772908	0.371852	1
M8	0.15	1	501	0.6	501.7526289	502	1.613545817	0.371852	1

As it is shown in the table, without the turning up, some result of # machine are less than x.5. Out of the thought of reducing initial investment, we think about doing some little adjustments in the schedule of machines, making some of the machines work for both Dashboard A and B, in order to reduce total number of each machine needed.

We need to pay attention here that we decide to do no adjustment on the assembly workstations，because the investment on assembly workstation is quite low, also it does no good to the production. We believe that if we assemble the components for both types of dashboard, it will cause a mess on the assembly workstation and may lead to lower production efficiency.

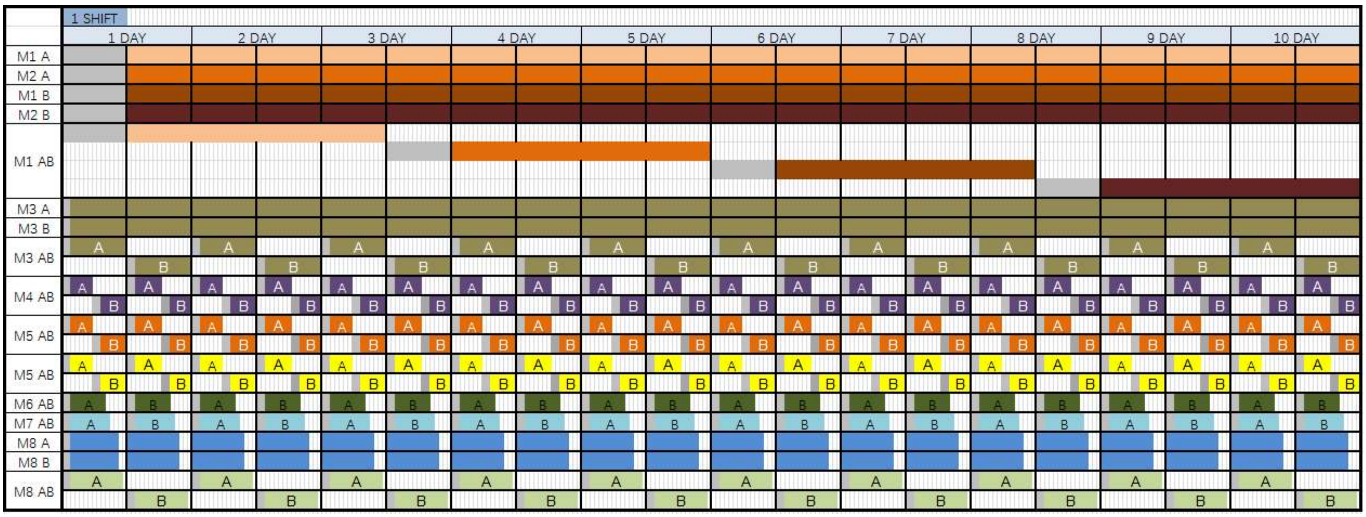
Based on the roughly calculated # of machines for one type of dashboard, we calculate again the number of the machine in an opposite way. We input the # of machine, working time per shift, # of units (# of items for the whole dashboard = 1 unit) each hour one machine can produce and all the other useful data, then calculate the annual production by all the machines. After that, we control the number of the machine or the production time in one shift to get the minimum working time and minimum number of the machine.

Calculation of # of machine by controlling the working time & the annual production

	Pressings /hour	#unit/ hour	#M	comment	#demand	Working hour/shift	eff. units /shift/M	eff. annual production	comment
M1	25	25	7	3A+3B+(1AB shared)	230000	7.5	157	230005	
M1 shared	25	25		1AB shared	230000	7.5	157		serving for (A,B; Body, Exterior cover)
M2	25	25	6	3A+3B+(1AB shared)	230000	7.5	157	230005	
M3	65	65	3	1A+1B	230000	7.5	427	230114	
				+1AB	230000	2.65	149		1 shift/type/day
M4	180	360	1	1AB	230000	3.15	1005	230130	0.5 shift/type/day
M5	250	250	2	1AB	230000	4.49	1005	230900	1 shift/type/day
M5	250	250		1AB	230000	4.49	1005	230900	1 shift/type/day
M6	350	350	1	1AB	230000	3.21	1006	231030	0.5 shift/type/day
M7	250	250	1	1AB	230000	4.49	1005	230145	1 shift/type/day
M8	100	100	3	1A+1B	230000	5.62	503	230374	
M8	100	200		1AB	230000	5.6	1005	230145	1 shift/type/day

Since the costs on M1 & M2 are the highest, and the setup time is 450mins=7.5 hrs, we want to reduce the number on M1 & M2 most. With the help of the machine schedule, we manage to do that by arranging a shared machine, serving for both Dashboard A & Dashboard B, producing both Body and Exterior Cover. (The press for M1 is 1200t, and 800t for M2, so we can use M1 also for producing exterior cover.)

Machine Schedule in first 10 days (later go on with the period of 10 days)



We plan machine schedule for M1 & M2 which satisfies strictly to the demand (annual production/type = 230,005). According to the minimum working time and the annual production of all the other machines, we learn that the annual production is mainly limited by M1 & M2. There is no denying that if we add more M1 or M2, the increase of annual production may cause the increase of both initial investment and revenue. However if we consider about the market demand, and in general the increase of supply may cause the decrease of selling price, we decide not to invest more on the machines and just keep the annual production = 230,005 and keep our project based on that.

The final number we decide for each machine is shown in the following table:

Machine	M1	M2	M3	M4	M5	M6	M7	M8	A0	A1	A2	A3
#	7	6	3	1	2	1	1	3	8	4	8	12

iv. Machine Layout

According to our layout decision, we focused on the flow of products between machines and assembly stations in order to have a rough dimensionless diagram of the final machine layout. We first apply the activity relationship analysis using the relative importance calculated according to weight and then we draw a dimensionless block diagram taking into account as a main priority the reduction of the distances associated with moved weights. At the end with adding dimensions to the departments and the extra spaces for maintenance (1m), workers (r=0.9m) and aisles (see 4.i) to have a rough layout.

In the table below there are the weights per item and per unit of product needed for the assembly of one finished product (for example we need 12 central fins for 1 dashboard). In the last two columns we calculate the relative importance from the raw material warehouse (using the gross weight) and the relative importance based on the net weight useful for all the others flow of materials.

Calculation Of The Relative Importance

				unit Weight/item		unit Weight/unit		Relat. importance	Relative importance
			#/unit	Gross	Net	Gross	Net	(fromRMW)	(Net weight)
A0	Dashboard Final Assembly		1			7427	6942		138,9
A1	Sub-Assembly 1		1			4937	4502		90,1
A2	Sub-Assembly 2		1			4620	4200		84
A3	Air Vent Assembly		4			2244	2200		44
M1	Body		1	2750	2500	2750	2500	55	50
M2	Ex. Cover		1	1870	1700	1870	1700	37,4	34
M3	G.Compartment		1	265	252	265	252	5,3	5,1
M4	G.Com.Bracket		2	26	25	52	50	1,1	1
M5	Fin(central)	left right	12	10,2	10	122,4	120	2,5	2,4
M5	Fin(side)	left right	8	10,2	10	81,6	80	1,7	1,6
M6	Shutter & Control Wheel		6	25,5	25	153	150	3,1	3
M7	Vent Frames (l&r)		4	51	50	204	200	4,1	4
M8	Inst. Frames (D & R)		2	82	80	164	160	3,3	3,2
M8	Inst. Frames (N)		1	82	80	82	80	1,7	1,6

Based on the relative importance we build the Weighted Activity Relationship Analysis where all the movements between warehouses, machines, and assembly stations are highlighted. We can notice that the more important flow of material is mostly in the assemblies and mainly where the main components (the ones produced by M1 and M2) are moved.

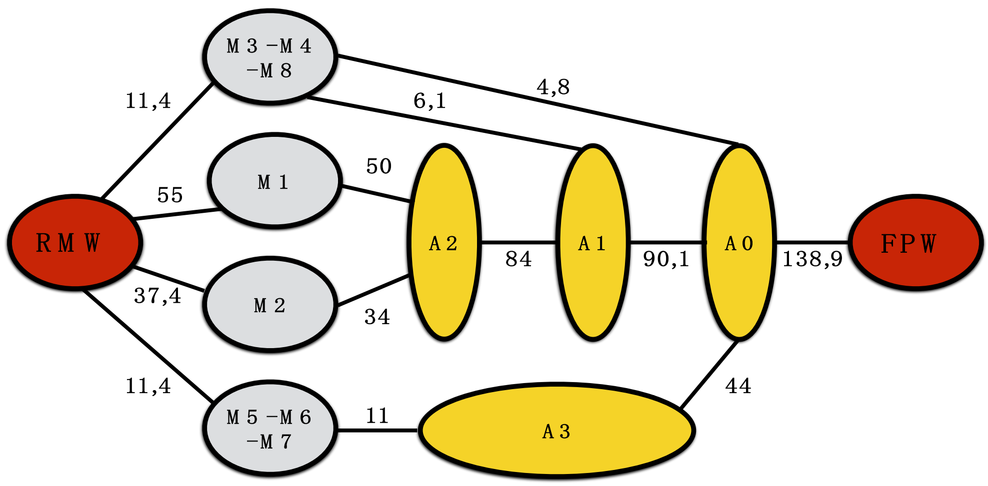
Weighted Activity Relationship Analysis

	FPW	M8	M7	M6	M5	M4	M3	M2	M1	A3	A2	A1	A0	RMW
RMW	0	5	4,1	3,1	4,2	1.1	5,3	37,4	55	0	0	0	0	114
A0	138,9	4,8	0	0	0	0	0	0	0	44	0	90,1	278	
A1	0	0	0	0	0	1	5,1	0	0	0	84	180		
A2	0	0	0	0	0	0	0	34	50	0	168			
A3	0	0	4	3	4	0	0	0	0	55				
M1	0	0	0	0	0	0	0	0	105					
M2	0	0	0	0	0	0	0	71,4						
M3	0	0	0	0	0	0	10,4							
M4	0	0	0	0	0	1								
M5	0	0	0	0	8,2									
M6	0	0	0	6,1										
M7	0	0	8,1											
M8	0	9,8												
FPW	138,9													

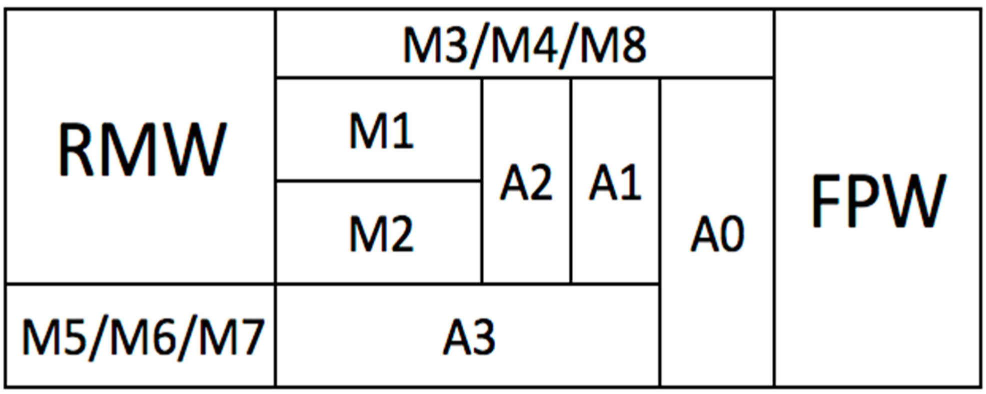
After the relationship analysis we finally draw a dimensionless diagram which points out the priority of the relationships between departments. Some presses have been put in the same department since the number of machines is very little and most of them, for example M5, M6 and M7, share the same flow of materials, to the Air vent Assembly (A3) as in the example. As said before, our aim is to reduce the transportation where the relative importance is higher and simplify as possible the total flow of material in production floor area.

After this relationship analysis about flows, we sketched a final dimensionless block layout that takes into consideration all the previously said requirements and that will be used later to determine the actual layout when all the elements (aisles, WIP, maintenance) will be added.

Dimensionless Block Diagram



Dimensionless Physical Floor Area Diagram



Although we have a job shop layout, which means each department contain one kind of machine, we manage to reduce the number of departments by combining some different kinds of machines into the same department, considering the number of these machine is low and their location in the layout is quite close.

List of Departments

Dept.	Machine	# of machine
D1	M1	7
D2	M2	6
D3	M3	7
	M4	
	M8	
D4	M5	4
	M6	
	M7	
D5	A3	12
D6	A0 A	10
	A1 A	
	A2 A	
D7	A0 B	10
	A1 B	
	A2 B	

3. Warehousing & Material Handling Equipment

i. Warehouse Storage Media & Layout

a. Raw Material Warehouse

To determine the most suitable design for the raw material storage warehouse we take into account the characteristics of our raw materials and all the parameters such as capacity, selectivity and queue processing techniques. We purchase from suppliers thermoplastic materials packed in octagonal–shaped carton box (Octabin). Each Octabin package contains 1,000kg of thermoplastic material and has the following dimensions: 1,000 x 1,200 x 1,500 (high) mm.

To calculate the maximum capacity of the warehouse we used the gross weight needed by each press during one day production multiplied for 10 days (as requested). Not all the presses use the same thermoplastic material. We have three different raw materials: High Density Polypropylene (HD PP); Acrylonitrile- butadiene-styrene (ABS); Polyamide (PA). In the tables below we find the grams needed by each press for 1 day production and the total number of raw materials unit load per each material and the total capacity of the RMW (C=122u.l.).

Weight of raw material needed for 1 day production

			#/unit	#M		Demand/day /machine	Demand/day	g/day	Material
M1	Body		1	6	3A+3B	336	2016	5544000	HD PP
				1	1AB	336	336	924000	
M2	Ex. Cover		1	6	3A+3B	336	2016	3769920	ABS
				1	1AB	336	336	628320	
M3	G.Compartment		1	2	1A+1B	876	1752	464280	ABS
				1	1AB	308	616	163240	
M4	G.Com.Bracket		2	1	1AB	2040	2040	53040	PA
M5	Fin(central)	left	12	1	1AB	2020	2020	20604	PA
		right							
M5	Fin(side)	left	8	1	1AB	2020	2020	20604	PA
		right							
M6	Shutter & Control		6	1	1AB	2022	2022	51561	PA
M7	Vent Frames (l&r)		4	1	1AB	2020	2020	103020	PA
M8	Inst. Frames (D & R)		2	2	1A+1B	1010	2020	165640	ABS
M8	Inst. Frames (N)		1	1	1AB	2016	2016	165312	

Total unit loads of raw material

Type of material	Total g/day	Total u.l./10d
HD PP	6468000	65
ABS	5356712	54
PA	248829	3
	TOTAL u.l.	122

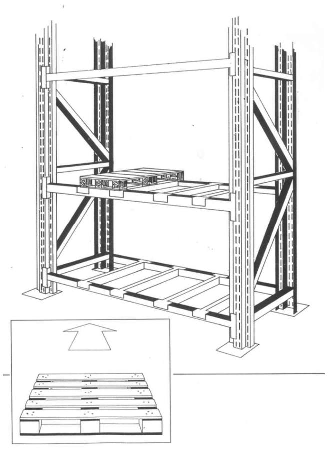
We have three different materials (3 product codes) and a total warehouse capacity of 122 unit loads. Since the constraint of the floor capacity is 2500kg/m^2 (neglecting the weight of the rack), the number of layers are limited.

According to the calculation:

$\#layers_{max}$=2500kg/m^2*$Area_{u.l.}$/$weight_{u.l.}$)=2500*1.2/1000=3

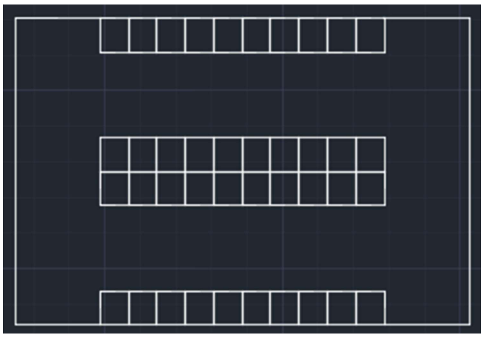
So we could not store more than 3 unit loads one over the other.

We decided to use traditional racks for the storage of the raw material in order to have selectivity = 1, no picking constraints, FIFO policy and also a lower costs compared to the other types of storage media. In the picture it's shown a three layers rack where unit loads over pallets are stored. Racks have horizontal support since u.l. are very heavy.



In order to have a quite regular RMW we rounded down the number of unit loads for HD PP and ABS since the number obtain is quite big, it's based on a 10 days production and comes up from a daily demand that has been already rounded up, so this change won't affect in any case the production.

Using this procedure we get 120 u.l./3 layers = 40 u.l per layer so we can have 4 rows with 10 u.l. each as in the picture below. In order to access every u.l. we put two aisles (3 m wide for forklifts). Two extra aisles are added at both ends in order to help movements in the RMW. We have a two-side rack in the middle and one-side rack on the two lateral sides. So the total dimensions of RMW are:



Horizontal length: 10*1m+2*3m=16m

Vertical length: 4*1.2m+2*3m=10.8m

Total Area= 10.8*16=172.8m^2

Utilization of storage space ratio:

R_S =S/TS[%]=40*1.2/172.8=27.8%

Utilization of cubic storage space ratio:

R_V=V/TV[%]=120*1.2*1.5/(172.8*4.5)=27.8%

Comment: The surface utilization is not so big due to aisles that we add to RMW in the top and bottom part than are not strictly necessary. The volume utilization is low due to the constraint of the floor capacity that didn't permit to store more than 3 u.l. one over the other.

b. Finished Product Warehouse

In the finished product warehouse, the unit loads which contain the finished dashboard are stored for 3 days before shipping. The unit loads used are large plastic bins that contain 4 complete dashboards each. Each bin is 61kg and has the following dimensions: 1,500 x 1,250 x 1,000 (high) mm. To calculate the capacity of the FPW we used the maximum number of finished dashboard produced in 3 days (maximum number since every day has a different number of dashboard produced due to the shared machine of M1 and M2).

Effective Finished Dashboards per day per type=1040

→ Based on our machine schedule)

Total #u.l.=1040*3days(as requested)*2types/(4dashboard/u.l.)=1560

For the FPW we want to ensure a FIFO policy even if dashboard are not perishable products, but our aim was to ensure an accurate picking regulation based on product codes. We first decided, for the previous reasons, drive-through racks to have a higher space utilization ratio but a problem occurred when u.l. had to be put on pallets since the measures of the u.l. are not compliant with pallets and drive-through racks sizes. So we decided to simplify our warehouse storage media into traditional racks. Traditional racks will ensure the highest selectivity but will also affect negatively the space utilization ratio.

The maximum number of layers is not constrained by floor capacity (since it would be equal to 49 layers) but due to the forklifts maximum lifting height and in order to have not a too high roof for the whole plant.

#layers=8/(1+0.15)=6.95=6

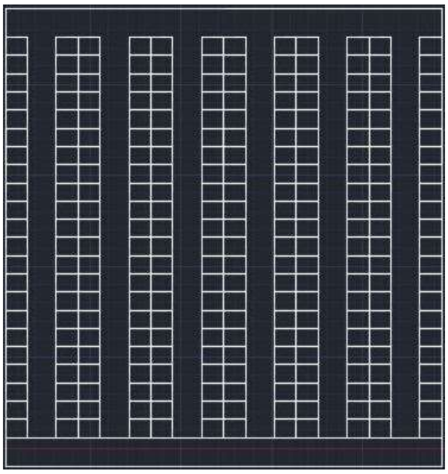
#u.l./layer=1560/6=260

In order to have a square shape we decide, as in the figure, to have 12 vertical rows composed of 22 u.l. each. In order to access every u.l. we put 6 aisles (2 m wide for forklifts). Two extra aisles are added at both ends in order to help movements in the FPW. As shown, we used two-side racks and one-side rack on the two lateral sides. So the total dimensions of FPW are:

Horizontal length: 12*1.5m+6*2m=30m

Vertical length: 22*1.25m+2*2m=31.5m

Total Area= 31.5*30=945m^2



Utilization of storage space ratio:

R_S = S/TS[%]

=260*1.25*1.5/945=51.6%

Utilization of cubic storage space ratio:

R_V = V/TV[%]

=1560*1.25*1.5/(945*8)=38.7%

Comment: The surface utilization is quite big since the FPW use smaller aisles compared to the RMW due to the size of the forklifts used. The volume utilization is also quite big since we use all the clearance below the roof.

As you can see in our final plant layout, the actual vertical length is 33.178m. This is an adjustment because of the pillars.

c. WIP Area

Because we arrange a shared machine (M1 shared) for producing both body and exterior cover for dashboard A & B, which also means we have a special timetable for the machines, a storage area for buffer is definitely needed. So we place a WIP area close to M1 & M2.

According to our timetable, we can see that each 10 days is a production period of M1 shared.

Production Schedule of M1 Shared In 1 Period (10 Days)

	1		2		3		4		5		6		7		8		9		10	
M1 shared		157	157	157	157		157	157	157	157		157	157	157	157		157	157	157	157

1shift

setup

Body A
Exterior Cover A

Body B
Exterior Cover B

**the number in the timetable means the effective piece one machine can produce in one shift.*

We can see from the excel that the in one period, the production duration for each is 4 shifts. Since with only Body, without the exterior cover, the sub-assembly 1 cannot begin, so

pieces waiting in process = 157*4 = 628 pieces

Once the exterior cover starts to be produced, sub-assembly 1 can begin and the buffer of body may be consumed. So the maximum time for the bodies waiting in process will be 4 shifts and the buffers can all be moved to the next process in another 4 shifts, we don't need a FIFO system, either a high selectivity. We use stacks directly in the WIP area to reduce the investment.

layer = 3 → maximum height = 3 m

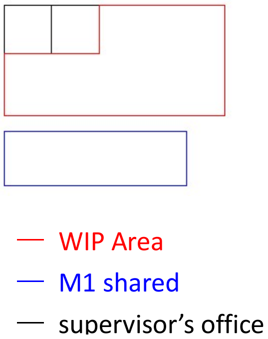
→a reasonable height for the electric pallet jack to get the u.l

u.l. = 628/6(#of bodies per u.l.) = 104.67 = 105 u.l.

u.l. per layer = 105/3 = 35 u.l./layer

min area for u.l. / layer = 1.5*1.25*35 = 65.625 m^2

According to the layout of machine, we are able to arrange a WIP area just next to M1 shared as the following picture.



Horizontal Length of [WIP area+supervisor's office *2] = 13.9m

Vertical Length of [WIP area+supervisor's office *2] = 7m

Area of WIP area = 13.9*7-3*3*2=79.3 m^2 > 65.625 m^2

So the area meets the request.

ii. Receiving Area & Shipping Area

a. Receiving Area

Next to the Raw Material Warehouse we have the receiving area needed for the incoming flow of raw materials. In particular we have the receiving docks for the incoming trucks, the space for forklift to unload the unit loads, for operators to open, inspect, count and report incoming materials and to move them in the RMW. Since not many raw materials are needed to be received each day, the receiving area will be also useful for trucks that bring back empty large plastic bins, that won't be store into the receiving area but into free spaces (e.g. close to M1 & M2) in the production floor area (just for a short time).

Since the incoming rate of trucks is quite small, one receiving dock will be enough for our plant.

For the calculation we have the following assumptions:

a. FEU is used by the supplier

Volume of trucks = 2.438*12.192*2.134m

b. Daily demand of incoming u.l. on average = 13,

c. One layer disposition into the FEU truck

(the raw materials are very heavy)

Based on all these assumptions, one receiving truck every day is enough:

Area of 13 u.l.=(1*1,2)m^2*13=15.6m^2< 29.7m^2=2.438*12.192=Area of 1FEU

The size of the receiving area will be calculated with the formula $S*Q*t_M$ assuming the quantity Q equal to 13 for incoming raw material and 30 for empty bins ((2.438*12.192)/(1.5*1.25)=15.85=15/layer) and the time t_M equal to an hour for raw materials and half an hour for empty bins. Since operations cannot occur at the same time the higher number will be selected (based on a single layer disposition). The calculated size of the receiving area will be compliant both for receiving empty bins or raw materials and to allow operators and forklifts movements.

Size of Receiving Area $=1.2*1.5*(Q*t_M)_{max}=1.8*30*1/2=27m^2$

Comments:

1. Trucks unload raw materials into the receiving area but they are attached to a portal (dock door) that is into a closed extension directly connected to the receiving area. The size of extension has been reduce and accurately sized in order to let the forklift move to the receiving area (See 5 ii.Final Layout).
2. In the layout the receiving area is smaller than the calculated data but there is the extension that is almost $19m^2$. So we have enonogh space to fit our demand.
3. Since it was not specified to apply an inventory management strategy and any raw materials shippment cost or ordering cost was not given, we preferred to have one daily truck every day (not completely full) in order not to create a bottleneck in the receiving area, due to the high rate of incoming trucks with empty unit loads, and also to minimize the unloading time of the raw materials in order to let the forklift free for other usages.

b. Shipping Area

For the FPW, the shipping area will be needed mainly for loading trailers (bills of lading). We have to determine the number of shipping docks and the needed size of the shipping area. To determine the number of shipping docks we need to know how many shipping trucks are needed based on our daily production. As mentioned in the *3.i.b FPW*, we produce 1040 finished dashboards/day/type so we ship every day 1040*2=2080 dashboards that it's equal to 2080/4=520 u.l..

#shipping trucks = Volume of total u.l. / Volume of 1 FEU

= 520*(1.5*1.25*1 m)/ (2.438*12.192*2.134m)

= 15.37 trucks = 16 trucks

However, we don't think this calculation is accurate because considering the unit loads are solid, the number of u.l. can be loaded in 1 FEU is also limited by the dimension.

Since every FEU truck can store up to 28u.l. (calculated in *3.ii.a. Receiving Area*),

# of trucks = 520 u.l. to be shipped per day/28u.l. per truck

=18.57 = 19 trucks / day

Assume: loading time is equal to 45minutes/truck

daily working hours = 7.5 h per shift * 2 shift = 15.

# of trucks each shipping dock can receive everyday

= (15(h)*60min)/(45min/truck) = 20 trucks > 19 trucks

→Just one shipping dock will be enough.

There is not a direct formula to size the shipping area, but it should be big enough to move boxes with a forklift and allow operators movements.

Size of Shipping Area = 39.4m^2

Comments: Forklift load unit loads into trucks from the FPW to the shipping dock passing through the shipping area (an outside closed extension directly connected to the FPW calculated above).

iii. Unit Loads

Our calculation aims to minimize the number of unit loads and at the same time simplify and increase the efficiency of the material flow.

For movements in the production floor area we calculate the number of unit loads using data from the layout such as distances between two departments, the time standard and the number of items in a single unit load. Based on that we plan to use 2 unit loads for each machine or assembly station in order to have, also when a unit load is moving from one department to another, always another close to the machine to be filled. Moreover is required to take into account enough unit loads, needed for finished products, since 3 days will be stored into the FPW and 2 days is the time in which are out of the plant. In fact finished products are shipped into unit loads that will return back after 2 days from the same shipping trucks.

Since the daily production is not constant we consider the max for safety.

units produced per day per type = 1052 finished dashboard/day

of large plastic bins for FPW and the 2 days outside the plant with the truck

= 1520 *2 types /4 units each bin *5 days

= 2630 bins

Calculation On The Unit Loads And Material Handling Equipment

<table>
<tr><th>name</th><th>kind</th><th>units</th><th>weight
[kg]</th><th>time standard</th><th>scrab rate</th><th>time 4 fill
[minuts]</th><th>#machines</th><th>#unit loads</th><th>#worker</th></tr>
<tr><td>body</td><td>large bin</td><td>6</td><td>55</td><td>2,4</td><td>2,00%</td><td>14,4</td><td rowspan="2">2 el jack</td><td rowspan="2">24</td><td rowspan="2">1 normal</td></tr>
<tr><td>ex corver</td><td>large bin</td><td>6</td><td>50,2</td><td>2,4</td><td>2,00%</td><td>14,4</td></tr>
<tr><td>sub assembly 2</td><td>large bin</td><td>6</td><td>65,2</td><td>2,4</td><td>2,00%</td><td>14,4</td><td rowspan="3">1 el jack</td><td>16</td><td rowspan="3">1 normal</td></tr>
<tr><td>g.comp.bracket</td><td>large odette</td><td>100</td><td>3,2</td><td>0,33</td><td>0,20%</td><td>33</td><td>2</td></tr>
<tr><td>g.compartment</td><td>small bin</td><td>100</td><td>50</td><td>0,92</td><td>1,00%</td><td>92</td><td>6</td></tr>
<tr><td>sub assembly 1</td><td>large bin</td><td>4</td><td>58,008</td><td>1</td><td>1,00%</td><td>4</td><td>1 el jack</td><td>8</td><td>1 normal</td></tr>
<tr><td>display frame</td><td>large odette</td><td>30</td><td>3,1</td><td>0,6</td><td>0,15%</td><td>18</td><td rowspan="5">1 hand jack</td><td rowspan="3">10</td><td rowspan="5">1 normal</td></tr>
<tr><td>radio frame</td><td>large odette</td><td>30</td><td>3,1</td><td>0,6</td><td>0,15%</td><td>18</td></tr>
<tr><td>navigator frame</td><td>large odette</td><td>30</td><td>3,1</td><td>0,6</td><td>0,15%</td><td>9</td></tr>
<tr><td>central air vent assembly</td><td>large odette</td><td>38</td><td>5,83</td><td>1,2</td><td>0,15%</td><td>45,6</td><td rowspan="2">24</td></tr>
<tr><td>side air vent assembly</td><td>large odette</td><td>37</td><td>5,88</td><td>1,2</td><td>0,15%</td><td>45,6</td></tr>
<tr><td>vent frame</td><td>large odette</td><td>50</td><td>3,2</td><td>0,24</td><td>0,15%</td><td>12</td><td rowspan="5">conveyor</td><td>8</td><td rowspan="5">0</td></tr>
<tr><td>fin (side)</td><td>small odette</td><td>133</td><td>1,53</td><td>0,24</td><td>0,15%</td><td>7,98</td><td rowspan="2">8</td></tr>
<tr><td>fin(central)</td><td>small odette</td><td>133</td><td>1,53</td><td>0,24</td><td>0,15%</td><td>5,32</td></tr>
<tr><td>shutter</td><td>small odette</td><td>53</td><td>1,525</td><td>0,17</td><td>0,15%</td><td>9,01</td><td>8</td></tr>
<tr><td>control wheel</td><td>small odette</td><td>53</td><td>1,525</td><td>0,17</td><td>0,15%</td><td>9,01</td><td>4</td></tr>
<tr><td>final assembly</td><td>large bin</td><td>4</td><td>61,168</td><td>3</td><td>0,08%</td><td>12</td><td>forklift</td><td>16</td><td>1 driver</td></tr>
</table>

*the MHE will be explained in the *3.iv.*

Total Number Of All Kinds Of Unit Loads And Material Handling Equipment

	ODETTE		BIN	
size	LARGE	SMALL	LARGE	SMALL
number	44	20	2904	6
cost	1.408,0 €	200,0 €	232.320,0 €	360,0 €

iv. Material Handling Equipment

Using almost the same data that for chose the number of unit loads as distance to travel, time standard of machines, number of items inside a unit load, from the point of view of the material handling equipment we've divided the factory into 8 sectors:

a. Pallet Jack

1) M1 & M2

About each 14 minutes we have to move 13 large bins of weight up to 55 kg and for be sure that we can perform the movement we've dedicated **2 electric pallet jack** just for M1 & M2, if the utilization index of the pallet jack is too low we can use them for order the empty boxes that come back from the shipment.

2) A2 & M3 & M4

On the up side of the layout we have the D3(M3 & M4), here we're less tight with the time than in group 1 but since the glove compartment bracket is even heavier than the body, and we have to dedicate **1 electric pallet jack**.

3) A1

We have dedicated a group just for D1 even if is composed just by 4 machines because grout 4 large plastic bins of 58 kg each 4 minutes. Here we have a tight schedule of quite heavy bins that drive us to use electric pallet jack. Since the distance to trail and the number of machines are relatively small, **1 electric pallet jack** is enough.

4) M8 & A3

At the very beginning we planned M8 & A3 as 2 divided groups and the movements was driven by hand of worker since the odettes are really light, but for the wellness of our worker and for reduce the traffic insight the factory we've decided to invest €2000 more for **1 hand pallet jack** and move the odette boxes in groups.

From the economic point of view is not a disadvantageous choice because in this way we need a worker less.

In this case, for move all the frames in group I consider 4 large odette dedicated to navigator frame, it's time for fill is the half of the other two frames so for move together requires the double of the odette.

Since for the frames we have to move each 18 minutes 4 odette of 3 kg and for the air vent assembly each 46 minutes 6 odette of 6 kg, the strategy is: 3 movements of frames for each of air vent assembly.

5) M5 & M6 & M7

This group is fed using a monorail overhead conveyor. The chain-driven trolley carries the unit loads coming from the air vent department that are loaded on the left side and unloaded, as needed, by operators in each air vent assembly. After the assembly process, empty and full unit loads are loaded again in the conveyor and unloaded where necessary (on the right part for full u.l. and in the left part for the empty ones in order to be filled again. The **monorail overhead conveyor** is sized high to perform load and unload by humans operators in assemblies.

In total, we need **4 electric pallet jack + 1 hand pallet jack**.

Total MHE We Applied In Our Plant

	electric pallet jack	hand pallet jack	forklift
number	4	1	3
cost	23.600,0 €	2.000,0 €	96.750,0 €

b. Forklift

Characteristics for Forklift (from Slide-Lesson 5)

Q	Capacity	kg	600	1.000	1.600	2.000	2.500	3.000
P	Weight	kg	1.500	2.500	3.000	4.000	4.500	4.900
I	Lenght of truck, w/o forks	mm	1.300	1.800	1.900	2.000	2.200	2.400
L	Total lenght of truck	mm	2.100	2.800	3.000	3.000	3.200	3.400
m	Distance b/w forks and front wheels	mm	220	330	350	440	440	440
p	Wheel base	mm	860	1.100	1.500	1.530	1.530	1.600
H	Max lift	mm	3.600	3.300	3.300	3.300	3.300	3.300
R	Min radius of curvature	mm	1100/1500 (3)	1400/1700 (3)	1500/1900 (3)	1.900 (4)	1.950 (4)	2.100 (4)
W	Minimum aisle width	mm	1800/2300 (3)	2900/3100 (3)	3.500 (4)	3.500 (4)	3.600 (4)	3.700 (4)
	Max speed loaded/unloaded -Movement	m/s	3/3,2	3/3,2	4,1/4,4	4,1/4,4	4,1/4,4	3,9/4,4
	- Lifting	m/s	0,3/0,45	0,3/0,45	0,4/0,55	0,4/0,55	0,45/,06	0,44/0,6

For some heavy unit loads, forklift is a better choice because its capacity is bigger and it moves faster. Besides, in the warehouses we need to pick up the boxes from high layers, which requires a forklift.

1) **For Raw Material Warehouse**

Considering the unloading of one (not full) truck every day and the unloading of empty unit loads (just unloading since the u.l are moved by an electric pallet jack) , the most time-consuming department is the one of M2 (with relatively longer distance than M1 department, most machines and heavy component): 1.87kg (let's roundup to 2 kg of net raw material). 1000kg of raw material in one silo, that's 500 presses, in one shift we produce 471 bodies, so very 8 hours we need to fill these silos. To fill one silo, it takes 40.95(distance)*2/1.5(average speed) =54.6 seconds. For 7 silos in this department, it takes only about 6.5 min.

So, we use **1 forklift with lifting height<3m**.

2) **For Final Product to Warehouse**

We use 2 forklifts in FPW and between FPW & A0: 1 for between A0 to FPW and 1 inside FPW to the shipping docks.

Then we need to give the verification that 1 forklift for all the eight final assembly stations is enough.

Here two assumptions are important: the average length to tread and the average speed of the forklift.

Since we must reach all the edge of the warehouse we've considered the distance between the entry port and the center as the average distance of warehouse, that is 20 meters and the average distance between the entrance and the final assembly station is 25, so in total 45 meters.

The average speed for the forklift, according with the theory is the half of the max： Speed of the forklift = 1 m/s.

To verify that one is enough:

45*2(round trip)*8(machines)/1(velocity) = 720 s =12 min

12 minutes is the time required by the forklift for move all the bins once and is the same for produce a new set of boxes (for safety we've underestimated the average velocity of the forklift and overestimated the average distance to tread) that means that the assumption of 1 forklift is verified.

3) **For shipping:**

average speed considering lifting = 1m/s * 3600s = 3600 m/h

→ considering lifting

# of forklift = 584u.l.*(15m*2 / 3600m/h) /7.5(hours/shift)

= 0.65 forklift = 1 forklift

So we use **1 forklift with lifting height 6m**.

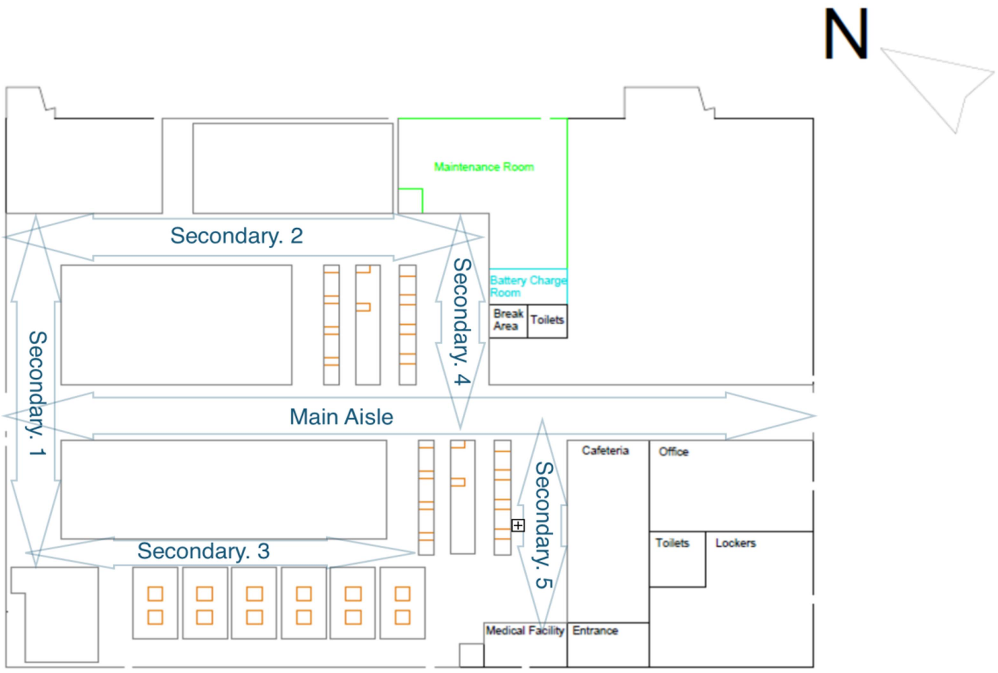
In total, we need **1 forklift with lifting height<3m** and **2 forklifts with 6m**.

4. Plant Support Functions

i. Aisles

a. Main & Secondary Aisles

Main & Secondary Aisles' Scheme



With the largest amount of transporting duties within the plant layout, most of them are equipped with the forklift aisles (3m) (the most wide kind of aisle in the layout) for serving the silos from RMW, and the maintenance of press machines.

1) **Main aisle**

7.2m = Double-way forklift (2*3m) + double-way pedestrians (2*0.6m)

Going through the whole plant layout with 5m-wide industrial doors on the both ends.

2) **Secondary 1**

6.6m = Double-way forklift (2*3m) + one-way pedestrian (1*0.6m)

3) **Secondary 2**

6.6m = One-way forklift (1*3m) + double-way trans-pallets (2*1.2m) + double-way pedestrians (2*0.6m)

4) **Secondary 3**

3.6m = Double-way trans-pallets (2*1.2m) + double-way pedestrians (2*0.6m)

5) **Secondary 4:**

6.6m = One-way forklift (1*3m)

+ double-way trans-pallets (2*1.2m)

+ double-way pedestrians (2*0.6m)

With actual width 8.6m, because of the design of other correlated parts (area of battery-charge-room & break area & toilets, FPW boundary position to suit in the pillar-rows, etc.), and the remained area would be shared to Final-assembly stations to store some empty unit loads;

Forklift aisle (3m) shared also to narrow-aisle forklifts (2m).

6) **Secondary. 5:**

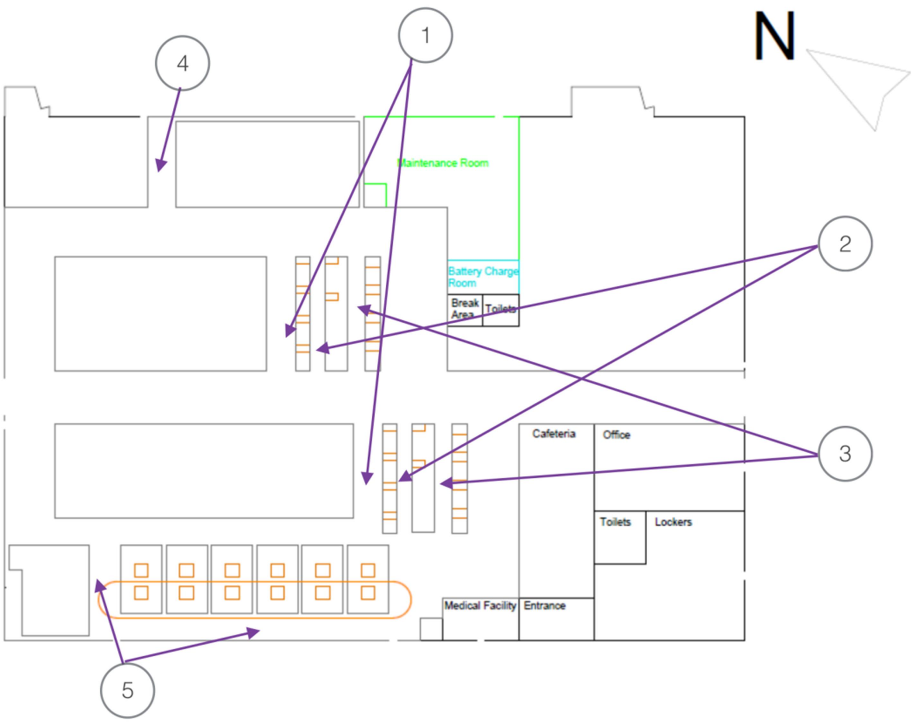
4.4m = Double-way narrow-aisle forklift (2*2m)

+ double-way trans-pallets (2*1.2m)

With actual width 6.83m, also because of the design of other correlated parts (boundaries of the beside employee facilities areas beside to suit in the pillar-rows)

b. Other assistant aisles

Other Aisles' Scheme



1) **Assistant Aisle 1**

3.9m = One-way trans-pallets (1*1.2m)

+ double-way pedestrians (2*0.6m)

+ space for empty unit load boxes of A2 (1.5m)

*we've performed calculation and sketching to ensure the space is enough

2) **Assistant Aisle 2**

2m → serving for horizontal transporting of u.l. between A2 & A1

& the area shared by A2 & A1 for empty assembly u.l. boxes storage

3) **Assistant Aisle 3**

3.5m = double-way pedestrians (2*0.6m)

+ aisle-space of A1 (0.8m)

+ aisle space for unit load boxes storage of A0 (1.5m)

4) **Assistant Aisle 4**

3.6m = One-way forklift (1*3m) + one-way pedestrian (1*0.6m)

5) **Assistant Aisle 5**

Both wide enough for one-way pedestrian (0.6m), and some extra-precautionary spaces for overhead conveyors load/unload.

6) **All the other aisle not signed in the graph**

Many small one-way pedestrian aisles (0.6m), usually occurring in the surrounding area of the plant layout, and also between assembly stations, which guarantee a sufficient space for all the employees to travel around without problems.

ii. Number Of Personnel

Based on the calculation of the number of machine, we can get first the number of workers operating the pressings. We need to underline that M1, M2, M3, M4 are manual-fed press which need 1 worker for each machine, and M5, M6, M7, M8 are presses assisted by automated material handling systems which 1 worker can take charge of 3 machines.

When it comes to the supervisors, we decide the number based on the number of departments.

Number of workers & supervisors

			# Machine	sum. # Machine	# worker	# supervisor
Machine	manual	M1	7	17	17	1
		M2	6			1
		M3	3			1
		M4	1			
	auto. MHS	M8	3	7	3	
		M5	2			1
		M6	1			
		M7	1			
Assembly Table		A0	8	20	20	2
		A1	4			
		A2	8			
		A3	12	12	36	1
storage		RMW	/			1
		FPW				1
TOT Workers/shift					76	9
TOT workers					152	18

For the drivers, we do the calculation on the fundamental of the number of material handling equipment decided.

Number of Drivers

		# MHE	# driver
Drivers	Hand pallet jack	1	1
	Electirc pallet jack	4	4
	forklift	3	3
TOT drivers/shift			8
TOT drivers			16

As is given in the instruction, office and auxiliary staff = 30% total number of direct employees (underlined in blue), so we calculate the staff on base of the number of workers and drivers.

Number of Staff & Total Employees

TOT DL	workers	152	168
	drivers	16	
TOT Supervisor		18	18
TOT Staff		=30% DL	51
TOT Employees			237

Comment: Since there are 2 shifts per day, and 1 shift is 7.5 hours, 1 worker or 1 driver or 1 supervisor can only work for 1 shift per day, which means the total number for worker, driver and supervisor(underlined in red) should be doubled from the figure per shift (underlined in green).

iii. Indoor Support Function Areas' List

Based on the given data and on the number of employees we calculated all the indoor support function and their position in the production floor area. Below there are the minimum required floor area for each support function and how they were calculated.

Office Spaces = 51staff workers*4.5m^2 (chair+desk+surr.area) = 229,5m^2

Lockers room = 1.6m^2*(Direct workers+supervisors)=1.6*186=297.6m^2

Restrooms and Toilets = 0.25m^2*#employee$_{TOT}$ = 0.25*237=59.25m^2

Cafeteria and lunchroom = 1.6m^2*(Direct workers+superv.+staff)$_{\text{ONE SHIFT}}$

= 1.6*144=230.4m^2

Break Area = 20m^2 @

Supervisors offices = 3m*3m (size of 1 office/person) * #supervisors

= 9m^2*9=81m^2

Tool/mold and maintenance room = 300m^2 @

Battery charging spaces = #(forklifts+elect. pallet jacks) * 7m^2=6*7=42m^2

Entrance = 50m^2 @

Medical facility = 50m^2

@: given data

Comment:

1. The size of the medical facility has been enlarged from the given data in the assignment since we thought that 20m^2 was not enough in order to ensure our employees the right safety and health measures. The data of 50m^2 was taken from the lectures.

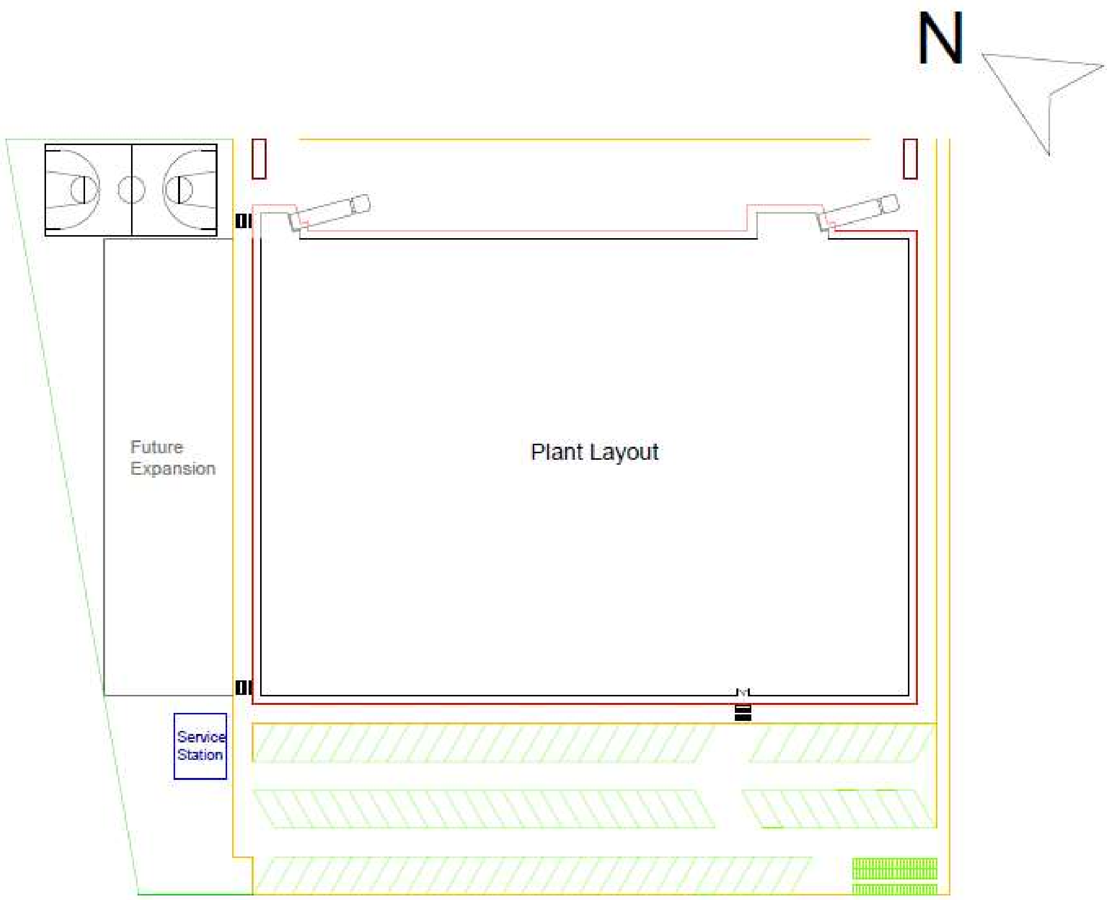
2. Toilets have been split into two parts: one is located in the support functions area close to offices and lockers while another one in the production floor area is placed next to the break area. Since "Restrooms and Toilets" has been split into two parts,

an extra 15% of the previously calculated area has been added to the final total floor area.

3. The assumption for the data of the battery charging space has been made in order to even store a forklift inside if needed. Battery charging room is placed in that particular position to be as close as possible to the maximum forklifts' flux point and in order to be reached easily and from anywhere in the plant through aisles such as for the maintenance room.

iv. Outdoor Areas

Final Outdoor Layout



As can been seen from the drawing, our receiving area and shipping area are outside and are on the north of the plant. For the trucks loading and unloading goods, we also need a 14-meter-wide driveway.

The industrial building is surrounded by a 1.2-meters-wide walkway (at the same level of driveway in order to let truck share the area if needed). A 3-meter-wide (according to the note taken in class) one-way driveway is placed around the plant main building (on three sides) for private cars. The entrance for employees is set on the south, which is why the parking place is put here. In total we have 91 parking lots, 74 for employees, 15 for visitors and 2 for the disabled. The 17 parking lots (for visitors and disabled) are located in the east part, to separate from those for workers more obviously, and are also closer to the entrance. We apply the rhomboid size to save the total space (specifically illustrated in the next paragraph). Cars come into the parking area through the western path and leave from the eastern path. The latter is right opposite to the entrance so the workers can enter the building through this path. Additionally, we have a two-way bikeway (in the very east of plant) and bike-parking lots for employees who come to work by bike.

Dimensional elements of possible parking layouts – *from the Internet*

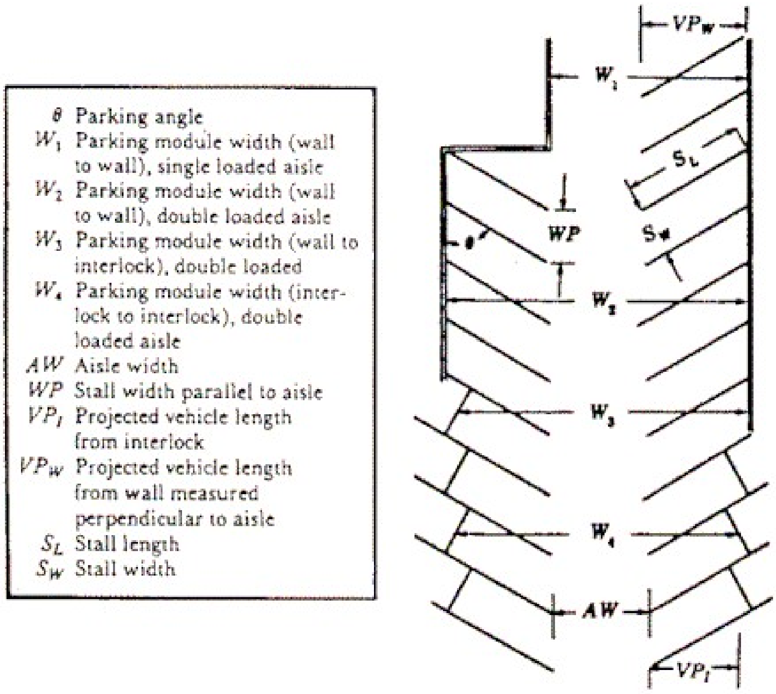


Table - Calculated Parking Dimensions

(Base on Ricker Formula) *– from the Internet*

Parking Angle and Projected Vehicle Length		*Stall Widths*		*Aisle Widths*	*Module Widths*				*Clearances*	
		Sw	*WP*	*AW*	W_1	W_2	W_3	W_4	*c*	*i*
Large-car Design Vehicle (77" by 215")										
90°	VP_w = 18.42' VP_i = 18.42'	8'6"	8.50'	24.04'	42.46'	60.88'	60.88'	60.88'	1.5'	2.0'
75°	VP_w = 19.45' VP_i = 18.62'	8'6"	8.80'	21.17'	40.62'	60.07'	59.24'	58.41'	1.5'	2.0'
60°	VP_w = 19.16' VP_i = 17.55'	8'6"	9.82'	14.09'	33.25'	52.41'	50.80'	49.19'	1.5'	2.0'
45°	VP_w = 17.21' VP_i = 14.94'	8'6"	12.02'	11.0'	28.21'	45.42'	43.15'	40.88'	1.5'	2.0'
Small-car Design Vehichle (66" by 175")ª										
90°	VP_w = 15.08' VP_i = 15.08'	7'6"	7.50'	22.27'	37.35'	52.43'	52.43'	52.43'	1.5'	2.0'
75°	VP_w = 15.99' VP_i = 15.28'	7'6"	7.76'	20.14'	36.13'	52.12'	51.41'	50.70'	1.5'	2.0'
60°	VP_w = 15.38' VP_i = 14.00'	7'6"	8.66'	13.9'	29.28'	44.66'	43.28'	41.90'	1.5'	2.0'
45°	VP_w = 14.20' VP_i = 12.26'	7'6"	10.61'	10.0'	24.20'	38.40'	36.46'	34.52'	1.5'	2.0'

a. Small car spaces normally are considered only for 90-degrees layouts.

Note: See Figure 8.4 for definition of terms.

**the unit used in the table is feet*

We searched online for the standard dimensional elements for parking layout, based on which we design our parking lots. It is shown that for perpendicular parking lot, the aisle width (turning space) is better 6.8m (not 5m). However, the 60° one we apply only needs 4.3m, saving 2.7m for each aisle compared with standard 90°one. Although space for a parking space is a bit larger, the whole area is still smaller and still larger than the 1/3 of roof covered area.

On the west, we have green area for future expansion. For the reason that our plant is designed to be at the corner of the given land, it is a trapezoid to coincide with the shape (since we thought the seller won't permit us to buy a perfect square area). We extend the length of the plant by 20% to get the size of green area.

The service station is put in the south of this area to make it as close as possible to the entrance of building and not disturb the future development. We also have decided to build a basketball court into the green area because our company cares about team-building and having a sports field does good to our employees.

As to the entrances and exits of the plant, two are designed for cars and trucks separately. Vehicles come in from the west and leave from the east. Bicycle has its own entrance and lane. Two guardrooms (2m*6m) are also designed.

The total area for the plant is 15213.094 m^2, its 70% is larger than industrial building and so meets the demand on the assignment. The location of the plant is shown in the following picture. It is adjacent to the road in the north and keeps a certain distance from Via Pavia because some building are beside this road.

The Location Of The Plant

5. Industrial Building

i. Structural Frame Material

The location, the land of the plant is already given in the assignment. The facility will be constructed in Rivoli, Torino, Italy, Allamano Road, near to the main city ring road. It is clear that we have a large scale of land available, so we decide to build a single-storey building. The decision is also out of the following consideration: 2 types of dashboards need to be produced to meet the demand; job shop is our decided layout; the raw material for all the machines are the same; we need a fluent material flow in the plant and it is quite impossible to transport raw material to the multi-storey.

We want to make our plant in a regular shape, and there is still enough space for all the indoor support function areas inside the plant besides the machines, therefore we plan no mezzanine.

For the structure frame material, we choose precast concrete because it has a better corrosion resistance, a good thermal capacity and high fire resistance. Considering that raw material need to be dried in the drying silos, and it is injected into the mold under the molten phase, a high temperature needs to be kept. In conclusion, constructing the structure precast concrete seems to be a sensible choice.

ii. Pillars

Basing on the choice of structural frame (precast concrete) and to suit as much as possible the plant layout, we chose a 0.5m*0.5m pillar, with distances of 34m(horizontal) * 12m(vertical).

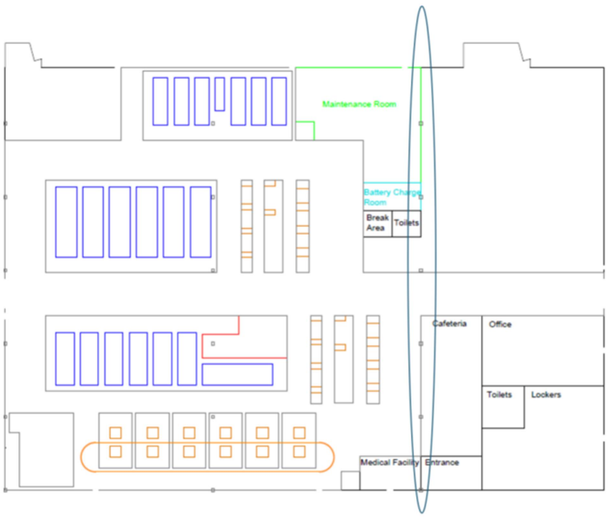
Positioning Strategy

Pillar Matrix Part1

The matrix of pillars are located basing on the two reference layout boundaries (circled out in the above figure), and they are positioned with distance mentioned previously. On these two reference boundaries the pillars are set half inside the layout and half inside the enclosing walls.

Some pillars are sharing the '1m-maintenance area' of the press machines, but since the dimension of the pillar is very small compared to the other elements in the plant layout, we suppose the influence of these interferences in the maintenance area are limited enough to be ignored.

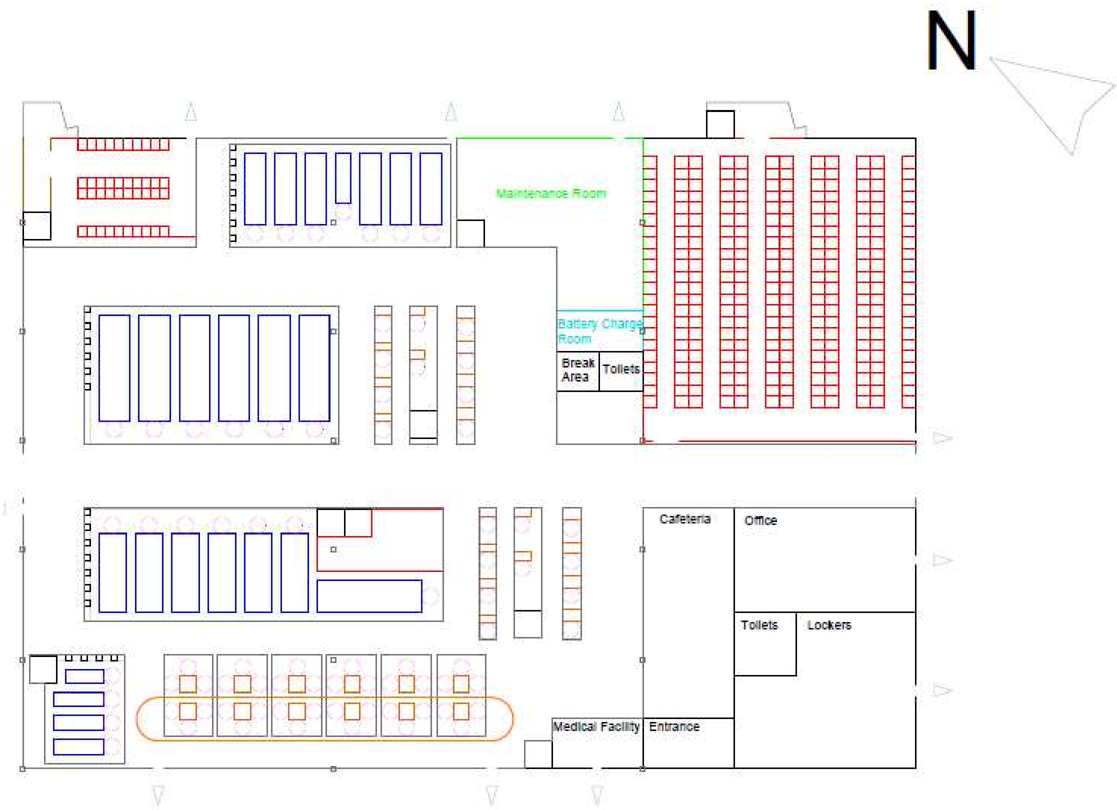
Pillar Matrix Part 2



The circled-out column of pillars are positioned separating different layout regions (partly inside the internal walls). However since we don't have the knowledge to calculate the thickness of the enclosing & internal walls (also the fact that the pillar-size is small), for the sake of simplicity we ignore the internal wall thickness.

iii. Final Layout

Final Layout of Indoors Plant Facilities



Some further explanation of the plant layout

Protection Grids:

Used for every department of the press machines (please refer to the 'Protection Grids' layer in the file 'Plant Layout.pdf'), with a standard 1m-distance to the machines, while in the cases where operators are involved, the distance would become 0.6m to ensure a sufficient walk-way.

Internal Wall:

Used in 'Employee Services' (toilets, entrances, cafeteria,etc.), warehouses, and some other production support facilities (maintenance room, battery-charge room,etc.). Among them only the internal wall of FPW is defined as 8m in height (due to the calculation of stack level), while internal walls for all the other facilities are calculated as 4.5m high (since this height serves all their functions pretty well).

Doors:

In the plant layout, for the sake of simplicity, all the normal doors (doors apart from industrial doors & emergency exit doors, used mainly for employee facilities) are not taken into account, since this kind of doors are not in the course content and at the mean time to predict their cost is also difficult (extra data would be needed). There are in total 7 industrial doors: two 5m-wide-type at both the ends of the main aisle; one 3m-wide-type respectively for RMW, FPW, receiving area, shipping area, and maintenance room.

Additionally 10 emergency exit doors are set within the plant layout (shown in the 'Plant Layout.pdf' with a 1.2m-wide blank on the layout boundary together with a green arrow for each one of them). They are set up according to the safety-risk level of each area (for example we assume those areas with 'large amount of press machines' or a 'high population density' are those with the higher safety-risk levels). For the 'medical facility' area we believe a special type of door should be positioned to allow I&O of some first-aid equipments (such as 'stretchers'), and in order to simplify the cost analysis we assume an emergency exit door is used also in this case.

6. Economics Evaluation

i. Final Financial Report

COST				
	unit cost	#	Cost	comment
Machine				
M1	€ 1,350,000.00	7	€ 9,450,000.00	
M2	€ 1,130,000.00	6	€ 6,780,000.00	
M3	€ 570,000.00	3	€ 1,710,000.00	
M4	€ 310,000.00	1	€ 310,000.00	
M5	€ 310,000.00	2	€ 620,000.00	
M6	€ 160,000.00	1	€ 160,000.00	
M7	€ 310,000.00	1	€ 310,000.00	
M8	€ 570,000.00	3	€ 1,710,000.00	
A0	€ 7,000.00	8	€ 56,000.00	
A1	€ 8,000.00	4	€ 32,000.00	
A2	€ 8,000.00	8	€ 64,000.00	
A3	€ 10,000.00	12	€ 120,000.00	
TOT Cost of Machines			€ 21,322,000.00	CC
land cost	€ 300.00	15213.094	€ 4,563,928.19	CC
BasketBall Field	€ 28,000.00	1	€ 28,000.00	CC
Building				
Industrial Building - Precast Concrete	€ 850.00	6838.3958	€ 5,812,636.43	
Building System	€ 330.00	6838.3958	€ 2,256,670.61	
TOT of Building Cost			€ 8,069,307.04	CC
Material Handling Equipment				
Electric Pallet Jack	€ 5,900.00	4	€ 23,600.00	
Hand Pallet Jack	€ 2,000.00	1	€ 2,000.00	
Forklifts -	€ 24,150.00	1	€ 24,150.00	
Forklifts -	€ 32,250.00	2	€ 64,500.00	
Conveyors	€ 900.00	88.272	€ 79,444.80	*Overhead mono-rail
TOT Cost of MHE			€ 193,694.80	CC
unit loads				
large plastic bin	€ 80.00	2904	€ 232,320.00	
small plastic bin	€ 60.00	6	€ 360.00	
large Odette box	€ 32.00	44	€ 1,408.00	
small Odette box	€ 10.00	20	€ 200.00	
TOT Cost of Unit Loads			€ 234,288.00	CC

(To be continue in next page)

warhouse				
Racks RMW	€ 135.00	144	€ 19,440.00	*traditional racks
Racks FPW	€ 135.00	2970	€ 400,950.00	*traditional racks
Receiving	€ 3,300.00	1	€ 3,300.00	
Shipping dock	€ 3,300.00	1	€ 3,300.00	
TOT Cost of Warhouse			€ 407,550.00	CC
Doors & Protection Grid				
Industrial Door	€ 13,000.00	7	€ 91,000.00	
Emergency Exit Door	€ 820.00	10	€ 8,200.00	
Internal Wall	€ 190.00	1547.11	€ 293,950.90	
Protection Grid	€ 90.00	313.56	€ 28,220.40	
TOT Cost of Doors & Protection Grid			€ 421,371.30	CC
Operation Costs- per year				
DM	€ 1,900.00	2551	€ 4,846,900.00	VC
DL+O/H	€ 53.24	264344	€ 14,073,674.56	VC
Maintenance of auxiliary services and office spaces	/	/	€ 116,252.73	FC *=Industrial Building * 2%
Selling & administrativ	€ 1,000,000.00	1	€ 1,000,000.00	FC
TOT Cost of Operation Cost			€ 20,036,827.29	FC+VC
TOTAL COST				
TOTAL Construction Cost (CC)			€ 35,240,139.33	
TOTAL Varied Cost (VC)			€ 18,920,574.56	
TOTAL Fixed Cost (FC)			€ 1,116,252.73	
REVENUE				
revenue	€ 85.00	460010	€ 39,100,850.00	

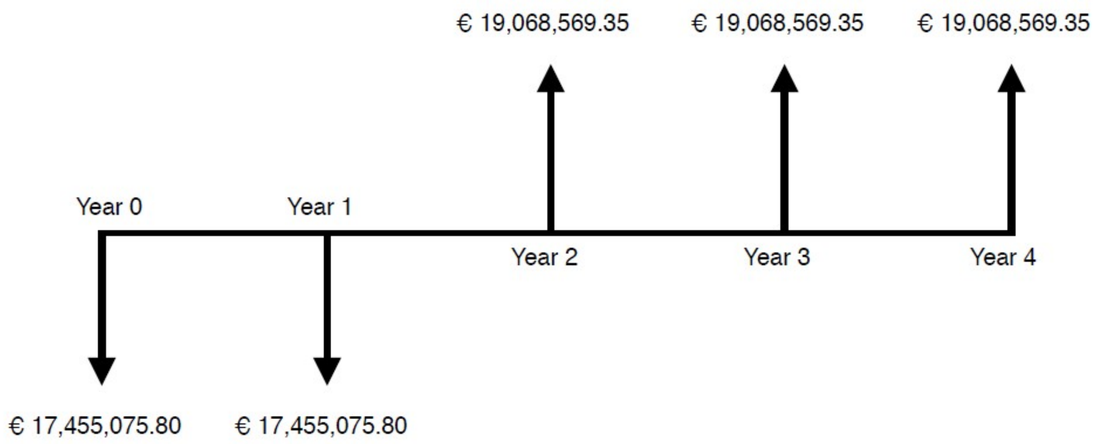
* The financial report will be attatched.

Calculation on DL hours

		# machine	working H/shift	working #shift	Set up time	# setup	machining hours	DL hours
Machine - DL of Workers								
M1	D1	6	7.5	458	7.5	1	20655	20655
M2	D2	6	7.5	458	7.5	1	20655	20655
M1 shared		1	7.5	364	7.5	92	3420	3420
M3	D3	2	7.5	458	1	1	6872	6872
M3 shared		1	2.65	458	1	458	1672	1672
M4		1	3.15	458	1	1	1444	1444
M8 D&R		2	5.62	458	1	1	5150	5150
M8 N		1	5.6	458	1	458	3023	
M5	D4	2	4.49	458	1	458	5029	5029
M7		1	4.49	458	1	458	2515	
M6		1	3.21	458	1	458	1929	1929
A3	D5	12	7.5	458	0	0	41220	123660
A2	D6 & D7	8	5.85	458	0	0	21435	21435
A1		4	4.75	458	0	0	8702	8702
A0		8	7.12	458	0	0	26088	26088
Total DL hours of workers								246711
MHE - DL of Drivers								
Electrical Pallet Jack		3	7.5	458	/	/	10305	10305
Hand Pallet Jack		2	7.5	458	/	/	6870	6870
Forklift-3m		1	1	458	/	/	458	458
Forklift-6m		2	7.5	458	/	/	6870	6870
Total DL hours of drivers								17633
Total DL hours								264344

ii. Cash Flow Analysis

Cash Flow Analysis



NPV analysis

$$NPV = \sum_{i=0}^{4} \frac{CF_i}{(1+0.06)^i}$$
$$= -\frac{17455075.8}{1.06^4} - \frac{17455075.8}{1.06^3} + \frac{19068569.35}{1.06^2} + \frac{19068569.35}{1.06^1} + 19068569.35$$
$$= 25535609.6$$

Payback Period & Net Profit

$$Payback\ period = 29\ October\ Year\ 2$$
$$Net\ profit = CF_{in} - CF_{out} = 22295556.45$$

7. Conclusion & Insight

We were very enthusiast and interested in doing a feasibility study of a facility and in designing a plant layout. Actually it was a big challenge and a big effort of time. To do this project our aim was to be as real as possible in our decisions and very precise on calculations. We faced some problems mainly during assumptions due to difficulties in determining data. It was not easy to determine at first how to share machines between the two dashboards or determine the exact number of unit loads needed in the production floor area. We still have some doubts about the moving times of unit loads and forklifts and about tool and mold maintenance.

We think that a bigger time schedule efficiency, a more realistic point of view, a more suitable material handling equipment, such as robotize ones, can improved our final plant. By increasing the autonomy of the factory, we would reduce humans errors, increase productivity and minimize flows and material traffic. Of course is a high cost investment solutions, also quite difficult to plan, so for both reasons we didn't take into account this plan for our factory for the moment.