Work Group 2: Manufacture of different products, with different batch sizes, with different processes
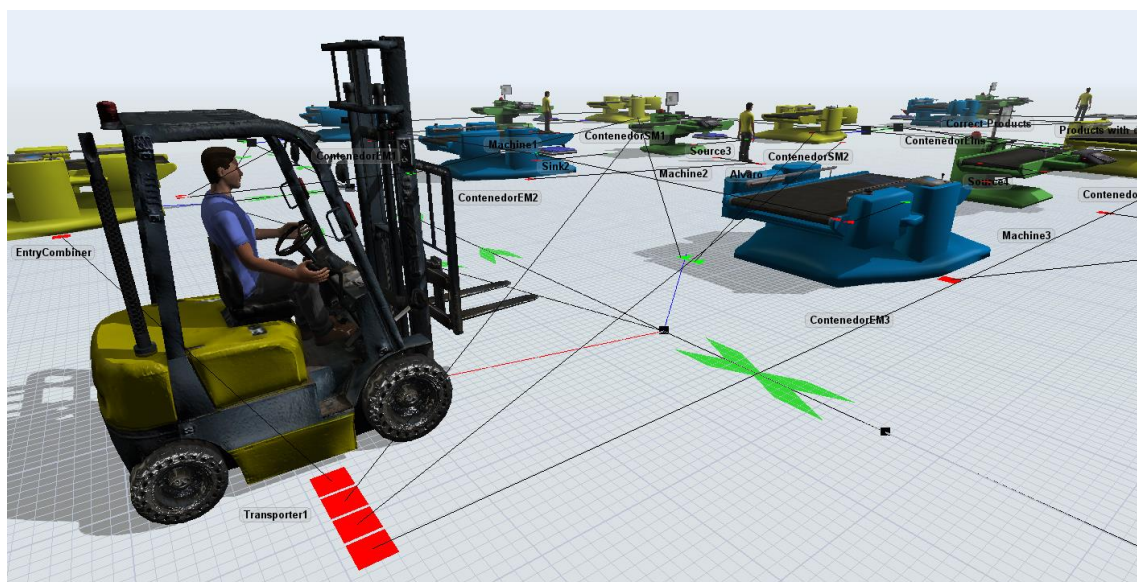
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Contenido

1. Case Description

The section of a factory that is going to determine our model has three different machines assisted by an operator. Depending on the product it will follow different paths and phases. The transport of those products is carried out by a forklift and batches of different sizes depending on the type of product.
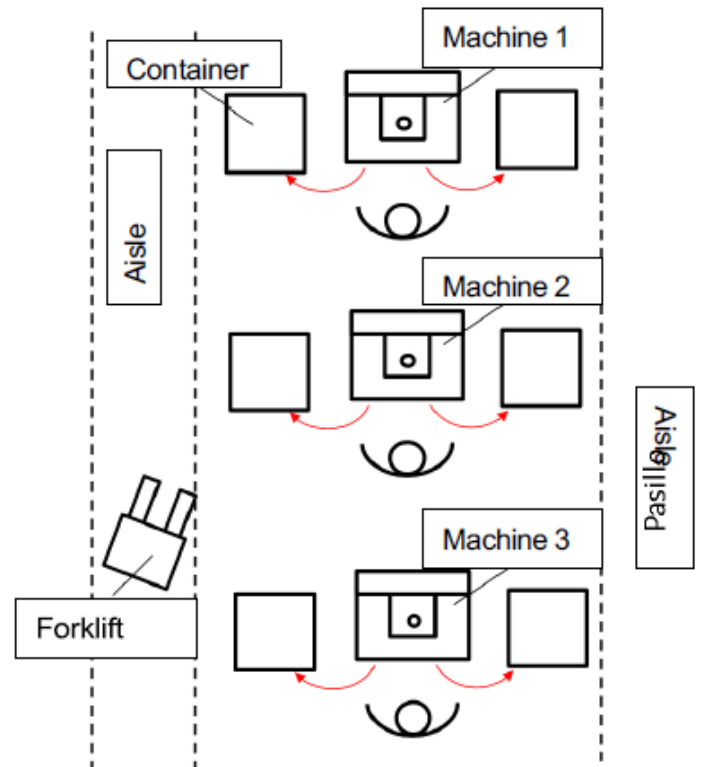
Not only the batches are different for each type, also, the type determines the times on the different machines. This data is collected on the next table:

Product	Machine 1		Machine 2		Machine 3	
	Preparation	Processing	Preparation	Processing	Preparation	Processing
A	17.5	11.7			11.8	7.7
B			20.1	13.5	15	10.2
C	18.8	12.3	15	10.5		
D	20.1	14.1	18.1	12.7	13.3	9.5

At the end of the section an inspection is done, which determines different levels of defects on the products.

2. VSM

For the case presented on the previous section we created the following VSM, in order to work on this idea on FlexSim.

Product	Preparation	Processing
A	17.5	11.7
C	18.8	12.3
D	20.1	14.1

A,C, D

SEPARATOR → MACHINE 1 → COMBINER

A

C, D

Product	Preparation	Processing
B	20.1	13.5
C	15	10.5
D	18.1	12.7

Forklift used for transport between red lines

COMBINER — B — SEPARATOR → MACHINE 2 → COMBINER — C — SEPARATOR → Inspection 5.5 mins

B, D

Product	Preparation	Processing
A	11.8	7.7
B	15	10.2
D	13.3	9.5

SEPARATOR → MACHINE 3 → COMBINER

A, B, D

Products with defects

3. FlexSim Model with Transportation and Dashboard

The resulting model, based on the previous VSM, and which we will go into in detail in the following section, is showed in the next image.
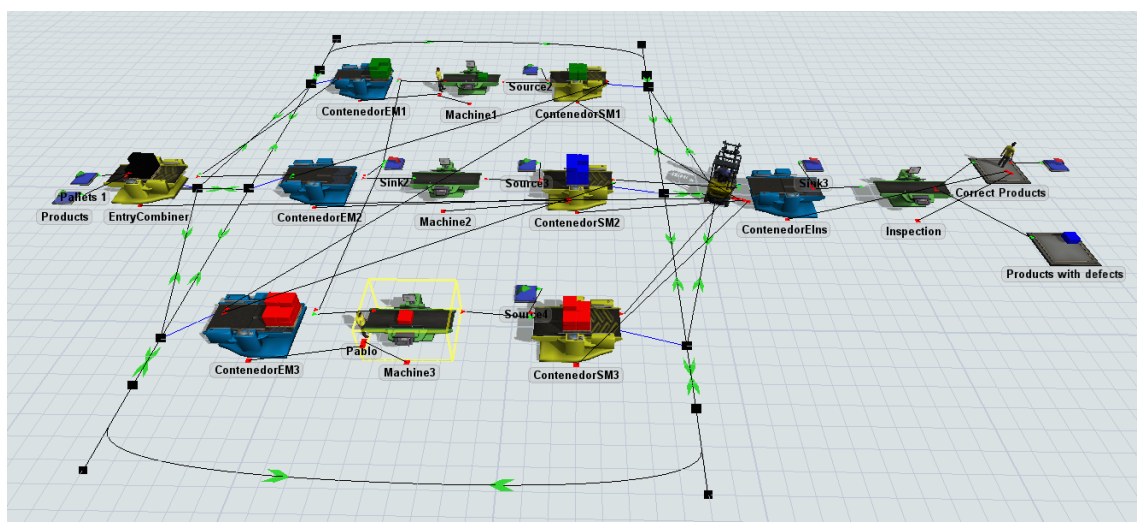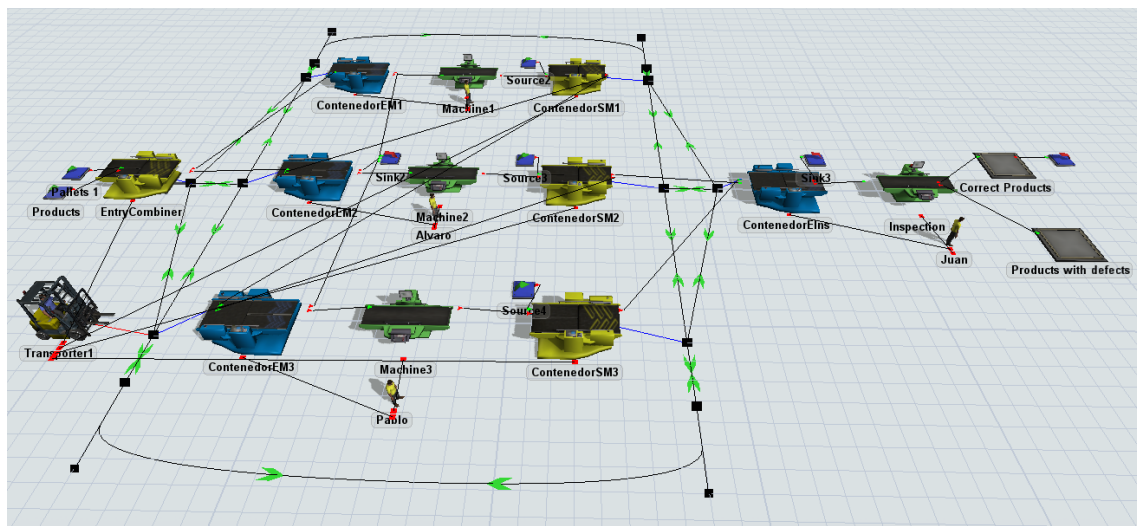
For that exact model and the total of 103425.89 s (cycle time) the dashboards created have the next results:

Output Per Hour

	Throughput
Machine1	3.09
Machine2	2.75
Machine3	3.43
Inspection	4.12

State Bar 1

Legend: Processing, Setup, Idle, Blocked, Waiting for operator, Waiting for transport

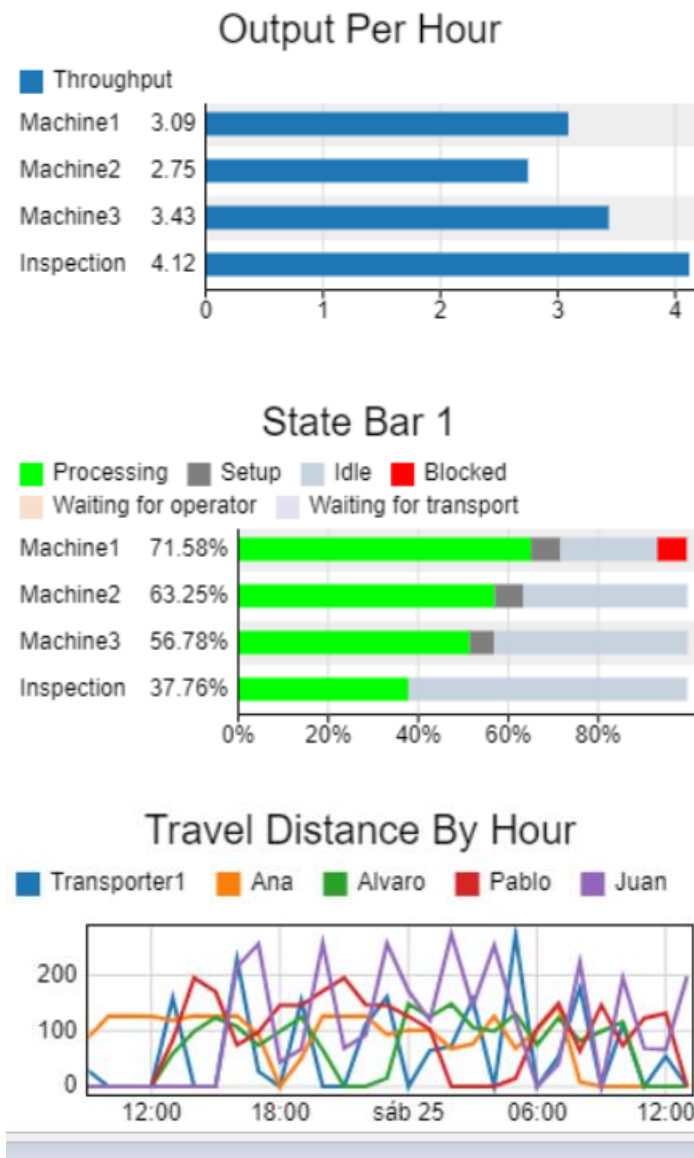|	
Machine1	71.58%
Machine2	63.25%
Machine3	56.78%
Inspection	37.76%

Travel Distance By Hour

Legend: Transporter1, Ana, Alvaro, Pablo, Juan

With these dashboards we can take the next conclusions: machine 1 has been block sometimes, that is why its output per hour are similar to the others despite being more demand. Also, we can see that Juan or the operator in charge of the inspection has a distribution of tasks less distributed, because it depends on the exits of the different machines.

4. <u>Detailed explanation of Scripts and/or configurations in the FlexSim Model</u>

The model of the manufacturing section starts with a source of the products from other sections or external input, and a source for pallets for the transportation of the different batches to the machine specified.

Previously, we defined a production table with all the data needed.

	Batch size	TSetupM1	TProcessM1	TSetupM2	TProcessM2	TSetupM3	TProcessM3	Defects	Code	Quantity
Producto A	20	1050	702	0	0	708	462	1	101	40
Producto B	15	0	0	1206	810	900	612	1.50	11	30
Producto C	20	1128	738	900	630	0	0	0.90	110	20
Producto D	10	1206	846	1086	762	798	570	1.50	111	30

The table configurated on the source to follow the description of the case and to get information of the times is:

Arrivals - Products

Arrivals 4   Labels 16

	ItemName	Quantity	Tipo	Codigo	ECM1	EM1	SM1	SCM1	ECM2	EM2	SM2	SCM2	ECM3	EM3	SM3	SCM3	ECIns	EIns
Arrival1	Producto A	40	1	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arrival2	Producto B	30	2	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arrival3	Producto C	20	3	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arrival4	Producto D	30	4	111	0	0	0	0	0	0	0	0	0	0	0	0	0	0

We can see different columns to specified later the time of entry or exit on the different machines. But we need to initialize them previously. On this source add a trigger of "Set Color by Case" so we can differentiate the products. With this table, not been repeated, we want to simulate a week of manufacturing.

The table of the pallets source is simpler and has been repeated until the week of work simulated is finished.

To move the different batches on a pallet we need to pack them on a starting combiner. In this machine we need to add labels and create custom codes. One of those custom codes is specified to send the products to the machine needed and described on the case description. In this case to send products A, C and D to machine 1 and B to machine 2.

EntryCombiner - Send To Port
```
1 Object item = param(1);
2 Object current = ownerobject(c);
3 /**First available*/
4
5 double codigo=current.Codigo;
6 //codigos 101, 111,110,011
7 if (codigo>=100)
8 return 1;
9 else
10 return 2;
11
```

The other code added is to get the information needed from the production table to fill the pallets with the correct batch sizes.

```
EntryCombiner - On Entry                                                              ▾ ✕
 1 /**Custom Code*/
 2 Object current = ownerobject(c);
 3 Object item = param(1);
 4 int port = param(2);
 5
 6 int tipo=item.Tipo;
 7
 8 int cant=Table("Produccion")[tipo][1];
 9
10 treenode target=Model.find("EntryCombiner>variables/componentlist/From Input Port 2/Target Quantity");
11 treenode suma=Model.find("EntryCombiner>variables/targetcomponentsum");
12
13 setnodenum(target,cant);
14 setnodenum(suma,cant);
15
16 int codigo=item.Codigo;
17 current.Codigo=codigo;
```

Then the batches and pallets are moved with a forklift to the corresponding machine. We needed to specify different trajectories so that it works as we want.

As the working lines are similar in operation, we will only define the configuration of the first machine.
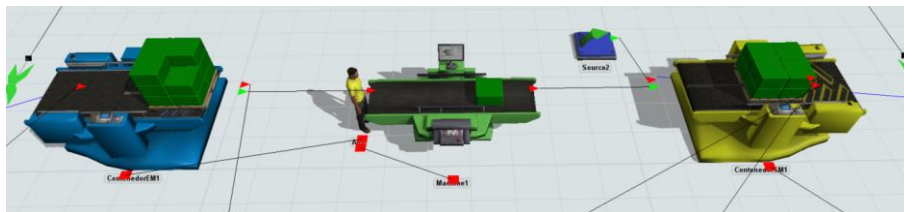
The batch enters the separator and we start to collect info of the different times, that is why we need to add labels (trigger on entry). In this section the batch is separated so that later the machine could work in each product separately. To get the data and save it on an auxiliar timetable we need to configure the code to do so.

```
ContenedorEM1 - On Exit
 1 /**Custom Code*/
 2 Object current = ownerobject(c);
 3 Object item = param(1);
 4 int port = param(2);
 5 //Tiempos
 6 double tiempoE=current.TiempoE; //lee la etiqueta "TiempoE" del objeto
 7 item.labels.assert("ECM1").value=tiempoE; //asigna la etiqueta "ECM1" al item
 8 item.labels["EM1"].value=Model.time; //asigna la etiqueta "EM1" al item
```

Then it starts the work of the machine. We configure it to get, depending on the type of product, thew set up and processing time.
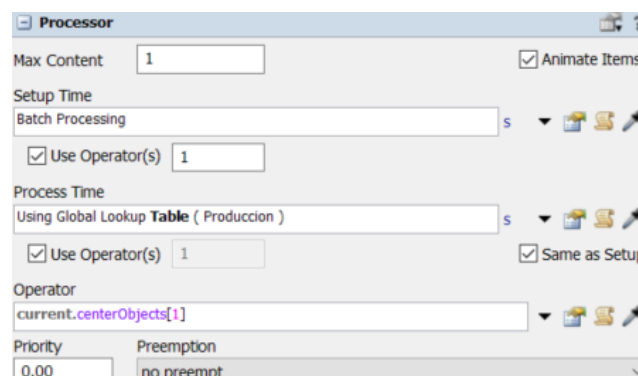
Then each processed product goes to a new combiner to create a new batch. In this combiner we define, as we have done previously on the separator, a new code and trigger so that we can save the times needed. Also, we need to configure the output so that depending on the code of the different products it goes to the inspection or another machine.

```
ContenedorSM1 - Send To Port
1 Object item = param(1);
2 Object current = ownerobject(c);
3 /**First available*/
4
5 double codigo=current.Codigo;
6 double resto=fmod(codigo,100);
7
8 if (resto>=10)
9 {return 2;}
10 else
11 //if (resto==1)
12 {return 1;}
13
14
```

The lines of the other machines are configured on the same way. The inspection starts with the same process on a separator. Then, the inspection needs to be configured on the exit with the percentages defined on the task. So that depending on the resault it is send to one container or another.

```
Inspection - Send To Port
1 Object item = param(1);
2 Object current = ownerobject(c);
3 /***popup:Percentage:valuestr=Port*/
4 /**By Percentage*/
5 int stream = /**\nStream number: *///***tag:stream*///**/getstream(current)/**/;
6 double randomnum = uniform(0.0, 100.0, stream);
7 double total = 0.0;
8 /***tagex:data*/
9 total += /**\nPercent: *///**/gettablenum("Produccion",item.Tipo,8)/**/;
10 if (randomnum <= total)
11     return /** Port: *///**/2/**/;
12 total += /**\nPercent: *///**/100 - gettablenum("Produccion",item.Tipo,8)/**/;
13 if (randomnum <= total)
14     return /** Port: *///**/1/**/;/***/
15
```

As it is the last point of the production line, we will define here the creation of the table "Times" and the values taken or saved so far will be attached.

```
Inspection - On Exit

 1 /**Custom Code*/
 2 Object current = ownerobject(c);
 3 Object item = param(1);
 4 int port = param(2);
 5
 6 double tipo=item.Tipo;
 7 double codigo=item.Codigo;
 8 double ecm1=item.ECM1;
 9 double em1=item.EM1;
10 double sm1=item.SM1;
11 double scm1=item.SCM1;
12 double ecm2=item.ECM2;
13 double em2=item.EM2;
14 double sm2=item.SM2;
15 double scm2=item.SCM2;
16 double ecm3=item.ECM3;
17 double em3=item.EM3;
18 double sm3=item.SM3;
19 double scm3=item.SCM3;
20 double ecins=item.ECIns;
21 double eins=item.EIns;
22
23 Table tabla=reftable("Tiempos");
24 int filas=current.stats.input.value;
25 tabla.setSize(filas,17);
26 tabla[filas][1]=tipo;
27 tabla[filas][2]=codigo;
28 tabla[filas][3]=ecm1;
29 tabla[filas][4]=em1;
30 tabla[filas][5]=sm1;
31 tabla[filas][6]=scm1;
32 tabla[filas][7]=ecm2;
33 tabla[filas][8]=em2;
34 tabla[filas][9]=sm2;
35 tabla[filas][10]=scm2;
36 tabla[filas][11]=ecm3;
37 tabla[filas][12]=em3;
38 tabla[filas][13]=sm3;
39 tabla[filas][14]=scm3;
40 tabla[filas][15]=ecins;
41 tabla[filas][16]=eins;
42 tabla[filas][17]=Model.time;
```

5. Time and Costs Analysis- Production Times Table

The final table called "Times" results on a recompilation of the data of the labels mentioned or similar. It is a large table, so we only share a few of it.

Tipo	Codigo	ECM1	EM1	SM1	SCM1	ECM2	EM2	SM2	SCM2	ECM3	EM3	SM3	SCM3	ECIns	EIns	Sins
3	110	30237.64	45038.93	45787.50	52626.25	52652.58	59389.79	60030.50	66548.32	0	0	0	0	66552.58	70039.85	70375.93
3	110	30237.64	45795.02	46543.86	52626.25	52652.58	58742.00	59382.41	66548.32	0	0	0	0	66552.58	70387.84	70724.21
3	110	30237.64	46551.06	47299.61	52626.25	52652.58	58094.23	58734.94	66548.32	0	0	0	0	66552.58	70736.03	71072.20
3	110	30237.64	47307.13	48055.97	52626.25	52652.58	57446.40	58086.83	66548.32	0	0	0	0	66552.58	71084.28	71420.68
3	110	30237.64	48063.17	48811.73	52626.25	52652.58	56798.62	57439.32	66548.32	0	0	0	0	66552.58	71432.28	71768.36
3	110	30237.64	48819.25	49568.10	52626.25	52652.58	56150.82	56791.24	66548.32	0	0	0	0	66552.58	71780.27	72116.63
3	110	30237.64	49575.29	50323.85	52626.25	52652.58	55503.05	56143.76	66548.32	0	0	0	0	66552.58	72128.46	72464.63
3	110	30237.64	50331.36	51080.20	52626.25	52652.58	54855.22	55495.65	66548.32	0	0	0	0	66552.58	72476.71	72813.11
3	110	30237.64	51087.40	51835.97	52626.25	52652.58	54207.44	54848.14	66548.32	0	0	0	0	66552.58	72824.71	73160.79
3	110	30237.64	51843.49	52605.10	52626.25	52652.58	52659.64	54200.06	66548.32	0	0	0	0	66552.58	73172.70	73517.10
4	111	51887.35	61594.86	62464.47	65894.11	65920.44	66522.97	68381.41	75439.72	75465.87	81559.10	82155.95	82177.50	82185.97	82193.02	82529.10
4	111	51887.35	60730.78	61587.34	65894.11	65920.44	68388.80	69161.51	75439.72	75465.87	80971.50	81551.82	82177.50	82185.97	82541.02	82877.38
4	111	51887.35	59866.74	60723.57	65894.11	65920.44	69168.57	69940.99	75439.72	75465.87	80383.93	80964.53	82177.50	82185.97	82889.20	83225.37
4	111	51887.35	59002.67	59859.22	65894.11	65920.44	69948.37	70721.07	75439.72	75465.87	79796.33	80376.65	82177.50	82185.97	83237.45	83573.85
4	111	51887.35	58138.63	58995.47	65894.11	65920.44	70728.15	71500.58	75439.72	75465.87	79208.77	79789.37	82177.50	82185.97	83585.45	83921.53
4	111	51887.35	57274.54	58131.11	65894.11	65920.44	71507.98	72280.69	75439.72	75465.87	78621.16	79201.49	82177.50	82185.97	83933.44	84269.81
4	111	51887.35	56410.50	57267.34	65894.11	65920.44	72287.75	73060.17	75439.72	75465.87	78033.60	78614.20	82177.50	82185.97	84281.63	84617.80
4	111	51887.35	55546.43	56402.99	65894.11	65920.44	73067.55	73840.25	75439.72	75465.87	77446.00	78026.32	82177.50	82185.97	84629.88	84966.28
4	111	51887.35	54682.39	55539.24	65894.11	65920.44	73847.33	74619.76	75439.72	75465.87	76858.44	77439.04	82177.50	82185.97	84977.88	85313.96
4	111	51887.35	52612.30	54674.87	65894.11	65920.44	74627.16	75407.29	75439.72	75465.87	75472.83	76851.16	82177.50	82185.97	85325.87	85670.28
4	111	61638.72	72822.02	73691.63	74653.51	74679.84	75414.37	77272.80	84331.11	84357.26	90450.50	91047.34	91068.90	91077.37	91084.42	91420.50
4	111	61638.72	71957.94	72814.50	74653.51	74679.84	77280.19	78052.91	84331.11	84357.26	89862.89	90443.21	91068.90	91077.37	91432.41	91768.77
4	111	61638.72	71093.90	71950.74	74653.51	74679.84	78059.96	78832.38	84331.11	84357.26	89275.32	89855.92	91068.90	91077.37	91780.59	92116.77
4	111	61638.72	70229.83	71086.38	74653.51	74679.84	78839.76	79612.46	84331.11	84357.26	88687.73	89268.04	91068.90	91077.37	92128.84	92465.24
4	111	61638.72	69365.79	70222.63	74653.51	74679.84	79619.54	80391.98	84331.11	84357.26	88100.17	88680.77	91068.90	91077.37	92476.85	92812.92
4	111	61638.72	68501.70	69358.27	74653.51	74679.84	80399.37	81172.09	84331.11	84357.26	87512.56	88092.88	91068.90	91077.37	92824.84	93161.20
4	111	61638.72	67637.66	68494.50	74653.51	74679.84	81179.14	81951.56	84331.11	84357.26	86924.99	87505.59	91068.90	91077.37	93173.02	93509.19
4	111	61638.72	66773.59	67630.15	74653.51	74679.84	81958.94	82731.64	84331.11	84357.26	86337.40	86917.71	91068.90	91077.37	93521.27	93857.67
4	111	61638.72	65909.55	66766.40	74653.51	74679.84	82738.72	83511.16	84331.11	84357.26	85749.83	86330.44	91068.90	91077.37	93869.28	94205.35
4	111	61638.72	62471.68	65902.03	74653.51	74679.84	83518.55	84298.68	84331.11	84357.26	84364.23	85742.55	91068.90	91077.37	94217.27	94561.67
4	111	72865.88	82681.40	83551.01	83560.95	83587.28	84305.76	86164.20	93195.33	93221.48	99314.71	99911.56	99933.12	99941.58	99948.64	100284.71
4	111	72865.88	81817.31	82673.88	83560.95	83587.28	86171.59	86944.30	93195.33	93221.48	98727.11	99307.43	99933.12	99941.58	100296.63	100632.99
4	111	72865.88	80953.27	81810.11	83560.95	83587.28	86951.36	87723.78	93195.33	93221.48	98139.54	98720.14	99933.12	99941.58	100644.81	100980.98
4	111	72865.88	80089.20	80945.76	83560.95	83587.28	87731.16	88503.86	93195.33	93221.48	97551.94	98132.26	99933.12	99941.58	100993.06	101329.46
4	111	72865.88	79225.16	80082.01	83560.95	83587.28	88510.94	89283.37	93195.33	93221.48	96964.38	97544.99	99933.12	99941.58	101341.06	101677.14
4	111	72865.88	78361.08	79217.64	83560.95	83587.28	89290.77	90063.48	93195.33	93221.48	96376.78	96957.10	99933.12	99941.58	101689.06	102025.42
4	111	72865.88	77497.03	78353.87	83560.95	83587.28	90070.54	90842.96	93195.33	93221.48	95789.21	96369.81	99933.12	99941.58	102037.24	102373.41
4	111	72865.88	76632.96	77489.52	83560.95	83587.28	90850.33	91623.04	93195.33	93221.48	95201.61	95781.93	99933.12	99941.58	102385.49	102721.89
4	111	72865.88	75768.92	76625.77	83560.95	83587.28	91630.12	92402.55	93195.33	93221.48	94614.05	95194.65	99933.12	99941.58	102733.49	103069.57
4	111	72865.88	73698.84	75761.40	83560.95	83587.28	92409.95	93190.08	93195.33	93221.48	93228.45	94606.77	99933.12	99941.58	103081.48	103425.89

On the last square, on the right side and below, we can see the cycle time. We specified all the times in seconds, so these results are seconds also. Resulting on 103425.89 seconds.

As we can see on the table, we have all the data of times, by products, by operations or machines, etc. With this information we can start to estimate the different costs of the production.

Cost of the machines

To calculate these costs, we need to get the information of the table that specified the work done on the machine and the work of the operator. Because the process has costs of people and machinery. The times needed, depend on the product because of the path follow, the times and the size of the batches. So, we start by calculating those different times and recollecting the data on a table.

$$t_{mechanization\ for\ a\ batch} = Setup\ time + n*Processing\ time; \qquad n = batch\ size$$

$$t_{operator\ for\ a\ batch} = \sum_{i=1}^{n} SM_x - EM_x \ ; n = batch\ size$$

Product	Mechanization times (s) for 1 batch			Operator times (s) for 1 batch		
	M1	M2	M3	M1	M2	M3
A	15090	-	9948	15306.57	-	10154.55
B	-	13356	10080	-	13512.89	10235.08
C	15888	13500	-	16104.8	13708.78	-
D	9666	8706	6498	9889.06	8812.83	6601.21

But we need to add a correction to those numbers because between the labels of the production line there are factors that does not affect on this type of cost, such as the transportation between the containers and the machine. Also, in this case is not define but here also is considered the unloading and loading times.

$$t_{mechanization} = t_{operator} - t_{transportation} - t_{loading} - t_{unloading}$$

With all the time data collected and verified we can calculate, with the information of costs provided, the costs of the different products. Because each type follows a different path.

$$c_{batch\ product\ A} = c_{M1} * t_{M1} + c_{M3} * t_{M3} + c_{operator} * (t_{opM1} + t_{opM3})$$

$$c_{batch\ product\ B} = c_{M2} * t_{M2} + c_{M3} * t_{M3}\ c_{operator} * (t_{opM2} + t_{opM3})$$

$$c_{batch\ product\ C} = c_{M1} * t_{M1} + c_{M2} * t_{M2}\ c_{operator} * (t_{opM1} + t_{opM2})$$

$$c_{batch\ product\ D} = c_{M1} * t_{M1} + c_{M2} * t_{M2} + c_{M3} * t_{M3} + c_{op} * (t_{opM1} + t_{opM2} + t_{opM3})$$

$$c_{batch\ product\ A} = 390.31€\ ;\ c_{batch\ product\ B} = 373.78€\ ;$$

$$c_{batch\ product\ C} = 442.52€\ ;\ c_{batch\ product\ D} = 386.02€$$

$$c_{total\ weekly\ production\ M1,M2,M3} = 2 * c_{batch\ A} + 2 * c_{batch\ B} + c_{batch\ C} + 3 * c_{batch\ D}$$

$$c_{total\ machines} = 3128.76€$$

We also calculated the weekly costs thanks to the information of the number of products produced.

Until now we estimated a total cost or costs by batches. But we considered more important to calculate the cost of one product of each type.

Product	Costs per component (machines and operators)
A	19.52€
B	24.92€
C	22.13€
D	38.60€

Costs of inspection

Following the same process as the one done on the calculation of costs of the different process and its machines or operators, we calculate the inspections costs. Here is easier to take the information of the times because no transportation is done between labels. First, we calculate the total costs and then we estimate the cost on a single product.

$$t_{inspection\ operator} = SIns - EIns = 336.4s\ (on\ average)$$

$$c_{total\ inspection} = 120 * (t_{inspection} * c_{insp} + t_{operator} * c_{op}) = 422.27€$$

Product	Costs per component (inspection and operator)
A,B,C,D	3.52€

Costs of transportation

As we have mentioned before, the different batches are moved, with a forklift and the operator in charge of it, between all the space of the manufacturing section. This is an additional time, and cost, for the products and its fabrication. We estimate a calculation, but we don't have information of all the movements done, such as the one between the first combiner and the first process. We decided to create a factor because depending on the type of the product the forklift is used more or not. This does not affect on the total cost, but it affects son the costs of each type of product or unit. To calculate this factor, we used the number of trips for each batch and the batches that the forklift needs to move.

$$c_{operator\ for\ the\ forklift} = t_{cycle\ for\ weekly\ production} * c_{op} = 430.94€$$

$$c_{forklift\ week} = \frac{c_{forklift\ annual}}{12 * 4} = 104.17€$$

$$c_{total\ forklift} = 535.11€$$

Product	Trips forklift	Batches	Ponderation factor
A	3	2	0.222222
B	3	2	0.222222
C	3	1	0.111111
D	4	3	0.444444

$$c_{forklift\ and\ operator\ per\ item} = c_{total\ forklift} * \frac{k_{ponderation\ factor}}{n}$$

By applying this formula, the results obtained are shown in the following table:

Product	Costs per component (forklift and operator)
A	2.97€
B	3.96€
C	2.98€
D	7.92€

Total costs

With all the different types of costs on the manufacturing section calculated thanks to the times collected on the model we calculate the final costs, total and by item.

$$Costs\ for\ Weekly\ Production\ Plan = c_{machines} + c_{inspection} + c_{forklift} = 4086.14€$$

Product	Total costs per component
A	26.01€
B	32.40€
C	28.63€
D	50.04€

6. <u>Improvements and conclusions</u>

As we have mentioned before, and we can see on one of the dashboards, the machine number one is oversaturated. To improve the model, we can change the paths to use less this machine or add another one that could work at the same time. But this could lead the oversaturation to another machine. Also, for the model to be more exact and calculate the exact costs of each product we will need additional information such as the load and unload time of the operator. And the travel time of the forklift between the different stations so we can estimate better the work of the operator in charge of it.