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Reduction of unproductive times in auto parts company by applying the time and motion methodology

Reducción de tiempos improductivos en una empresa de autopartes aplicando la metodología de tiempos y movimientos

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Abstract

A study of times and movements was developed to reduce unproductive travel times in an assembly line of an auto parts company. The tools used for the study were three: time analysis by elements (ten samples were filmed for each method and the videos were analyzed breaking down the cycle into elements); flow process diagram, to identify each of the activities and the spaghetti diagram that shows the actual flow with measures and trajectories. A proposal for the redistribution of materials was created taking into account the principle of the minimum distance traveled, the collaborators were trained on the modifications in both methods (one piece at a time and several pieces at a time); subsequently, a pilot test was run to verify the feasibility of the proposal. Both the distance and the time were reduced between 20 to 30% for the two methods analyzed.

Time and motion study, Cycle time, Spaghetti diagram

Resumen

Se desarrolló un estudio de tiempos y movimientos para reducir tiempos improductivos de recorrido en una línea de ensamble de una empresa de autopartes. Las herramientas utilizadas para el estudio fueron tres: análisis de tiempos por elementos (se filmaron diez muestras por cada método y se analizaron los videos descomponiendo el ciclo en elementos); diagrama de proceso de flujo, para identificar cada una de las actividades y el diagrama de espaguetti que muestra el flujo real con medidas y trayectorias. Se creó una propuesta de redistribución de materiales tomando en cuenta el principio de la mínima distancia recorrida, se capacitó a las colaboradoras sobre las modificaciones en ambos métodos (una pieza a la vez y varias piezas a la vez); posteriormente, se corrió una prueba piloto para verificar la factibilidad de la propuesta. Tanto la distancia como el tiempo se redujeron entre un 20 a 30% para los dos métodos analizados.

Estudio de tiempos y movimientos, tiempo ciclo, diagrama de spaguetti

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Introduction

Information from the 2019 Economic Census indicates that the manufacturing sector in Mexico in 2018[1] was the most important in terms of total gross production, generating 48.2% of the national total. SMEs accounted for 97.9% of the sector's total economic units, 27.6% of total employed personnel and generated 5.9% of total gross production. Given their impact on the national economy, researchers such as Palomo[2] document that SMEs dedicated to manufacturing lack training, techniques, tools, quality management systems, a culture of innovation and technological development that would allow them to remain and/or survive in the face of the demand and quality standards required by transnationals.

The products produced in these companies have high percentages of waste and/or reprocessing, which is reflected in high production costs, a greater number of customer complaints, a decrease in competitiveness, and, in addition to this, does not allow them to access other market sectors and position their products.

In this sense, work measurement as part of industrial engineering is one of the areas that has several support tools for process optimisation.

Authors such as Kanawaty [3] and Baines [4], agree that work measurement provides a means of measuring the time spent in carrying out an operation or series of operations, in such a way that it separates effective times from those that are not.

Guha and Verma [5] mention that there is a close relationship between time study and motion study, both of which are work measurement techniques used by industrial engineers to improve performance or operational efficiency. Motion surveying is concerned with the reduction of work content, waste and posture difficulties that lead to worker fatigue and aims to establish the best possible way of performing the work; whereas time surveying is concerned with investigating and reducing any non-value added activities associated with the work and establishing the standard time for an operation. Therefore, by using time and motion studies, it is possible to reduce waste and increase the efficiency and productivity of an organisation.

Moreover, proper space utilisation is an important source of cost reduction; proper layout of work areas reduces unnecessary movements and waste of time and energy.[3] Chandra et al.

Chandra et al. document in a time and motion study, conducted in the erection of steel structures in the construction industry, an increase in efficiency of 37.95%, and a reduction of idle time by 40.24% (after two weeks of implementation).[6] Su and Quiliche describe in a study of time and motion in the erection of steel structures in the construction industry an increase in efficiency of 37.95%, and a reduction of idle time by 40.24% (after two weeks of implementation).

Su and Quiliche describe in the time and motion study for a fishing industry, the reduction of standard operating times by 40.18%, as well as the increase of raw material productivity by 7.8%.[7] In the same study, Su and Quiliche describe the reduction of standard operating times by 40.18%, as well as the increase of raw material productivity by 7.8%.

Quintero and Omaña evidenced the optimisation of the supply chain in the creation of an oncology centre through the analysis and evaluation of the time and movements with the PERT - CPM technique, minimising the time from 52 to 39.10 weeks (24.79%).[8] Andrade-del Rio et al.

Andrade-del Rio et al. showed an increase in production of 5.49% as a result of a time and motion study in an industry that manufactures footwear, thus proving that the use of production management techniques increases productivity and efficiency in production processes.[9] Something similar occurs in a review article, in which Ankur and Darshak document the application of the work study tool in 10 different companies, in which a reduction in process time ranging from 5 to 20% was observed.[10] In this project, a study of time and motion was developed using the PERT - CPM technique.

In the present project, a time and motion study was developed to reduce unproductive travel times in an auto parts company.

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In one of the assembly lines of the VR model, excessive travel times were observed in the movements of the employees within the operation.

The tools used for the study were three: time analysis by elements [11, 12], process flow diagram to identify each of the activities [13, 14] and the spaghetti diagram [15, 16, 17], which is represented by the real flow with measurements and trajectories made by the collaborator. For the time analysis, ten samples were filmed (five for each method), it is worth mentioning that two methods were used: one piece at a time (UPV) and several pieces at a time (VPV) and the videos were analysed by decomposing the cycle into elements.

Subsequently, a proposal for redistribution of materials was created taking into account the principle of minimum distance travelled, which consists of placing the materials so that the distance is minimal, the pilot test was carried out taking into account restrictions and space factors, the results were analysed using the same three tools and the information was compared.

The objective of the project was to reduce unproductive travel times by at least 20% in the assembly line by studying times and movements and relocation of materials.

Development

For the development of this project it was necessary to determine the sequence of each of the activities that the employees carry out and to identify the problem of the distances travelled that affect their production time.

The company works with the UPV method, which consists of taking the parts one at a time so as not to damage them, however, this is complicated for the employees, causing delays in their activities, which is why they carry out their operations using VPV so as not to fall behind in the sequences.

It is worth mentioning that the programmed production per shift is 250 sequences and the real production is 238. This is why the walking time is an important factor that affects their cycle time and the delivery of sequences to the customer.

Five-time samples were taken by both methods (UPV and VPV) to get an approximation of the percentage of cycle time spent walking the parts (see Table 1).

UPV					
Model	VR				
Samples	30.23 s	32.26 s	41.16 s	28.07 s	46.13 s
Average	35.57 s				
T. Cycle	1.24 min				
Percentage in C.T.	42%				

VPV					
Model	VR				
Samples	30.59 s	30.97 s	24.44 s	32.85 s	29.86 s
Average	29.74 s				
T. Cycle	1.24 min				
Percentage in C.T.	35%				

Table 1: Average walking time of both methods and the percentage it represents in the cycle time of the VR model.

The following areas of opportunity for improvement were identified for the distribution of materials:

- Performing combined activities.
- Box racking takes up too much space.
- Unoccupied space on the shelves of the Cover
- Retractor and Cover RR of collaborator 1 right side.
- The space taken up by the water waste box.
- The space taken up by the foam box and cleaning equipment.

Methodology

To develop the time and motion study it was necessary to break down the operation into the different activities called "elements" to observe in detail if repetitive activities do not add value, ten samples were taken (videos of the two methods in which they make the operation) that were recorded to subsequently obtain accumulated operations and averages of each element.

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Flow of taking VPV, VR LD model:

The following tables show the summaries of the time analysis by elements for each contributor; the average times for each activity are shown with their total average cycle time (see Table 2 and 3).

Summary of time analysis by elements VR LD VPV flow model		
Activity		Average time (s)
1	Takes box from rack	1.40
2	Walks and puts box on table	2.50
3	Walk around part	2.80
4	Takes part VRLD01	2.45
5	Cleaning and inspection	1.05
6	Walks to table	1.95
7	Places part in box	1.85
8	Walk around part	5.10
9	Takes part VRLD02	1.80
10	Cleaning and inspection	2.00
11	Walks part	2.30
12	Takes part VRLD03	1.89
13	Walk around part	2.40
14	Takes part VRLD04	2.00
15	Walk to table	4.70
16	Cleaning and inspection	7.40
17	Places in box	4.50
18	Waiting time	2.10
19	Walks to computer	2.90
20	Scan	3.10
	TOTAL average cycle time (s):	56.19

Table 2 Summary of the time analysis by elements, average times of the VPV method, employee LD

Summary of time analysis by elements VR LI VPV flow model		
Activity		Average time (s)
1	Walk by part	5.20
2	Take part VRLI01	2.35
3	Walk by part	1.75
4	Take part VRLI02	1.00
5	Walk through part	1.25
6	Take part VRLI03	1.15
7	Walk around part	2.10
8	Takes part VRLI04	1.80
9	Walk to table	3.40
10	Cleaning, inspection	15.70
11	Places parts in box	7.35
12	Waiting time	6.10
13	Walks to computer equipment	1.00
14	Detaches and attaches label	1.00
15	Walks to desk	0.90
16	Takes box	1.00
17	Walks to dolie	2.80
18	Deposits box in dolie	1.60
	TOTAL average cycle time (s):	57.45

Table 3 Summary of the time analysis by elements, average times of the VPV method, collaborator LI

Subsequently, process flow diagrams of the activities with their times and distances were made to identify operations, displacements, delays, etc. for each method and collaborator. The observed distances were measured with the help of a flexometer from the position of the table where they start the operation to the location of each material (Annexes 1- 4). Table 4 shows the summary of actual times and distances for the VPV method for both collaborators.

VR	
VPV method	
CURRENT DISTRIBUTION	
LD	LI
Cycle time: 56.19 s	Cycle time: 57.45 s
Distance travelled: 27.78 m	Distance travelled: 18.81 m
Travel time: 24.65 s	Travel time: 18.4 s
Target 20% reduction in travel time	
20% = 4.93 s	20% = 3.68 s

Table 4 Summary of times and distances for the VPV method for both collaborators

Subsequently, with the results obtained for both the average cycle time and the distance travelled in metres, the travel time was obtained by adding the seconds in which the flowchart indicates that the operator walks.

A layout of the current situation was designed in AutoCAD software and the spaghetti diagrams were drawn up on this.

This diagram shows this extracted information together with its walking flow represented by curved lines (see Figure 1).

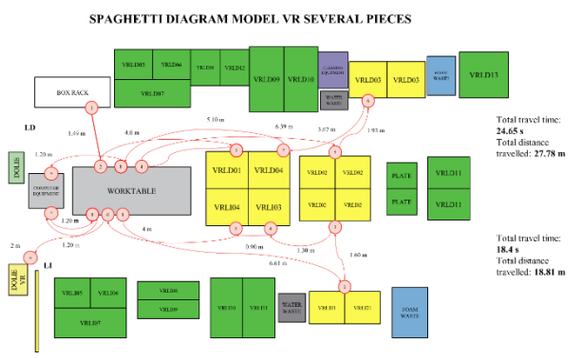

Figure 1 Spaghetti diagram of the VR model, VPV flow of both collaborators

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UPV flow of VR model:

The following table shows the time summaries with the averages of the activities performed with the UPV flow of the VR model (see Table 5 and 6).

Summary of time analysis by elements Model VR LD flow UPV		
Activity		Average time (s)
1	Takes box from rack	1.80
2	Walks and puts box on table	2.00
3	Walk around part	5.60
4	Takes part VRLD02	1.30
5	Walks to table	5.20
6	Cleaning and inspection	3.20
7	Places in box	2.20
8	Walk around part	5.70
9	Takes part VRLD03	1.60
10	Cleaning and inspection	3.90
11	Walk to table	6.50
12	Place in box	1.05
13	Walk around part VRLD04	4.45
14	Takes part	1.00
15	Cleaning and inspection	2.06
16	Walks to table	8.60
17	Place in box	1.05
18	Walk around part VRLD01	2.10
19	Takes part	1.45
20	Cleaning and inspection	2.25
21	Walk to table	3.60
22	Places in box	1.00
23	Walks to computer equipment	1.10
24	Scans	6.80
	TOTAL average cycle time (min):	1.26

Table 5 Summary of the time analysis by elements, average times of the UPV method, collaborator LD.

Summary of time analysis by elements VR LI UPV flow model		
Activity		Average time (s)
1	Walk by part	4.40
2	Take part VRLI01	1.00
3	Walk to table	4.80
4	Cleaning and inspection	3.10
5	Places in box	1.00
6	Walk around part	5.55
7	Takes part VRLI02	0.85
8	Walk to table	4.90
9	Cleaning and inspection	3.55
10	Places in box	1.85
11	Walks by part	3.70
12	Takes part VRLI03	1.10
13	Walk to table	3.70
14	Cleaning and inspection	2.90
15	Place in box	1.25
16	Walks by part	2.90
17	Takes part VRLI04	1.22
18	Walk to table	3.00
19	Cleaning and inspection	2.90
20	Place in box	1.20
21	Waiting time	12.20
22	Walks to computer equipment	1.60
23	Detaches and places sequence in box	1.25
24	Walks to desk	1.50
25	Takes box	1.00
26	Walks to dolie	3.00
27	Deposits box in dolie	1.00
	TOTAL average cycle time (min):	1.27

Table 6 Summary of the time analysis by elements, average times of the UPV method, collaborator LI.

Table 7 shows the summary of current times and distances for the UPV method, for both collaborators.

VR UPV Method	
CURRENT DISTRIBUTION	
LD	LI
Cycle time: 1.26 min	Cycle time: 1.27 min
Distance travelled: 47.29 m	Distance travelled: 48.6 m
Travel time: 40.75 s	Travel time: 39.05 s
Target 20% reduction in travel time	
20% = 8.15 s	20% = 7.81 s

Table 7 Summary of times and distances for the UPV method for both collaborators

The following spaghetti diagram representing the route flow, tracing the trajectories with curved lines, can be observed (see Figure 2)

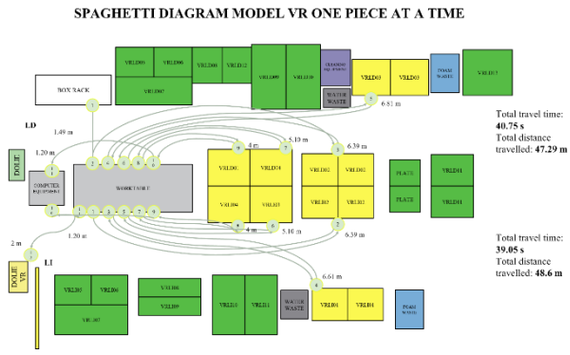

Figure 2 Spaghetti diagram of the VR model path, UPV flow. It shows the path of both collaborators

Proposed relocation of materials:

Having obtained the results of times for each of the models, collaborators and methods, the proposal for the relocation of materials was made, the areas of opportunity previously described were taken into account and the materials with the highest consumption for each model were identified, with the help of the materials area, which provided the necessary information. The following table shows the LD and LI materials ordered by model, from highest to lowest consumption with their standard pack and their existence in the line (see Table 8).

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Side	Name	Quantity	On-line
LI	VRLI04	6	12 boxes
LD	VRLD01	6	12 boxes
LI	VRLI03	8	12 boxes
LD	VRLD04	8	12 boxes
LI	VRLI02	22	2 containers
LD	VRLD02	22	2 containers
LI	VRLI01	21	2 containers
LD	VRLD03	21	2 containers

Table 8 Order of materials from highest to lowest consumption with their standard pack and the quantity on the line

The following layout proposal was made in the AutoCAD software, the most consumable materials were arranged and brought closer together, thus contemplating the following restrictions that would affect the test results:

- The box rack was proposed to be rotated 90° to the right to save space; the current layout is like this because another model's dollie is placed in that area.
- The rack containing very low consumption parts was changed from standard pack to container.
- The container for the larger and heavier material was placed at the end of the assembly area, leaving a 67 cm aisle.
- The worktable is 2.85 m long, and it was not possible to move it during the test, so it is necessary to adjust the length by two thirds.

The foam waste containers are set up in the lay-out because the VRLD02 and VRLI02 material arrives with a protective foam packaging on each piece; therefore, the container is changed 3 or 4 times per shift, so it is not possible to relocate it.

Once all of the above points had been taken into account, the final proposal was created in which the materials were arranged according to their frequency of consumption (see Figure 3).

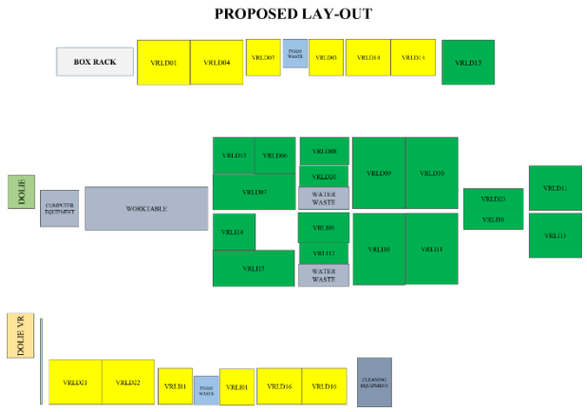

Figure 3 Lay-out proposal

Based on the new distribution of materials proposed for the pilot test, the collaborators were trained in relation to the new distribution of racks, and once they were located in their work area, the test was carried out.

Three samples were taken for each of the methods of the model, then the distances for the new distribution were measured and finally the flow diagrams of operations and spaghetti were drawn up.

Flow of taking VPV, VR model:

With the samples taken, the analysis of times by elements was carried out by taking out their accumulated and the averages of each activity in seconds; collaborator 1 LD (see Table 9), collaborator 2 LI (see Table 10).

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TIME ANALYSIS BY ELEMENTS						
Line or process:		Sequencing line A			Date:	
Operation:		Indoor sequencing LD model VR			Number of observations: 3	
Model VR VPV		REMARKS			TOTAL	PROM
	Description of the element	1	2	3	cs	seg
1	Takes box from rack	0.01 0.01	0.43 0.01	0.85 0.01	0.03	1.00
2	Walks and puts box on table	0.03 0.02	0.455 0.025	0.88 0.03	0.075	2.50
3	Walk around part	0.1 0.07	0.515 0.06	0.95 0.07	0.2	6.67
4	Takes part VRD02	0.11 0.01	0.53 0.015	0.96 0.01	0.035	1.17
5	Walk around part	0.13 0.02	0.55 0.02	0.97 0.01	0.05	1.67
6	Takes part VRD03	0.14 0.01	0.56 0.01	0.98 0.01	0.03	1.00
7	Walks through part	0.16 0.02	0.58 0.02	1 0.02	0.06	2.00
8	Take part VRD04	0.17 0.01	0.59 0.01	1.01 0.01	0.03	1.00
9	Walk around part	0.18 0.01	0.6 0.01	1.02 0.01	0.03	1.00
10	Take part VRD01	0.185 0.005	0.61 0.01	1.03 0.01	0.025	0.83
11	Walk to table	0.21 0.025	0.63 0.02	1.05 0.02	0.065	2.17
12	Cleaning and inspection	0.31 0.1	0.72 0.09	1.13 0.08	0.27	9.00
13	Place in box	0.35 0.04	0.77 0.05	1.17 0.04	0.13	4.33
14	Walks to computer equipment	0.36 0.01	0.78 0.01	1.19 0.02	0.04	1.33
15	Scans	0.42 0.06	0.84 0.06	1.23 0.04	0.16	5.33
Total cycle time		0.42	0.42	0.39	1.23	41

Table 9 Results of the time analysis by elements of the collaborator 1 LD of the VR model, method several pieces at a time

Time analysis by elements						
Line or process:		Sequencing line A			Date:	
Operation:		Indoor sequencing LI model VR			Number of observations: 3	
Model VR VPV		Remarks			Total	Prom
	Item description	1	2	3	cs	seg
1	Walk by part	0.04 0.04	0.515 0.045	0.945 0.04	0.125	4.17
2	Take part VRLI02	0.05 0.01	0.52 0.005	0.955 0.01	0.025	0.83
3	Walk by part	0.06 0.01	0.525 0.005	0.965 0.01	0.025	0.83
4	Take part VRLI01	0.07 0.01	0.535 0.01	0.975 0.01	0.03	1.00
5	Walk through part	0.09 0.02	0.555 0.02	0.995 0.02	0.06	2.00
6	Take part VRLI03	0.1 0.01	0.565 0.01	1.015 0.02	0.04	1.33
7	Walk around part	0.11 0.01	0.575 0.01	1.025 0.01	0.03	1.00
8	Takes part VRLI04	0.12 0.01	0.585 0.01	1.035 0.01	0.03	1.00
9	Walk to table	0.135 0.015	0.605 0.02	1.055 0.02	0.055	1.83
10	Cleaning, inspection	0.255 0.12	0.715 0.11	1.14 0.085	0.315	10.50
11	Places parts in box	0.31 0.055	0.755 0.04	1.18 0.04	0.135	4.50
12	Waiting time	0.39 0.08	0.835 0.08	1.26 0.08	0.24	8.00
13	Walks to computer equipment	0.4 0.01	0.845 0.01	1.27 0.01	0.03	1.00
14	Detaches and attaches label	0.42 0.02	0.855 0.01	1.29 0.02	0.05	1.67
15	Walks to desk	0.43 0.01	0.865 0.01	1.3 0.01	0.03	1.00
16	Takes box	0.44 0.01	0.875 0.01	1.31 0.01	0.03	1.00
17	Walks to dolie	0.46 0.02	0.895 0.02	1.33 0.02	0.06	2.00
18	Deposits box in dolie	0.47 0.01	0.905 0.01	1.34 0.01	0.03	1.00
Total cycle time		0.47	0.435	0.435	1.34	45

Table 10 Results of the time analysis by elements of the collaborator 2 LI of the VR model, method several pieces at a time

The flow charts of collaborator 1 LD (see Annex 5) and collaborator 2 LI (see Annex 6) are shown with the proposed activities and the times obtained from the test (see Table 11).

Proposed distribution	
LD	LI
Cycle time: 41 s	Cycle time: 44.66 s
Distance travelled: 17.62 m	Distance travelled: 18.37 m
Travel time: 17.34 s	Travel time: 13.83 s
The distance travelled was reduced:	
36.57% = **10.16 m**	2.33% = **0.44 m**
Travel time was reduced:	
29.65%=**7.31 s**	24.83% = **4.57 s**

Table 11 Proposed distribution for the VPV method

With the times and distances obtained, a spaghetti diagram was created showing their route when taking their material (see Figure 4).

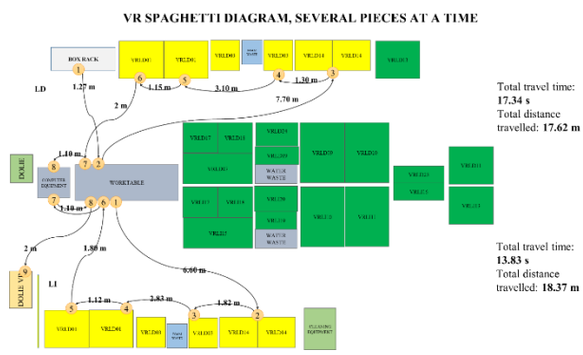

Figure 4 Spaghetti diagram of the VR model, method several pieces at a time

Flow of taking one piece at a time, model VR:

The following tables represent the time analysis by elements with their cumulative and averages for each activity in seconds, contributor 1 LD (see Table 12), contributor 2 LI (see Table 13).

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Time analysis by elements						
Line or process:		Sequencing line A			Date:	
Operation:		Indoor sequencing LD model VR			Number of observations: 3	
Model VR UPV		Remarks			Total cs	.Prom seg
	Item description	1	2	3		
1	Takes box from rack	0.005	0.61	1.265	0.02	0.67
		0.005	0.01	0.005		
2	Walks and puts box on table	0.02	0.63	1.28	0.05	1.67
		0.015	0.02	0.015		
3	Walk around part	0.08	0.68	1.33	0.16	5.33
		0.06	0.05	0.05		
4	Takes part VRD02	0.09	0.69	1.34	0.03	1.00
		0.01	0.01	0.01		
5	Walks to table	0.135	0.74	1.39	0.145	4.83
		0.045	0.05	0.05		
6	Cleaning and inspection	0.205	0.78	1.44	0.16	5.33
		0.07	0.04	0.05		
7	Places in box	0.215	0.795	1.46	0.045	1.50
		0.01	0.015	0.02		
8	Walk around part	0.265	0.84	1.5	0.135	4.50
		0.05	0.045	0.04		
9	Takes part VRD03	0.275	0.85	1.51	0.03	1.00
		0.01	0.01	0.01		
10	Cleaning and inspection	0.315	0.89	1.55	0.12	4.00
		0.04	0.04	0.04		
11	Walk to table	0.345	0.925	1.58	0.095	3.17
		0.03	0.035	0.03		
12	Place in box	0.355	0.935	1.59	0.03	1.00
		0.01	0.01	0.01		
13	Walk around part VRD04	0.375	0.945	1.61	0.05	1.67
		0.02	0.01	0.02		
14	Takes part	0.385	0.955	1.62	0.03	1.00
		0.01	0.01	0.01		
15	Cleaning and inspection	0.405	0.975	1.64	0.06	2.00
		0.02	0.02	0.02		
16	Walk to table	0.435	1.005	1.67	0.09	3.00
		0.03	0.03	0.03		
17	Place in box	0.445	1.025	1.68	0.04	1.33
		0.01	0.02	0.01		
18	Walk around part VRD01	0.46	1.04	1.695	0.045	1.50
		0.015	0.015	0.015		
19	Takes part	0.465	1.055	1.705	0.03	1.00
		0.005	0.015	0.01		
20	Cleaning and inspection	0.5	1.155	1.72	0.15	5.00
		0.035	0.1	0.015		
21	Walk to table	0.525	1.18	1.745	0.075	2.50
		0.025	0.025	0.025		
22	Places in box	0.535	1.195	1.755	0.035	1.17
		0.01	0.015	0.01		
23	Walks to computer equipment	0.545	1.205	1.765	0.03	1.00
		0.01	0.01	0.01		
24	Scans	0.6	1.26	1.81	0.155	5.17
		0.055	0.055	0.045		
Total cycle time		0.6	0.66	0.55	1.81	1.01

Table 12 Results of the time analysis by elements of collaborator 1 LD of the VR model, one piece at a time method

Time analysis by elements						
Line or process:		Sequencing line A			Date:	
Operation:		Indoor sequencing LI model VR			Number of observations: 3	
Model VR UPV		Remarks			Total cs	Prom seg
	Item description	1	2	3		
1	Walk by part	0.06	0.64	1.17	0.175	5.83
		0.06	0.06	0.055		
2	Take part VRLI01	0.065	0.645	1.175	0.015	0.50
		0.005	0.005	0.005		
3	Walk to table	0.115	0.69	1.225	0.145	4.83
		0.05	0.045	0.05		
4	Cleaning and inspection	0.145	0.72	1.255	0.09	3.00
		0.03	0.03	0.03		
5	Places in box	0.155	0.73	1.265	0.03	1.00
		0.01	0.01	0.01		
6	Walk around part	0.195	0.77	1.305	0.12	4.00
		0.04	0.04	0.04		
7	Takes part VRLI02	0.2	0.775	1.31	0.015	0.50
		0.005	0.005	0.005		
8	Walk to table	0.23	0.805	1.34	0.09	3.00
		0.03	0.03	0.03		
9	Cleaning and inspection	0.25	0.83	1.36	0.065	2.17
		0.02	0.025	0.02		
10	Places in box	0.26	0.84	1.37	0.03	1.00
		0.01	0.01	0.01		
11	Walks by part	0.27	0.86	1.38	0.04	1.33
		0.01	0.02	0.01		
12	Takes part VRLI03	0.28	0.865	1.385	0.02	0.67
		0.01	0.005	0.005		
13	Walk to table	0.3	0.89	1.405	0.065	0.17
		0.02	0.025	0.02		
14	Cleaning and inspection	0.315	0.91	1.42	0.05	1.67
		0.15	0.02	0.015		
15	Place in box	0.32	0.92	1.43	0.025	0.83
		0.005	0.01	0.01		
16	Walk around part	0.34	0.94	1.45	0.06	2.00
		0.02	0.02	0.02		
17	Takes part VRLI04	0.35	0.95	1.46	0.03	1.00
		0.01	0.01	0.01		
18	Walk table	0.365	0.97	1.475	0.05	1.67
		0.015	0.02	0.015		
19	Cleaning and inspection	0.39	0.985	1.495	0.06	2.00
		0.025	0.015	0.02		
20	Places in box	0.4	0.995	1.505	0.03	1.00
		0.01	0.01	0.01		
21	Waiting time	0.48	0.995	1.555	0.013	4.33
		0.08	0	0.05		
22	Walks to computer equipment	0.49	1.01	1.565	0.035	1.17
		0.01	0.015	0.01		
23	Detaches and places sequence in box	0.51	1.035	1.59	0.07	2.33
		0.02	0.025	0.025		
24	Walks table	0.52	1.045	1.6	0.03	1.00
		0.01	0.01	0.01		
25	Takes box	0.54	1.065	1.62	0.06	2.00
		0.02	0.02	0.02		
26	Walks to dolie	0.57	1.095	1.65	0.09	3.00
		0.03	0.03	0.03		
27	Deposits box in dolie	0.58	1.115	1.66	0.04	1.33
		0.01	0.02	0.01		
Total cycle time		0.58	0.535	0.545	1.66	0.55

Table 13 Results of the time analysis by elements of contributor 2 LI of the VR model, one piece at a time method

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The flow charts of contributor 1 LD (see annex 7) and contributor 2 LI (see annex 8) are shown with the proposed activities and the times obtained from the test (see Table 14).

Proposed distribution	
LD	**LI**
Cycle time: 1.01 min	Cycle time: 55.33 s
Distance travelled: 39.27 m	Distance travelled: 34.9 m
Travel time: 29.17 s	Travel time: 30 s
The distance travelled was reduced:	
16.95% = **8.02 m**	28.18% = **13.70 m**
Travel time was reduced:	
28.41%=**11.58 s**	23.17% = **9.05 s**

Table 14 Proposed distribution for the UPV method

With the measured times and distances, a spaghetti diagram was created showing their route when taking their material (see Figure 5).

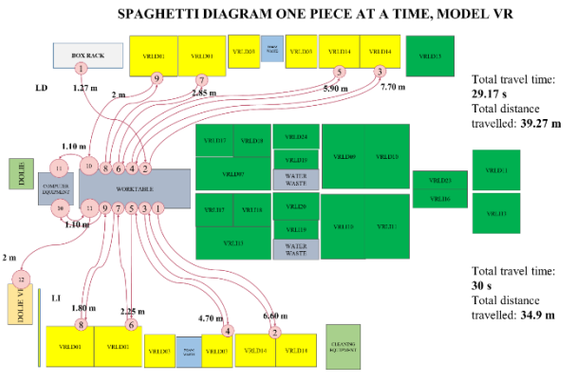

Figure 5 Spaghetti diagram of the VR model, one piece at a time method

Results

As part of the diagnostic stage, five runs were carried out to take the walking times performed by the collaborators in both methods (UPV and VPV) and on both sides (LD and LI), it was identified that the distance travelled by the UPV method on the right side is 47.29 m, and 48.6 m on the left side; while for the VPV method it is 27.78 m and 18.81 m on the right and left side respectively. When implementing the improvements in terms of material relocation, it was observed that the results of distance reduction for the VR model had a positive impact on time reduction. The new distribution of materials, racks and containers allowed a reduction of up to 13 m in the distances travelled by the collaborators in the UPV method and a reduction in time of 8 to 9 s; while for the VPV method the reductions in distances were up to 10 m and in time ranged from 4 to 7 s. (See figure 6).

VR	
UPV Method	
CURRENT DISTRIBUTION	
RH	LH
Cycle time: **1.26 min**	Cycle time: **1.27 min**
Distance travelled: **47.29 m**	Distance travelled: **48.6 m**
Travel time: **40.75 s**	Travel time: **39.05 s**
Target 20% reduction in travel time	
20% = 8.15 s	20% = 7.81 s
PROPOSED DISTRIBUTION	
RH	LH
Cycle time: **1.01 min**	Cycle time: **55.33 s**
Distance travelled: **39.27 m**	Distance travelled: **34.9 m**
Travel time: **29.17 s**	Travel time: **30 s**
The distance travelled was reduced:	
16.95% = **8.02 m**	28.18% = **13.70 m**
Travel time was reduced:	
28.41%=**11.58 s**	23.17% = **9.05 s**

VR	
VPV Method	
CURRENT DISTRIBUTION	
RH	LH
Cycle time: **56.19 s**	Cycle time: **57.45 s**
Distance travelled: **27.78 m**	Distance travelled: **18.81 m**
Travel time: **24.65 s**	Travel time: **18.4 s**
Target 20% reduction in travel time	
20% = 4.93 s	20% = 3.68 s
PROPOSED DISTRIBUTION	
RH	LH
Cycle time: **41 s**	Cycle time: **44.66 s**
Distance travelled: **17.62 m**	Distance travelled: **18.37 m**
Travel time: **17.34 s**	Travel time: **13.83 s**
The distance travelled was reduced:	
36.57% = **10.16 m**	2.33% = **0.44 m**
Travel time was reduced:	
29.65%=**7.31 s**	24.83% = **4.57 s**

Figure 6 Comparative table of time and distance reduction results of the two methods, VR model

Annexes

Ubicación: Área de producción		Resumen				
DIAGRAMA DE FLUJO DE PROCESO						
Actividad: Secuenciado de pilares A LD		Actividad	Actual	Propuesto	Ahorros	
Fecha: 10 de Octubre del 2018		Operación	11			
Colaborador: LD		Transporte	5			
Analista:		Demora	1			
Marque el método y tipo apropiados:		Inspección	3			
Método: ● Actual ○ Propuesto		Almacenaje	0			
Tipo: ● Obrero ○ Material		Tiempo (seg)	59.19			
Comentarios:		Distancia (m)	27.78			
	Descripción de la actividad:	Símbolo				Tiempo (seg)	Distancia (m)
1	Toma caja de rack					1.40	
2	Camina y pone caja en mesa					2.50	1.49
3	Camina por parte					2.80	4
4	Toma parte VRD01					2.45	
5	Limpieza e inspección					1.05	
6	Camina a la mesa					1.95	4
7	Coloca parte en caja					1.85	
8	Camina por parte					5.10	6.39
9	Toma parte VRD02					1.80	
10	Limpieza e inspección					2.00	
11	Camina por parte					2.30	1.93
12	Toma parte VRD03					1.89	
13	Camina por parte					2.40	3.67
14	Toma parte VRD04					2.00	
15	Camina a la mesa					4.70	5.10
16	Limpieza e inspección					7.40	
17	Coloca en caja					4.50	
18	Tiempo de espera					2.10	
19	Camina al equipo de cómputo					2.90	1.20
20	Escanea					3.10	
TOTAL:		11	5	1	3	56.19	27.78

Annex 1: Process flow diagram of partner 1 LD, VPV flow.

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Ubicación: Área de producción		Resumen				
Actividad: Secuenciado de pilares A LI modelo VR		**Actividad**	**Actual**	**Propuesto**	**Ahorros**	
Fecha: 10 de Octubre del 2018		Operación	11			
Colaborador: LI		Transporte	5			
Analista:		Demora	1			
Marque el método y tipo apropiados: Método: ◉Actual ☐Propuesto Tipo: ◉Obrero ☐Material		Inspección	1			
		Almacenaje	0			
		Tiempo (seg)	57.45			
Comentarios:		Distancia (m)	18.81			
	Descripción de la actividad:	Símbolo				**Tiempo (seg)**	**Distancia (m)**
1	Camina por parte					5.20	6.61
2	Toma parte VRLI01					2.35	
3	Camina por parte					1.75	1.60
4	Toma parte VRLI02					1.00	
5	Camina por parte					1.25	1.30
6	Toma parte VRLI03					1.15	
7	Camina por parte					2.10	0.90
8	Toma parte VRLI04					1.80	
9	Camina a mesa					3.40	4
10	Limpieza, inspección					15.70	
11	Coloca partes en caja					7.35	
12	Tiempo de espera					6.10	
13	Camina a equipo de cómputo					1.00	1.20
14	Desprende y coloca secuencia a caja					1.00	
15	Camina a mesa					0.90	1.20
16	Toma caja					1.00	
17	Camina a dolie					2.80	2
18	Deposita caja en dolie					1.60	
TOTAL		11	5	1	1	0	57.45	18.81

Annex 2: Process flow diagram of contributor 2 LI, VPV flow.

Ubicación: Área de producción		Resumen				
Actividad: Secuenciado de pilares A LD modelo VR		**Actividad**	**Actual**	**Propuesto**	**Ahorros**	
Fecha: de Octubre del 2018		Operación	15			
Colaborador: LD		Transporte	5			
Analista:		Demora	0			
Marque el método y tipo apropiados: Método: ◉Actual ☐Propuesto Tipo: ◉Obrero ☐Material		Inspección	4			
		Almacenaje	0			
		Tiempo (min)	1.26			
Comentarios:		Distancia (m)	47.29			
	Descripción de la actividad:	Símbolo				**Tiempo (seg)**	**Distancia (m)**
1	Toma caja de rack					1.80	
2	Camina y pone caja en mesa					2.00	1.49
3	Camina por parte					5.60	6.39
4	Toma parte VRD02					1.30	
5	Camina a mesa					5.20	6.39
6	Limpieza e inspección					3.20	
7	Coloca en caja					2.20	
8	Camina por parte					5.70	
9	Toma parte VRD03					1.60	6.81
10	Limpieza e inspección					3.90	
11	Camina a la mesa					6.50	6.81
12	Coloca en caja					1.05	
13	Camina por parte					4.45	5.10
14	Toma parte VRD04					1.00	
15	Limpieza e inspección					2.06	
16	Camina a mesa					8.60	5.10
17	Coloca en caja					1.05	
18	Camina por parte VRD01					2.10	4
19	Toma parte					1.45	
20	Limpieza e inspección					2.25	
21	Camina a mesa					3.60	4
22	Coloca en caja					1.00	
23	Camina a equipo de cómputo					1.10	1.20
24	Escanea					6.80	
TOTAL:		15	5	0	4	0	1.26 min	47.29

Annex 3: Process flow diagram of collaborator 1 LD, UPV method.

Ubicación: Área de producción		Resumen				
Actividad: Secuenciado de pilares A LI		**Actividad**	**Actual**	**Propuesto**	**Ahorros**	
Fecha: 10 de Octubre del 2018		Operación	17			
Colaborador: LI		Transporte	5			
Analista:		Demora	1			
Marque el método y tipo apropiados: Método: ◉Actual ☐Propuesto Tipo: ◉Obrero ☐Material		Inspección	4			
		Almacenaje	0			
		Tiempo (min)	1.27			
Comentarios:		Distancia (m)	48.6			
	Descripción de la actividad:	Símbolo				**Tiempo (seg)**	**Distancia (m)**
1	Camina por parte					4.40	6.39
2	Toma parte VRLI01					1.00	
3	Camina a mesa					4.80	6.39
4	Limpieza e inspección					3.10	
5	Coloca en caja					1.00	
6	Camina por parte					5.55	6.61
7	Toma parte VRLI02					0.85	
8	Camina a la mesa					4.90	6.61
9	Limpieza e inspección					3.55	
10	Coloca en caja					1.85	
11	Camina por parte					3.70	5.10
12	Toma parte VRLI03					1.10	
13	Camina a mesa					3.70	5.10
14	Limpieza e inspección					2.90	
15	Coloca en caja					1.25	
16	Camina por parte					2.90	4
17	Toma parte VRLI04					1.22	
18	Camina a mesa					3.00	4
19	Limpieza e inspección					2.90	
20	Coloca en caja					1.20	
21	Tiempo de espera					12.20	
22	Camina al equipo de cómputo					1.60	1.20
23	Desprende y coloca secuencia a caja					1.25	
24	Camina a mesa					1.50	1.20
25	Toma caja					1.00	
26	Camina a dolie					3.00	2
27	Deposita caja en dolie					1.00	
TOTAL:		17	5	1	4	0	1.27 min	48.6

Annex 4: Process flow diagram of the UPV method of collaborator 2 LI.

Ubicación: Área de producción		Resumen			
Actividad: Secuenciado de pilares A LD modelo VR		**Actividad**	**Actual**	**Propuesto**	**Ahorros**
Fecha: 25 de Noviembre del 2018		Operación		9	2
Colaborador: LD		Transporte		5	0
Analista:		Demora		0	1
Marque el método y tipo apropiados: Método: ☐Actual ◉Propuesto Tipo: ◉Obrero ☐Material		Combinada		1	2
		Almacenaje		0	0
		Tiempo (seg)		41	15.19
Comentarios:		Distancia (m)		17.62	10.16
	Descripción de la actividad:	Símbolo		**Tiempo (seg)**	**Distancia (m)**
1	Toma caja de rack			1.00	
2	Camina y pone caja en mesa			2.50	1.27
3	Camina por parte			6.67	7.70
4	Toma parte VRD02			1.17	
5	Camina por parte			1.67	1.30
6	Toma parte VRD03			1.00	
7	Camina por parte			2.00	3.10
8	Toma parte VRD04			1.00	
9	Camina por parte			1.00	1.15
10	Toma parte VRD01			0.83	
11	Camina a la mesa			2.17	2
12	Limpieza e inspección			9.00	
13	Coloca en caja			4.33	
14	Camina al equipo de cómputo			1.33	1.10
15	Escanea			5.33	
TOTAL:		9	5	0	1	0	41	17.62

Annex 5: Process flow diagram of collaborator 1 LD, VPV method.

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Ubicación: Área de producción		Resumen				
Actividad: Secuenciado de pilares A LI modelo VR		Actividad	Actual		Propuesto	Ahorros
Fecha: 10 de Octubre del 2018		Operación			11	0
Colaborador: LI		Transporte			5	0
Analista:		Demora			1	0
Marque el método y tipo apropiados:		Combinada			1	0
Método: ☐Actual ◉Propuesto		Almacenaje			0	0
Tipo: ◉Obrero ☐Material		Tiempo (seg)			44.66	12.79
Comentarios:		Distancia (m)			18.37	0.44
		Símbolo			Tiempo	Distancia
	Descripción de la actividad:	●	⇨	D	□	▼	(seg)	(m)
1	Camina por parte						4.17	6.60
2	Toma parte VRLI02						0.83	
3	Camina por parte						0.83	1.82
4	Toma parte VRLI01						1.00	
5	Camina por parte						2.00	2.83
6	Toma parte VRLI03						1.33	
7	Camina por parte						1.00	1.12
8	Toma parte VRLI04						1.00	
9	Camina a mesa						1.83	1.80
10	Limpieza e inspección						10.50	
11	Coloca partes en caja						4.50	
12	Tiempo de espera						8.00	
13	Camina a equipo de cómputo						1.00	1.10
14	Desprende y coloca secuencia a caja						1.67	
15	Camina a mesa						1.00	1.10
16	Toma caja						1.00	
17	Camina a dolie						2.00	2
18	Deposita caja en dolie						1.00	
TOTAL		11	5	1	1	0	44.66	18.37

Annex 6: Process flow diagram of contributor 2 LI, VPV method.

Ubicación: Área de producción		Resumen				
Actividad: Secuenciado de pilares A LD modelo VR		Actividad	Actual		Propuesto	Ahorros
Fecha: 25 de Noviembre del 2018		Operación			15	0
Colaborador: LD		Transporte			5	0
Analista:		Demora			0	0
Marque el método y tipo apropiados:		Combinada			4	0
Método: ☐Actual ◉Propuesto		Almacenaje			0	0
Tipo: ◉Obrero ☐Material		Tiempo (min)			1.01	25 seg
Comentarios:		Distancia (m)			39.27	8.02
		Símbolo			Tiempo	Distancia
	Descripción de la actividad:	●	⇨	D	□	▼	(seg)	(m)
1	Toma caja de rack						0.67	
2	Camina y pone caja en mesa						1.67	1.27
3	Camina por parte						5.33	7.70
4	Toma parte VRD02						1.00	
5	Camina a mesa						4.83	7.70
6	Limpieza e inspección						5.33	
7	Coloca en caja						1.50	
8	Camina por parte						4.50	5.90
9	Toma parte VRD03						1.00	
10	Limpieza e inspección						4.00	
11	Camina a la mesa						3.17	5.90
12	Coloca en caja						1.00	
13	Camina por parte						1.67	2.85
14	Toma parte VRD04						1.00	
15	Limpieza e inspección						2.00	
16	Camina a mesa						3.00	2.85
17	Coloca en caja						1.33	
18	Camina por parte						1.50	2
19	Toma parte VRD01						1.00	
20	Limpieza e inspección						5.00	
21	Camina a mesa						2.50	2
22	Coloca en caja						1.17	
23	Camina a equipo de cómputo						1.00	1.10
24	Escanea						5.17	
TOTAL		15	5	0	4	0	1.01 min	39.27

Annex 7: Process flow diagram of partner 1 LD, VPV method.

Ubicación: Área de producción		Resumen				
Actividad: Secuenciado de pilares A LI		Actividad	Actual		Propuesto	Ahorros
Fecha: 25 de Noviembre del 2018		Operación			17	0
Colaborador: LI		Transporte			5	0
Analista:		Demora			1	0
Marque el método y tipo apropiados:		Combinada			4	0
Método: ☐Actual ◉Propuesto		Almacenaje			0	0
Tipo: ◉Obrero ☐Material		Tiempo (seg)			55.33	20.87
Comentarios:		Distancia (m)			34.9	13.70
		Símbolo			Tiempo	Distancia
	Descripción de la actividad:	●	⇨	D	□	▼	(seg)	(m)
1	Camina por parte						5.83	6.60
2	Toma parte VRLI02						0.50	
3	Camina a mesa						4.83	6.60
4	Limpieza e inspección						3.00	
5	Coloca en caja						1.00	
6	Camina por parte						4.00	4.70
7	Toma parte VRLI01						0.50	
8	Camina a la mesa						3.00	4.70
9	Limpieza e inspección						2.17	
10	Coloca en caja						1.00	
11	Camina por parte						1.33	2.25
12	Toma parte VRLI03						0.67	
13	Camina a mesa						2.17	2.25
14	Limpieza e inspección						1.67	
15	Coloca en caja						0.83	
16	Camina por parte						2.00	1.80
17	Toma parte VRLI04						1.00	
18	Camina a mesa						1.67	1.80
19	Limpieza e inspección						2.00	
20	Coloca en caja						1.00	
21	Tiempo de espera						4.33	
22	Camina al equipo de cómputo						1.17	1.10
23	Desprende y coloca secuencia a caja						2.33	
24	Camina a mesa						1.00	1.10
25	Toma caja						2.00	
26	Camina a dolie						3.00	2
27	Deposita caja en dolie						1.33	
TOTAL:		17	5	1	4	0	55.33	34.9

Annex 8: Process flow diagram of contributor 2 LI, UPV method.

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Conclusions

At the beginning of the project, an inadequate distribution of materials was identified in the assembly area, with the most consumed materials being further away than those of lower consumption. This problem was addressed with a study of times and movements with the help of an analysis of times by elements, which served as support to visualise the time of each activity carried out, the delays and distances involved.

It was possible to carry out the pilot test in spite of space restrictions that did not allow all the necessary adjustments to be made.

The proposed objective was achieved as it was possible to reduce by more than 20% the time and distance travelled for the realisation of the VR model for both methods.

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It is worth mentioning that this distribution remained fixed on the line and it is preferable to take into account the space of the work table, and also to train both collaborators as there is still a difference in the operating times of each one.

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