Technological feasibility for the Application of Cellular Manufacturing in a Typical Costume Workshop (Caporales)

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Abstract

This article aims to verify the technological feasibility of installing a workshop for the production of typical caporal costumes based on the Cellular Manufacturing methodology. By taking samples of times used in the production process, the standard times of each activity were obtained considering constant and variable supplements resulting from the different conditions to which the operators are exposed. It was determined that, under the chosen methodology, the process needs 6 operators and 8 machines to cover the projected demand of 897 suits per month, with a production capacity of 17.89 suits per day. Finally, a u-shaped distribution of the workshop was proposed, which maintains a constant flow within the process and allows exploiting the versatility of the workers.

Keywords
Cellular Manufacturing, Technological Feasibility, Operator Balance Chart, Typical Suits, Lean Manufacturing.

1. Introduction
Culturally, it has been demonstrated that Peru is one of the most diverse countries in America and the world, with a great variety of traditions throughout its regions, cities, and towns. The culture of each people is expressed through music, costumes, dances and more (Sandoval et al. 2014). Peru has as a cultural heritage of humanity the "Festivity of the Virgin of Candelaria" which is celebrated every year during the month of February in the department of Puno. This celebration includes masses, contests, parades, and other activities carried out throughout the month, has the participation of more than 170 dance groups with approximately 40,000 dancers in total (United Nations Educational, Scientific and Cultural Organization [UNESCO] n.d.).

Like many festivities in the country, the dancers use folkloric costumes in the programmed activities, generating a demand. These costumes, which stand out for being bright and colorful, are designed individually by each ensemble, with different colors, designs, and meanings (Podjajcer et al. 2009). Because of these factors the demand for costumes, mainly for the Diablada, Morenada and Caporales dances, is accompanied by a constant search for quality and reliable delivery times. Currently, these costumes are handmade; that is, each unit is made and embroidered by hand. This work is an accepted and valued method by the clients; however, on many occasions, there are problems in their deliveries due to a lousy measurement of the production time required for the requested demand and, in some cases, there are defects in the suits due to bad seams or manufacturing defects.

The present study seeks to find the appropriate technology for its manufacture, which should be adapted to the demand requirements. Based on the market segmentation of the project, it was determined that the demand for caporal costumes in the first year is 2,386 units, which could increase to 4,159 units in the fifth year of operation.

Therefore, it was established as an objective to develop a lean manufacturing approach based on cellular manufacturing to reduce the defects present in manufacturing caporal costumes, covering the opportunities for improvement in both manufacturing time and product quality. The following chapters will present the development of the proposed model for increasing productivity based on the collection of information and the simulation of the application of lean techniques to propose an adequate strategy based on the conditions requested by the customers. Finally, validating that the required technology is available, the technological feasibility of the project is determined.

1.1 Objectives
To determine the technical and operational feasibility of the application of manufacturing cell models in a typical costume workshop, these costumes are used by dancers who participate in the Festivity of the Virgin of Candelaria.

2. Literature Review
Market analyses developed in apparel companies conclude that the application of various tools of the Lean Manufacturing methodology improves quality indicators such as productivity, process cycle times, and waiting times between processes (Bonilla 2007; Lista et al. 2021; Niño 2018).

Therefore, after successful cases applying pull-type manufacturing (Luon et al. 2008; Vargas et al. 2019) and mediating the Cellular Manufacturing tool (Nallusamy 2016; Pattanaik and Sharma 2018), this study will seek to demonstrate through the engineering analysis of the project, in the caporal folk costume market, the application of Lean Manufacturing methodology where the productivity of companies can be highly benefited.

The investigation of the technological feasibility of the implementation of the costume-making workshop will be carried out according to the following aspects:

2.1 Definition of the Production Process
In this article, the description of the production process using a Process Operations Diagram will be used to represent it graphically, considering the operations and inspections in each of the production activities (Balvin et. al, 2022; Fin et al. 2017; Miller et al. 2022).

Finally, the production process of caporal costumes will be presented, applying standardization in the artisanal techniques that cover the current market demand.

2.2 Modular line balancing
A critical factor of a company to improve its productivity. Through time measurements by activities, it aims to find a distribution for the capacity to follow a constant flow of products (Andrade et al. 2019).

The modular line balancing tool will be used to identify the requirement of operators and machinery to meet the projected demand in the study.

2.3 Lean Manufacturing
The technological feasibility test was based on the Lean Manufacturing methodology, which focused on the elimination of the 7 types of lean waste (Muda) using tools such as Manufacturing Cells and cellular manufacturing, which show positive results applied in companies (Bruce 2020; Ibarra and Ballesteros 2017).

The objective is to demonstrate the positive results applying this methodology in the textile sector focused on elaborating of caporal costumes.

2.4 Cellular Manufacturing
According to case studies applied in medium-sized companies, it can be proven that the application of Cellular Manufacturing can increase labor productivity by up to 93%, 50% in the level of quality, and 35% in the use of machines and equipment (Choobineh 2007; Wemmerlöv and Hyer 2007).

The cycle time will be identified to evaluate the productivity of the process, looking for a well-elaborated product and a reliable delivery time.

2.5 Operator Balance Chart
The use of operator takt time measurement allows the identification of bottlenecks of various processes within a process and the ease of redistribution of operator responsibilities to decrease the cycle time of a producer process (Binninger et al. 2018; Loayza 2014).

In the present study, the takt time of each activity will be measured, distributing in an Operator Balance Chart the activities of each worker to optimize the productivity of a caporal costume manufacturing workshop.
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3. Methodological design
The product of this research is a folkloric costume for caporales, which covers the needs of the dancers who are members of groups that participate in the Festivity of the Virgin of Candelaria.

The designs of the elaborate costumes are proposed independently by each of the groups annually, characterized by the presence of embroidery in thread and rhinestones.

These suits will be manufactured in standard sizes; Figure 1 shows the prototypes of the caporal costumes to be delivered to the groups.
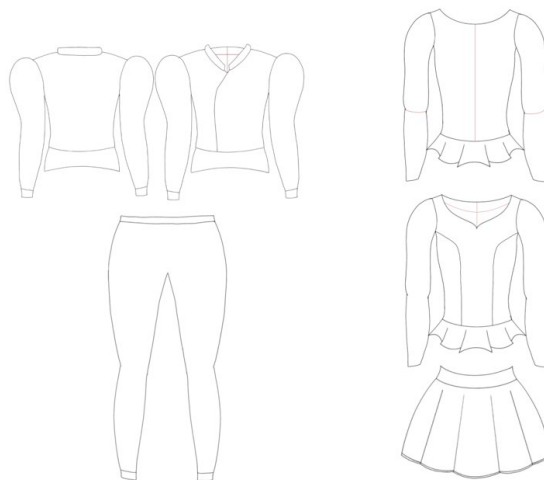

Figure 1. Sketch of caporal costumes

The caporales costume is made of the following materials:
- Taffeta fabric
- Sewing thread
- Embroidery thread
- Embroidery stones
- Fabric labels

Each design has different inputs according to what is requested, so, for the current research, the process of making a basic caporal costume like Figure 2 will be considered.

Figure 2. Basic caporal costume

The process of elaboration of the caporales folkloric costumes is detailed below:

- Receive fabrics, measure, and control quality:

The rolls of fabric supplied by the supplier are received at the sewing plant, followed by their respective measurement to corroborate that the amount of fabric requested conforms. Finally, the fabric undergoes an initial quality control check to ensure it is in good condition.

- Measure and Cut (1):

A first cut is made depending on the piece to be addressed (jacket, pants, sash, or skirt) to facilitate the placement of the molds.

- Cut (2) and Check:

The assigned fabric is cut by an operator using the cutting machine and a respective mold of the piece in standard size. During the cutting process, it is verified that the piece keeps the exact shape of the mold.

- Embroidery:

The piece goes to the embroidery station where the machine is located to embroider the designs on the fabric by adding embroidery threads; this depends on the design and the colors requested by the customer.

- Add rhinestones:

The pieces with the embroidery included are taken to the next machine, which is in charge of adding the rhinestones under the control of an operator.

- Joining and Riveting:

The parts are taken to the next station, where the machines that will be in charge of joining the parts are located.

In all cases, sewing thread is added and, depending on the piece being made, elastic or leather is added. Finally, the joining areas are overlocked so that there are no flaws in the garment later on.

The Process Operations Diagram (POD) of the caporal costumes is shown in the Figure 3.
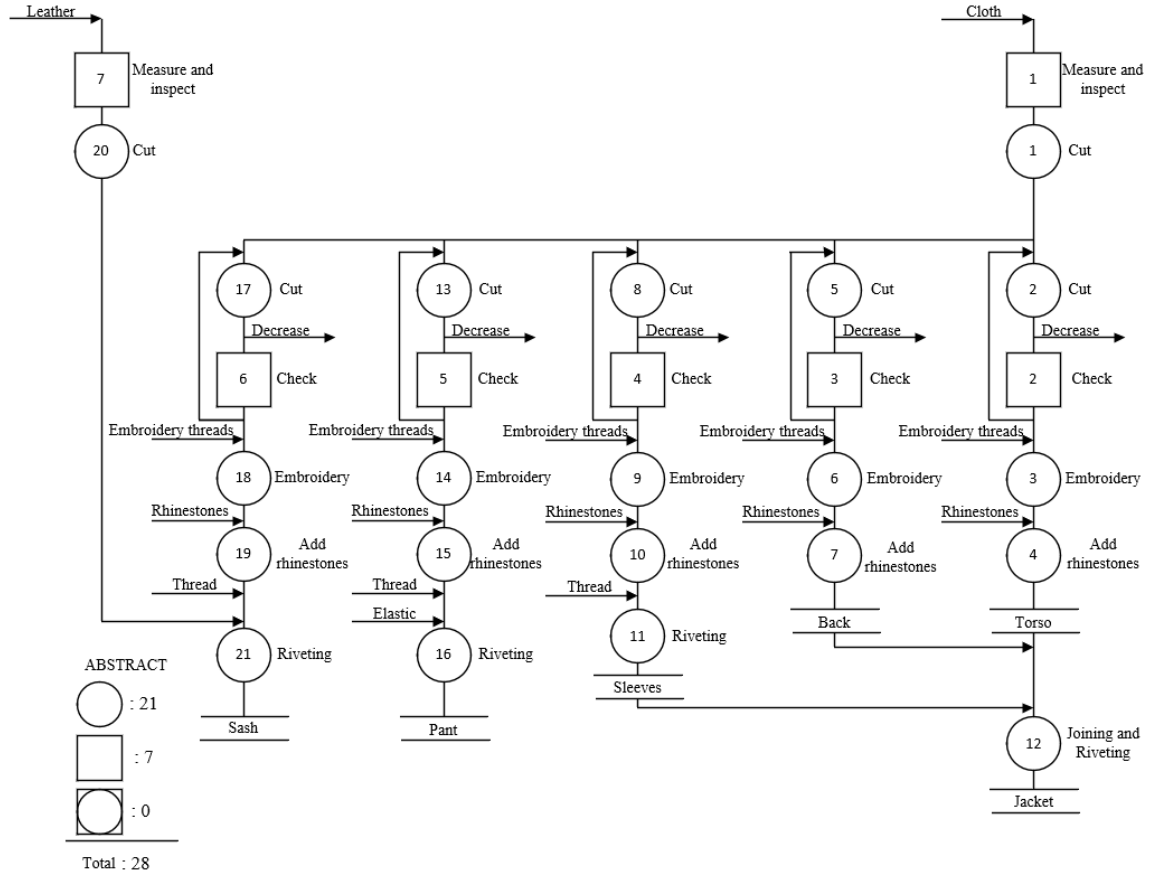
Figure 3. Operations Diagram of the Process of making a caporal costume

The concept of polyvalence is managed for the workers in the workshop so that each operator can perform different activities. The details are shown in the Table 1.

Table 1. Polyvalance matrix

Operator	Operation					
	Cutting Cloth	Piece cut	Cutting inspection	Thread embroiderer	Stone embroiderer	Overlocker
A	x	x	x	x		
B			x	x	x	
C			x	x	x	
D			x	x	x	
E			x	x	x	
F				x	x	x

On the other hand, an analysis was made of the number of machines required to cover the incoming material in each process. As a result, the efficiency used is 85%, maintaining the principle of Overall Equipment Efficiency (OEE), as well as 100% utilization, since these are mechanical machines. The results are show in Table 2.

Table 2. Calculation of machines for production process

Machine	Unit	Incoming amount per year (unit)	Standar Time	E: Efficiency factor	U: Utilization factor	Period time (hours/year)	n	# Machines
Clorh Cutter – Initial	Meter	16,636.00	0.0083	85%	100.00%	2080	0.08	**1**
Cloth Cutter – Sleeves	Meter	3,327.20	0.0083	85%	100.00%	2080	0.02	**1**
Thread embroiderer – Sleeves	Meter	16,636.00	0.0417	85%	100.00%	2080	0.39	**1**
Stone embroiderer – Sleeves	Kilograms	1,247.70	0.0833	85%	100.00%	2080	0.06	**1**
Overlocker – Sleeves	Meter	8,318.00	0.0417	85%	100.00%	2080	0.20	**1**
Cloth cutter – Torso	Meter	4,159.00	0.0083	85%	100.00%	2080	0.02	**1**
Thread embroiderer – Torso	Meter	33,272.00	0.0417	85%	100.00%	2080	0.78	**1**
Stone embroiderer – Torso	Kilograms	2,079.50	0.0833	85%	100.00%	2080	0.10	**1**
Cloth cutter – Back	Meter	4,159.00	0.0083	85%	100.00%	2080	0.02	**1**
Thread embroiderer – Back	Meter	24,954.00	0.0417	85%	100.00%	2080	0.59	**1**
Stone embroiderer – Back	Kilograms	1,663.60	0.0833	85%	100.00%	2080	0.08	**1**
Overlocker – Jacket	Meter	16,636.00	0.0417	85%	100.00%	2080	0.39	**1**
Cloth cutter – Pants	Meter	6,238.50	0.0083	85%	100.00%	2080	0.03	**1**
Thread embroiderer – Pants	Meter	33,272.00	0.0417	85%	100.00%	2080	0.78	**1**
Stone embroiderer – Pants	Kilograms	2,079.50	0.0833	85%	100.00%	2080	0.10	**1**
Overlocker – Pants	Meter	14,556.50	0.0417	85%	100.00%	2080	0.34	**1**
Cloth cutter – Sash	Meter	2,079.50	0.0083	85%	100.00%	2080	0.01	**1**
Thread embroiderer – Sash	Meter	8,318.00	0.0417	85%	100.00%	2080	0.20	**1**
Stone embroiderer – Sash	Meter	1,247.70	0.0833	85%	100.00%	2080	0.06	**1**
Overlocker – Sash	Meter	14,556.50	0.0417	85%	100.00%	2080	0.34	**1**
Cloth cutter – Leather	Meter	2,079.50	0.0083	85%	100.00%	2080	0.01	**1**

Finally, at least one machine is needed to meet the monthly demand of the caporal costume workshop.

The following will show the line balance for each activity or operation within the production process. Considering overtime and projected daily production of 16 suits, working in 8-hour shifts.

Based on the minutes per operation measured, the theoretical positions necessary to meet the established demand were calculated, making a workload distribution per operator, considering that each one can to perform any task within the process. Likewise, the calculation of machines per module and the degree of occupation of each one was made according to the minutes required per operation. The results are show in Table 3.

Table 3. Modular line balance

N°	Operation	Mach.	To (sec)	To (min)	Supl. Const	Sup. Var	To + s (min)	Lot quantity	Min x oper	Actual Efficiency	P/H per person	Theorical positions	Assigned operator	Assigned machine	% Occup. machine
1	Measure and inspect cloth	-	16	0.27	6%	13%	0.32	16	5.08	100%	189.08	0.01	A	-	1.06%
2	Cloth cutter – Initial	CRT	18	0.30	6%	13%	0.36	16	5.71	100%	168.07	0.01	A	CRT	1.19%
3	Cloth cutter – Sleeves	CRT	32	0.53	6%	13%	0.63	16	10.15	100%	94.54	0.02	A	CRT	2.12%
4	Check cut – Sleeves	-	11	0.18	6%	13%	0.22	16	3.49	100%	275.02	0.01	A	-	0.73%
5	Thread embroiderer – Sleeves	BHI	728	12.13	6%	13%	14.44	16	231.02	100%	4.16	0.48	A	BHI (1)	48.13%
6	Stone embroiderer – Sleeves	BPE	953	15.88	6%	13%	18.90	16	302.42	100%	3.17	0.63	D	BPE (1)	63.00%
7	Overlocker – Sleeves	REM	118	1.97	6%	13%	2.34	16	37.45	100%	25.64	0.08	F	REM	7.80%
8	Cloth cutter – Torso	CRT	43	0.72	6%	13%	0.85	16	13.65	100%	70.35	0.03	A	CRT	2.84%
9	Check cut – Torso	-	14	0.23	6%	13%	0.28	16	4.44	100%	216.09	0.01	A	-	0.93%
10	Thread embroiderer – Torso	BHI	1050	17.50	6%	13%	20.83	16	333.20	100%	2.88	0.69	E	BHI (2)	69.42%
11	Thread embroiderer – Torso	BPE	1118	18.63	6%	13%	22.17	16	354.78	100%	2.71	0.74	D, E	BPE (1), BPE (2)	73.91%
12	Cloth cutter – Back	CRT	45	0.75	6%	13%	0.89	16	14.28	100%	67.23	0.03	A	CRT	2.98%
13	Check cut – Back	-	13	0.22	6%	13%	0.26	16	4.13	100%	232.71	0.01	A	-	0.86%
14	Thread embroiderer – Back	BHI	882	14.70	6%	13%	17.49	16	279.89	100%	3.43	0.58	C	BHI (3)	58.31%
15	Stone embroiderer – Back	BPE	526	8.77	6%	13%	10.43	16	166.92	100%	5.75	0.35	C	BPE (3)	34.77%
16	Overlocker – Jacket	REM	262	4.37	6%	13%	5.20	16	83.14	100%	11.55	0.17	F	REM	17.32%
17	Cloth cutter – Pants	CRT	51	0.85	6%	13%	1.01	16	16.18	100%	59.32	0.03	A	CRT	3.37%
18	Check cut – Pants	-	17	0.28	6%	13%	0.34	16	5.39	100%	177.95	0.01	A	-	1.12%
19	Thread embroiderer – Pants	BHI	798	13.30	6%	13%	15.83	16	253.23	100%	3.79	0.53	B	BHI (4)	52.76%

N°	Operation	Mach.	To (sec)	To (min)	Supl. Const	Sup. Var	To + s (min)	Lot quantity	Min x oper	Actual Efficiency	P/H per person	Theorical positions	Assigned operator	Assigned machine	% mach occupation
20	Stone embroiderer – Pants	BPE	689	11.48	6%	13%	13.67	16	218.64	100%	4.39	0.46	B	BPE (4)	45.55%
21	Overlocker – Pants	REM	216	3.60	6%	13%	4.28	16	68.54	100%	14.01	0.14	F	REM	14.28%
22	Cloth cutter – Sash	CRT	39	0.65	6%	13%	0.77	16	12.38	100%	77.57	0.03	A	CRT	2.58%
23	Check cut – Sash	-	17	0.28	6%	13%	0.34	16	5.39	100%	177.95	0.01	A	-	1.12%
24	Thread embroiderer – Sash	BHI	325	5.42	6%	13%	6.45	16	103.13	100%	9.31	0.21	A	BHI (1)	21.49%
25	Stone embroiderer – Sash	BPE	259	4.32	6%	13%	5.14	16	82.19	100%	11.68	0.17	F	BPE (2)	17.12%
26	Overlocker – Sash	REM	205	3.42	6%	13%	4.07	16	65.05	100%	14.76	0.14	F	REM	13.55%
27	Cloth cutter – Leather	CRT	37	0.62	6%	13%	0.73	16	11.74	100%	81.76	0.02	A	CRT	2.45%
28	Measure and inspect leather	-	9	0.15	6%	13%	0.18	16	2.86	100%	336.13	0.01	A	-	0.60%

Considering the calculation of operators, and machinery, a workshop layout is presented considering the methodology of cellular manufacturing in Figure 4.
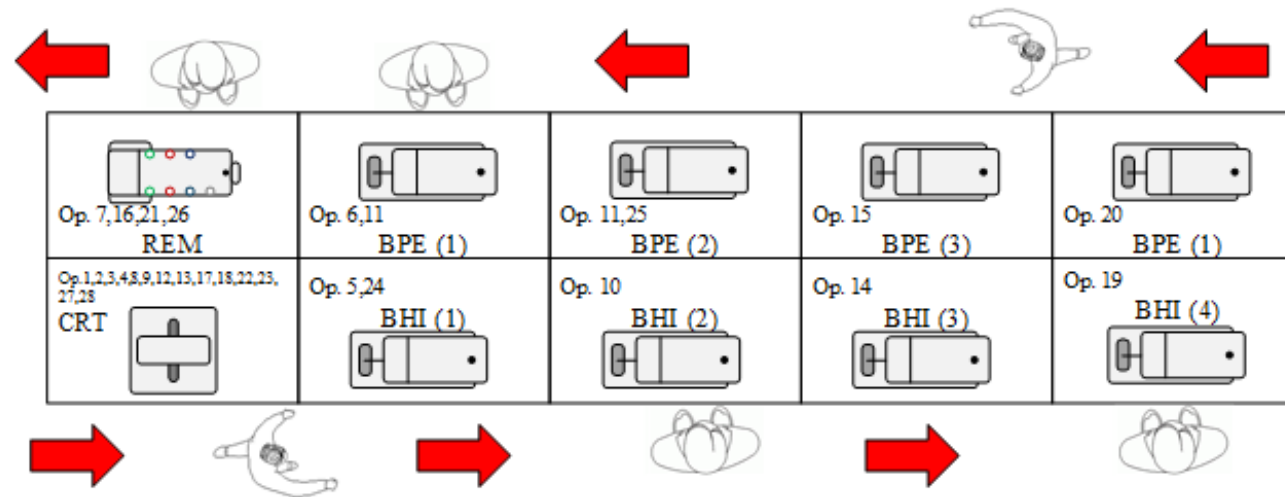

Figure 4. Layout of dressmaking workshop

4. Conclusion

Finally, the Multiple Operations Diagram was made, considering the times and activities performed by each operator and the sequence of these. As a result, obtaining a production of 17 suits per day, meeting the demand of 897 suits per month calculated for the study and a daily productivity of 2.98 suits per operator. The results are show in Figure 5.

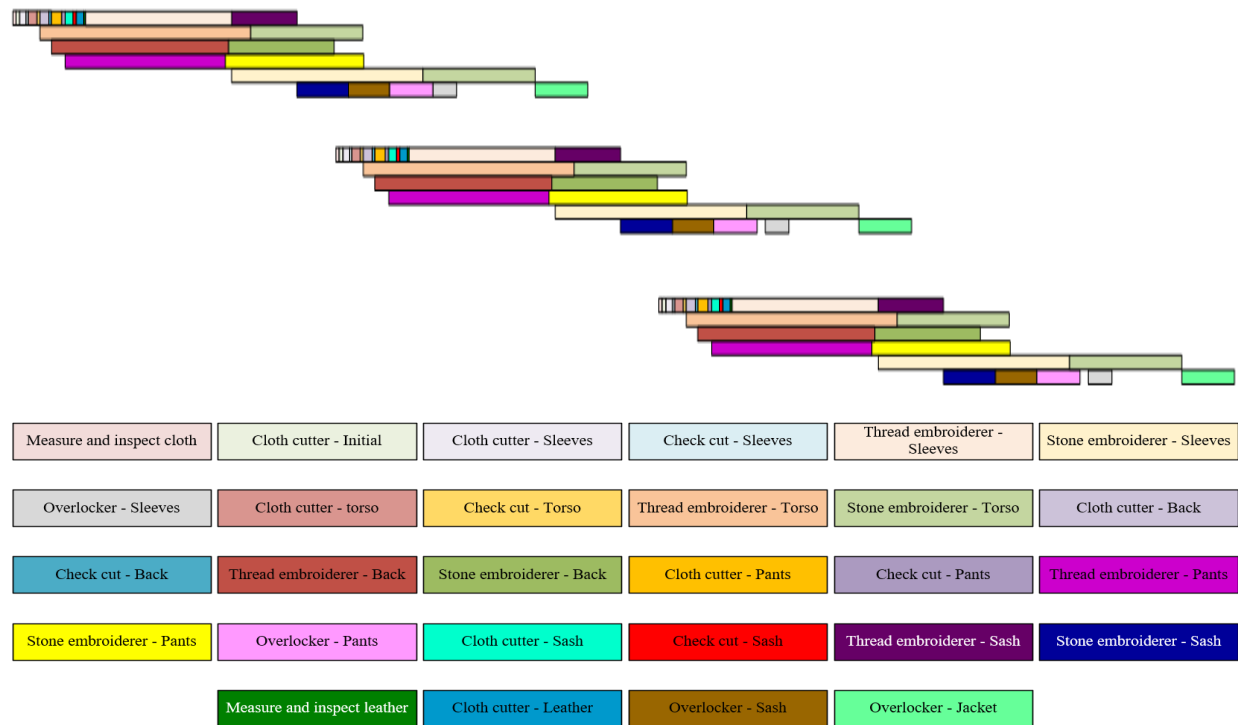| Measure and inspect cloth	Cloth cutter - Initial	Cloth cutter - Sleeves	Check cut - Sleeves	Thread embroiderer - Sleeves	Stone embroiderer - Sleeves
Overlocker - Sleeves	Cloth cutter - torso	Check cut - Torso	Thread embroiderer - Torso	Stone embroiderer - Torso	Cloth cutter - Back
Check cut - Back	Thread embroiderer - Back	Stone embroiderer - Back	Cloth cutter - Pants	Check cut - Pants	Thread embroiderer - Pants
Stone embroiderer - Pants	Overlocker - Pants	Cloth cutter - Sash	Check cut - Sash	Thread embroiderer - Sash	Stone embroiderer - Sash
Measure and inspect leather	Cloth cutter - Leather	Overlocker - Sash	Overlocker - Jacket		

Figure 5. Layout of dressmaking workshop

Based on the analysis, it can be concluded that the key factors for the proposed layout of the workshop were the number of operators and the number of machines needed to cover the monthly demand, for which it is necessary to have multipurpose operators. With a total of 6 operators and 8 machines, it is possible to cover the monthly demand of 897 caporal suits per month, with a production of 17.89 suits, a takt time of 26.81 minutes and a cycle time of 47.73 minutes.

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Biography

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