SEVEN publicações acadêmicas

Unification of processes in production lines in a factory environment: An application of time and motion study

Crossref doi
https://doi.org/10.56238/Connexpemultidisdevolpfut-162

Daniel Guzmán del Río
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0003-4321-0465
E-mail: drio@uea.edu.br

Fernanda Carla dos S. de Oliveira
University of the State of Amazonas, Brazil
E-mail: fcdscarla@gmail.com

Lucas Martins Pacheco
University of the State of Amazonas, Brazil
E-mail: lukspacheco@hotmail.com

Karolayne Barbosa Martins
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0009-0006-7636-8583
E-mail: karolaynebmartins@gmail.com

Andreia Vasconcelos da Silva
University of the State of Amazonas, Brazil
E-mail: andreia.silvand@gmail.com

Daniel Benício de Assis
University of the State of Amazonas, Brazil
E-mail: danielbassis@hotmail.com

Daniel de Farias Soares
University of the State of Amazonas, Brazil
E-mail: danyelsoares@gmail.com

André Luiz Printes
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/ 0000-0001-7915-283X
E-mail: aprintes@uea.edu.br

Israel Gondres Torné
University of the State of Amazonas, Brazil
ORCID: https://orcid.org/0000-0002-1267-1878
E-mail: itorne@uea.edu.br

ABSTRACT
The study of time and motion in the production lines of companies has become important to increase the productivity of companies today in times of Industry 4.0. In this work, which aims to present the unification of processes in production lines in a manufacturing environment of an industry in the Industrial Pole of Manaus - PIM, the authors address the concepts and fundamentals of the "Time and Motion Study"; it examines in detail the movements of workers, machines and equipment and the accounting of time required to do certain activities within the production process, to ensure the optimization of the process. Finally, the reduction of cycle time, optimization of line capacity, and the balancing ratio are presented.

Keywords: Processes, Production, Optimization, Time and Motion.

1 INTRODUCTION

Due to the high competitiveness in the productive market, and the rapid evolution of computer technologies and their introduction in production processes, the traditional industry is transforming, raising it to a new level of organizational development (SANTOS ET AL, 2018). This fact causes companies to be forced to reorganize their work methodologies. One of the main methodologies used by companies is the "Study of Times and Movements", which seeks to determine the time spent by a qualified and properly trained person, working at a normal pace, to perform a specific movement or operation (BARNES, 1977).

The study of time employed in the industrial context was introduced by Taylor, and the study of movements was initiated by the Gilbreth couple. However, the term "Study of Times and Movements" began to be used jointly from 1930 (REZENDE et al., 2016).

In this context, at the level of global survival, the target company of the study had to restructure all its manufacturing in order to find waste in the production lines, where the greatest added value of the product is found, to reduce costs and thus remain competitive.

According to Maximiano (2017, p. 66), studies of times and working methods began in the late nineteenth century with contributions from Taylor at the end. The objective was to solve the wage problems of the workers, and for this, it was necessary to standardize the production per unit of time, in a certain way the study of time "consists in dividing each task into its basic elements and, with the collaboration of the workers, timing and recording them, defining the standard time for each basic element" keeping control of each phase and aspect of each operation of the productive process.

One of Taylor's major contributions was the development and application of timekeeping. In addition, one of the consequences of the study of times and movements was the implementation of the division of labor and the specialization of workers in order to increase productivity. As a result, each worker began to specialize in the execution of a single task, adjusting to the standards described and the performance norms established by the method (CASTRO; BRANCHES; COSTA, 2012).

Figueiredo, Oliveira and Santos (2011) state that the objective of using the tool of studies of times and movements, in the first place, is to eliminate unnecessary efforts when performing an operation; seek to enable employees to perform their role; establish standards for the execution of the work and discover methods that will provide improvements in the production process. There are many flaws that can be solved simply, without many investments. However, certain types of bottlenecks require the application of the methods studied to reduce unnecessary movements and waste of material.

By adopting the Time and Movement Study, companies can achieve a more agile and lean production, optimizing performance and achieving greater profitability. In addition, it allows an in-depth analysis of processes, identifying opportunities for improvement and increasing operational efficiency.

Using the analysis of times and methods as a tool of paramount importance to identify bottlenecks and excess production, timing each step of the production process, it was possible to identify the biggest offenders that were driving the negative result in the factory environment under study.

The objective of this work is to apply the studies of times and movements in a production line of a manufacturing environment. For this, an analysis of workers' movements, machines and equipment was carried out and the accounting of the time needed to do certain activities within the production process, which led to the unification of processes in the production line. It is presented here the before and after of the manufacturing plant, and the gains obtained with the application of improvements and standardization of processes.

2 MATERIALS AND METHODS

To apply the Study of Times and Movements in a factory environment, the following steps were performed:

a) Observation and recording: For the study, the activities performed by the workers were observed, recording the movements performed, the execution times and the methods used.

b) Analysis and classification: The activities were analyzed and classified according to their importance, added value and time required. Bottlenecks, redundant tasks, inefficient movements and opportunities for improvement were identified.

c) Development of more efficient methods: Based on the analysis performed, alternative and more efficient methods to perform the tasks were proposed. This includes redesigning the layout of the workplace, reorganizing production flows, automating certain steps, or introducing new technologies.

d) Testing and implementation: The proposed methods have been tested on a small scale to verify their feasibility and efficacy. Those that showed promise were gradually implemented in the factory environment, with adequate training for the workers involved.

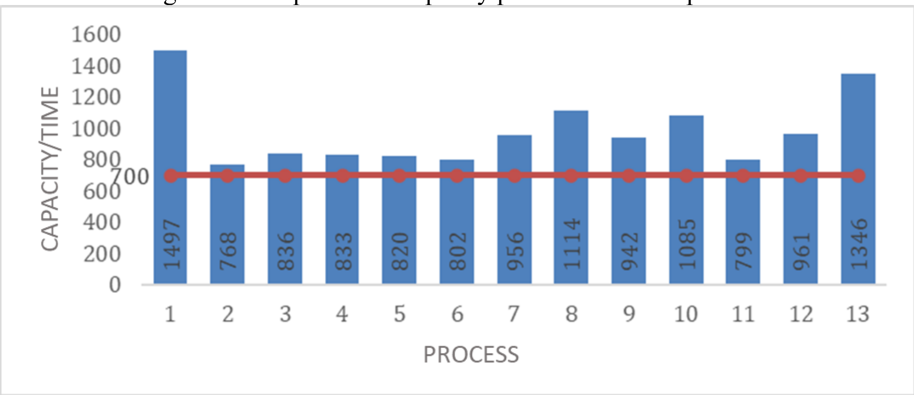
e) Monitoring and continuous review: After the implementation of the improvements, a regular monitoring of the performance and review of the methods adopted was made. This allows you to identify new optimization opportunities and ensure that the improvements implemented are bringing the expected results.

2.1 PROPOSAL TO UNIFY THE ACTIVITIES OF LINE OPERATORS

From the research carried out, the main bottlenecks of a production line of the factory environment under study were identified, which were driving the negative result in the process. For this, a proposal was elaborated to update the plant, based on the unification of activities of the operators of the line.

Figure 1 below shows the line capacity per hour for each process:

Figure 1 - Graph of line capacity per hour for each process.



Source: Own authorship.

Where you have:

Line Capacity	700 pieces/h
Minimum capacity (bottleneck)	768 pieces/h
Maximum capacity (excess)	1497 pieces/h
Balancing rate	49%
Total operators	19
Total processing time	123.18 s

2.2 LINE STATE WITHOUT OPTIMIZATION

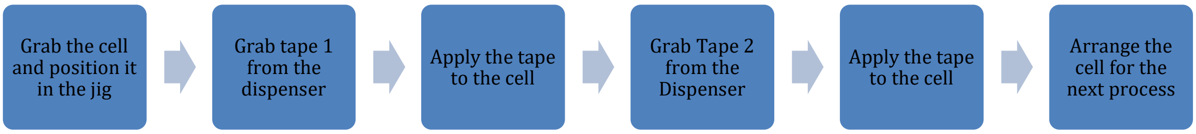
In the current scenario, the production line presents a retention in the flow caused by means of a "bottleneck" *that, from English, means* bottleneck, limiting its productivity with unnecessary accumulation of kamban in the previous stations, idle operators with the lack of raw material, low efficiency in production and high labor costs. Within the impactful context caused by the *bottleneck* it is necessary to make some adaptations.

2.3 SIDE TAPE APPLICATION PROCESS

Using the flow diagram, in Figure 2, each movement necessary to perform the process of application of the lateral tape performed by two operators is demonstrated, as well as the time of each movement demonstrated in Figure 3.

Table 1 shows the sum of the micro-times totaling 8.2 seconds the execution time of the lateral tape application process per operator.

Figure 2 - Flow diagram of the side tape application process.



Source: Own authorship.

Figure 3: Time flow diagram of the side tape application process

Source: Own authorship.

Table 1. Total cycle time of the side-tape application process

Side tape application		Micro-Tempo (s)	Cycle Time(s)
1	Grab the cell and position it in the jig	1.00	8.20
2	Grab tape 1 from the dispenser	1.20	
3	Apply ribbon 1 to the cell	1.90	
4	Grab Tape 2 from the Dispenser	1.20	
5	Apply ribbon 2 to the cell	1.90	
6	Arrange the cell for the next process	1.00	

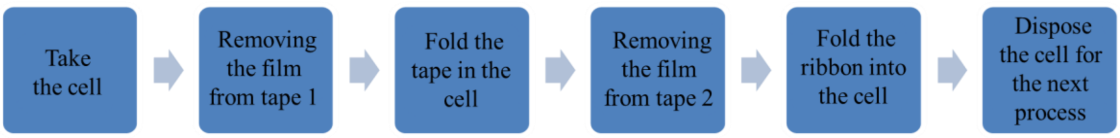
Source: Own authorship.

2.4 SIDE TAPE BENDING PROCESS

Using the flow diagram in Figure 4, each movement necessary to perform the lateral tape bending process performed by two more operators is demonstrated, as well as the time of each movement, shown in Figure 5.

Table 2 shows the sum of the micro-times, totaling 8.4 seconds, the execution time of the lateral tape application process per operator.

Figure 4: Flow diagram of the side tape bending process.



Source: Own authorship.

Figure 5 - Time flow diagram of the side tape bending process.

Source: Own authorship.

Table 2. Total cycle time of the side tape bending process

Side tape folding		**Micro-Time(s)**	**Cycle Time(s)**
1	Grab the cell	1.00	
2	Remove film 1 from tape	1.20	
3	Bending tape 1 into the cell	1.90	**8.40**
4	Remove film 2 from the tape	1.20	
5	Fold tape 2 into the cell	2.10	
6	Arrange the cell for the next process	1.00	

Source: Own authorship.

2.5 PROCESS IMPROVEMENT – UNIFICATION OF PROCESSES

By analyzing the method of each step that makes up the processes of application and folding of the tape, it was possible to identify points of improvement in the method of execution of the steps marked in blue unifying them.

In addition to the improvement in the method performed above, it was possible to eliminate two handles (item 6 and 1).

Adding the total cycles of the two operations (8.2s and 8.4s), it can be stated that the two operations total 16.6s without intervention.

Table 3. Total cycle time of the side-tape application process

Side tape application		**Micro-Time(s)**	**Cycle Time(s)**
1	Grab the cell and position it in the jig	1.00	
2	Grab tape 1 from the dispenser	1.20	
3	Apply ribbon 1 to the cell	1.90	
4	Grab Tape 2 from the Dispenser	1.20	**8.20**
5	Apply ribbon 2 to the cell	1.90	
6	**Arrange the cell for the next process (this step is eliminated)**	**1.00**	

Source: Own authorship.

Table 4. Total cycle time of the side tape bending process.

	Side tape folding	Micro-Tempo (s)	Cycle Time(s)
1	**Grab the cell (eliminates this step)**	**1.00**	**8.40**
2	Remove film 1 from tape	1.20	
3	Bending tape 1 into the cell	1.90	
4	Remove film 2 from the tape	1.20	
5	Fold tape 2 into the cell	2.10	
6	Arrange the cell for the next process	1.00	

Source: Own authorship.

After applying the improvements in the marked movements and eliminating two other movements, demonstrated in the tables above in black, it can be evidenced in table 5 the reduction in the execution time after the unification of these two processes.

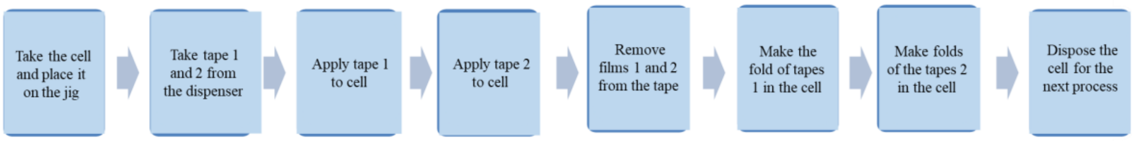
Table 5. Total cycle time of the side-tape bending application process after unification.

	Application and Folding of the Side Tape	Micro-Tempo (s)	Cycle Time(s)
1	Take the cell and position it in the jig;	1.00	13,4
2	**Take tapes 1 and 2 from the dispenser;**	1.80	
3	**Apply tape 1 to the cell;**	1.90	
4	**Apply tape 2 to the cell;**	1.90	
5	**Remove films 1 and 2 from the tape;**	1.80	
6	**Make the fold of tape 1 in the cell;**	1.90	
7	**Make the fold of tape 2 in the cell;**	2.10	
6	Arrange the cell for the next process.	1.00	

Source: Own authorship.

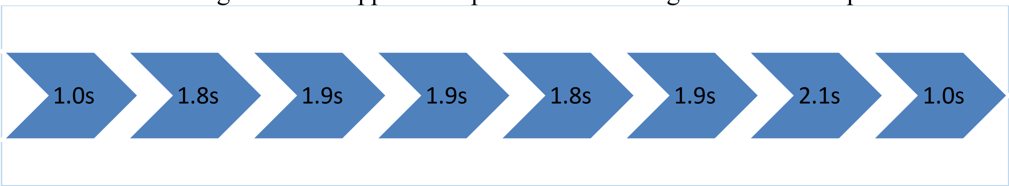
After unification of the processes, the flow diagram of the process of application and folding of the lateral tape is shown in figures 6 and 7.

Figure 6 - Flow diagram of the process of application and folding of the lateral tape after unification.



Source: Own authorship.

Figure 7 - Time flow diagram of the application process and folding of the lateral tape after unification.



Source: Own authorship.

3 ANALYSIS OF RESULTS

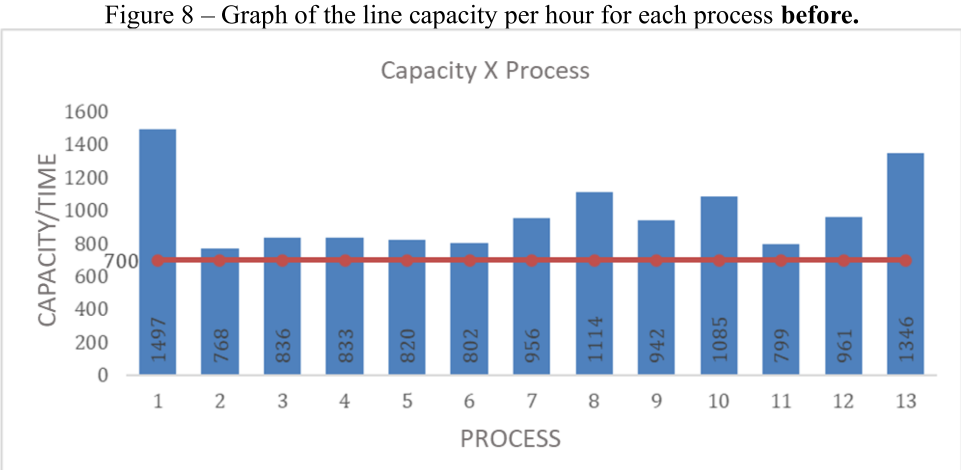
Applying the unification of processes, which was demonstrated earlier, the processes of the production line that could be improved, the following results were achieved.

Minimum capacity (bottleneck)	From 768 to 1,495 pieces/h
Maximum capacity (excess)	From 1497 to 1,923 pieces/h
Balancing rate	From 49% to 78%
Total operators	From 19 to 23

It is noteworthy that until this moment 768 parts/hour were produced using 19 operators, where each operator produced 40.42 parts/hour, after application of the improvements in the processes started to produce 1,495 parts/hour using 23 operators, where each operator started to process 65 parts/hour. With this, a gain of parts produced per operator of 24.58 pieces/hour was obtained.

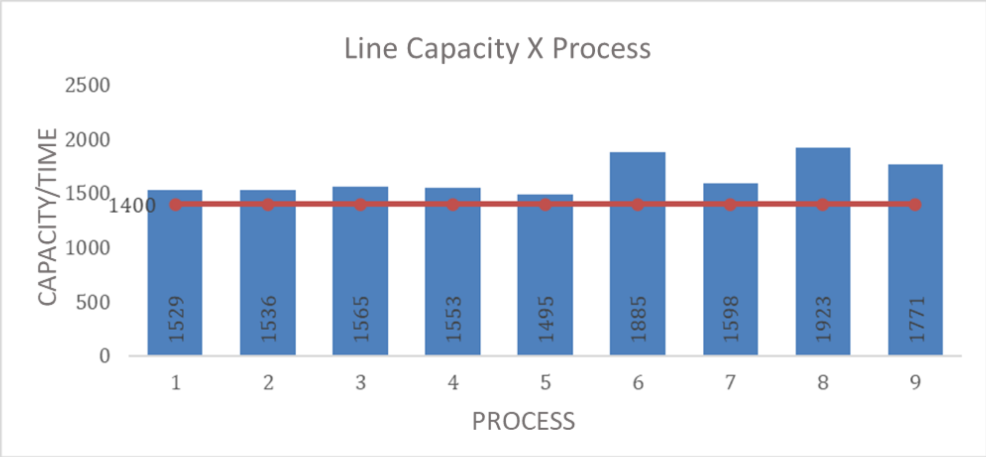
Figures 8 and 9 show the difference between before and **after the** intervention in the production line.

Figure 8 – Graph of the line capacity per hour for each process **before.**



Source: Own authorship.

Figure 9 - Graph of line capacity per hour for each process **later**.



Source: Own authorship.

In addition to the increase in parts produced per operator, there was an improvement in the line balancing rate from 49% to 78%.

3.1 LINE BALANCING

For Moreira (2004), the task of line balancing consists of assigning the activities to the jobs to achieve the desired production rate, thus ensuring that the activities are distributed in a balanced way among the posts. Also, according to the author, the time available to perform the operation at the workstation is called cycle time. The author further states that a basic quantity in line balancing is its efficiency, which is calculated as the quotient between the effective operating time on the line and the total time available.

4 CONCLUSION

In this work we opted for the unification of processes in production lines in a manufacturing environment, through the application of "Studies of Times and Movements", this method of analysis that not only allows to detect in a timely manner the root cause of the problem, but also to provide the best action without costly expenses.

To fulfill the objectives that had been proposed, the study was focused on dividing each task into its basic elements and, with the collaboration of the workers, timing and recording them, defining the standard time for each basic element while maintaining control of each phase and aspect of each operation of the production process. This allowed us to get out of a negative scenario, in which the capacity per process before the unifications held a performance of 49% and after implementation reached the expressive mark of 78%, totaling exactly 29% of gains.

The study allowed to have a tool of paramount importance for the identification of bottlenecks and excess production, timing each step of the process, being able to identify the biggest offenders that were driving the negative result.

ACKNOWLEDGMENT

Thanks to the PD&I Project "Lato Sensu Postgraduate Course in Intelligent Industry Management", to the Laboratory of Embedded Systems and GPA Project of the School of Technology of the University of the State of Amazonas.

REFERENCES

BARNES, R. M. Estudo de movimentos e de tempos: projeto e medida do trabalho. 6. ed. São Paulo: Blucher, 1977. Disponível em: <https://www.academia.edu/29062346/Estudo_de_Tempos_e_Movimentos>.

CASTRO, D. R. C.; RAMOS, M. O.; COSTA, D. Estudo de Tempos e Movimentos no processo de Flow Rack em uma empresa de distribuição. XXXII Encontro Nacional de Engenharia de Produção. Bento Gonçalves, 2012. Disponível em: <https://www.researchgate.net/publication/337167640_ESTUDO_DE_TEMPOS_E_MOVIMENTOS_NO_PROCESSO_DE_FLOW_RACK_EM_UMA_EMPRESA_DE_DISTRIBUICAO>.

FIGUEIREDO F. J. S.; OLIVEIRA T. R. C.; SANTOS A. P. B. M. Estudo de tempos em uma indústria e comércio de calçados e injetados LTDA. XXXI Encontro Nacional de Engenharia de Produção. Belo Horizonte, 2011. Disponível em: <https://abepro.org.br/biblioteca/enegep2011_TN_STO_135_855_19103.pdf >

MAXIMIANO, A. C. A. Teoria Geral da Administração - Da Revolução Urbana à Revolução Digital. 8ª ed. São Paulo: Atlas, 2017.

MOREIRA, D. A. Administração da produção e operações. São Paulo: Pioneira, 2004.

REZENDE, P. A.; MARTINS, T. L. R.; ROCHA, M. F. Aplicação do Estudo de Tempos e Movimentos no Setor Administrativo: Estudo de Caso em Uma Empresa Mineradora. Revista Eletrônica Produção & Engenharia, v. 8, n. 1. Minas Gerais, 2016. Disponível em: <https://periodicos.ufjf.br/index.php/producaoeengenharia/article/view/28766/19663>.

SANTOS, B. P. ALBERTO, A.; LIMA, T.D.F.M.; CHARRUA-SANTOS, F.M.B. Indústria 4.0: Desafios e oportunidades. Revista Produção e Desenvolvimento, 4(1), 111-124. Disponível em: <http://revistas.cefet-rj.br/index.php/producaoedesenvolvimento>.