INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

PRODUCTION BATCH SIZING AND INVENTORY LEVEL CONTROL USING SIMULATION SOFTWARE

Bruna Christina Battissacco
Universidade de São Paulo, Brazil
E-mail: brunacb@usp.br

Walther Azzolini Junior
Universidade de São Paulo, Brazil
E-mail: wazzolini@sc.usp.br

José Henrique de Andrade
Instituto Federal de São Paulo - IFSP, Brazil
E-mail: jose.andrade@ifsp.edu.br

Maicom Sergio Brandão
Universidade Federal de São Carlos, Brazil
E-mail: maicom.brandao@usp.br

José Marcelo Barbosa Palma
Núcleo de Estudos e Pesquisa em Gestão (NEPGEST), Brazil
E-mail: jmarcelo.palma@gmail.com

Submission: 2/24/2021
Accept: 8/10/2021

ABSTRACT

Computer simulation has great application potential in the area of Production Engineering as a tool to support decision making as it allows to simulate the functioning of a real system through logical relationships, in order to observe its behavior under different scenarios. Which could not be practiced in the real system. In line with this aspect, the present work aims to present a report on the application of simulation for the design of production batches and inventory control, highlighting the process necessary for the construction of the generated simulation model, as well as the challenges and opportunities observed. In order to achieve the proposed objective, a literature review was carried out on the topics of interest; the choice and understanding of simulation software and; the survey of data from a large auto parts manufacturer located in the interior of the state of São Paulo. The main results were an increase in production volume from the inclusion and dimensioning of a buffer after the assembly process and a balance between the number of items of each component of the product structure in the supply with the real capacity of manufacturing cell processing. Cabe ressaltar que o modelo de simulação produto da pesquisa deste artigo pode ser aplicado como um sistema de apoio à decisão do gestor para a elaboração do planejamento estratégico e do planejamento operacional com o propósito de melhorar a capacidade de análise e decisão. It is important mentioning that the simulation model in this article can be applied as a support system decision for the preparation of strategic planning and operational planning, with the purpose of improving the analysis capacity for decision-making.

Keywords: Logistics; Cellular manufacturing; Production Management; Simulation

1. INTRODUCTION

The crescent use of technology as a support for the process of productive systems management have shown great potential. It is able to assist decision making, increasing business results accuracy, therefore contributing to efficiency and overall accuracy.

In the emerging context and progressive consolidation of Industry 4.0 (I4.0) and associated paradigms, finding ways to perfect and integrate production management, and making adequate use of the available technologies will be both a challenge and an advantage for the companies that aim to acquire competitive advantages in this new context.

Industry 4.0 is a term conceived in the 2011 Hannover Fair as a part of a long-term strategy from Germany to strengthen their manufacturing sector competitiveness (Liao et al., 2017), and to promote the emergence of dynamic value chains, real time optimized and auto-organized based on criteria as cost, availability and resource consumption (Kagermann et al., 2013). Thus, it could provide the necessary flexibility to companies answering the market's demands, the crescent product personalization, smaller product life cycle, as well as the crescent complexities of products and production (Hirsch-Kreinsen, 2016).

The main technologies and development tendencies that are driving these innovations in the I4.0 include the following themes: Green Information Systems, big data, autonomous robots, horizontal and vertical integration between systems, cyber security, virtual and augmented reality, industrial IoT, additive manufacture, cloud technologies, modeling and simulation, this last one being a key tool for I4.0 solutions by allowing improvement evaluation in a highly complex and dynamic scenario (Goienetxea Uriarte, 2018). The

http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

simulation is defined as the procedure of designing a model of a real or hypothetical system to describe and analyze the system's behavior (Scheidegger et al., 2018).

Simulation is a technology used to develop exploratory and planning models to optimize decision making, as well as to project and operate complex production systems (De Paula Ferreira, 2020; Goienetxea Uriarte, 2018).

Academic studies about risks, costs, receipt potential, and implementation barriers of I4.0 are scarce (Kagermann et al., 2013). Lugert et al (2018) suggest that simulation techniques would be useful to address those issues since they offer the possibility of evaluating multiple I4.0 scenarios through exploratory and complex systems planning methods that can help in the partial treatment of the mentioned problems. Computational simulation, even preceding I4.0, regains relevance since allows the use of computational techniques to simulate the operation of a system from mathematical models. This method comes up as an important tool for it allows the simulation of a real system through logic relations, in order to observe its behavior under different scenarios - which couldn’t be practiced in the real system (Morabito & Pureza, 2010).

Another reason for using simulations is the high costs associated with experiment development in the real system or with building a physical model (Scheidegger et al., 2018).

Particularly, simulations have performed a significant role in assessing the project and the operational performance of the manufacturing systems. Successful applications of simulation in various real-life problems proved their efficiency in approaching several challenges in the manufacturing sector (Negahban, 2014).

Soares et al. (2011) point out that in many studies it is perceived the benefits of simulation, either for previsions or analysis of unexpected events, individual or simultaneous, generated by changes in a productive process. Other benefits of simulation include providing a systemic vision of such changes, which are hardly obtained through conventional analytic studies. In this sense the present article considers the coronavirus (Covid-19) pandemic period and its impacts on scale economy since social isolation is pointed by the World Health Organization (WHO) as an efficient preventive measure to control and contain the sickness, negatively affecting the offer and demand conditions.

In this way, the companies found themselves with their operations totally or partially interrupted, disarticulating the commercial and personal relations and consequently the

http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

supply chain, turning explicit the necessity of integration and review of the operation mode practiced.

Due to this context and given of the computational simulation potential, the objective of the current work is presenting an application report of simulation for the production lots dimensioning and inventory control, highlighting the necessary process to constructing the generated simulation model also the challenges and opportunities observed.

In order to reach the proposed objective, a literature review was made regarding the themes of interest, the choice and comprehension of a simulation software, the data survey from a large auto parts factory located in the interior of São Paulo, and the construction and application of a simulation model for the studied case.

This work is structured in five sections. Beyond the present introduction, section two presents the theoretical references utilized to base the study, section three presents the methodological aspects, followed by data analysis and discussion (section four) and conclusion (section five). In the end, the bibliographical references are presented.

2. THEORETICAL REFERENCES

2.1. Computational Simulation

Simulation is a type of mathematical modeling that aims primarily to portray the dynamics of an existing or planned system for solution evaluation. This technique is recommended to approach a higher detail level on the process (Peixoto & Pinto, 2006). The simulation consists of one of the 4.0 Industry tools, providing more precise and agile information (Gaziero & Cecconello, 2019).

Besides definitions of computational simulations, Gaziero and Cecconello (2019) emphasize that simulation can be used to deal with uncertainty and to create dynamic visions, taking into account stock levels, waiting times, and resource utilization for different scenarios, supporting decision making. Authors as Biswas and Narahari (2004) highlight the importance of utilizing the simulation for analyzing product flow and supply chain information in the decision-making process. It is useful because of the large-scale information from supply chains involving a hierarchical structure of decisions with dynamic interactions between two organizations. In this direction, Hernandez and Librantz (2013) approaches, through a simulation model, the possibility of reducing stock maintenance costs by using a new planning strategy.

http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

Corroborating with the authors, Silva (2005) supported the following hypothesis: the combination between simulation and optimization has great value on decision-making support, bringing significant advantages on elaborating a manufacturing cell with lower production costs.

According to the author, the utilization of Activity Based Management (ABM) / Activity Based Costing (ABC) made it possible to combine necessary information for obtaining more precise costs. Therefore the results of a cell also triggered off an "optimized" production cell. For Negahban and Smith (2014), some of the factors that contribute to the growth of successful publications and applications of simulations are: the incorporation of optimization algorithms in simulation software packages, the reduction of variability and other efficiency increasing techniques. Such factors increased the tool's credibility between researchers and professionals.

2.2. PRODUCTION DIMENSIONING

2.2.1. Production lot dimensioning and inventory control

In the work of Catelan et al. (2020), the problem of lot dimensioning is pictured as basically determining the number of items to be produced in each period of limited time. Variations of machinery quantities involved in the process will consider both resource restrictions satisfaction and demand attendance.

According to the authors, the lot dimensioning problem has an economic origin and involves production costs, stock, and machine preparation. Besides, dimensioning is a tactical and operational competence that interprets strategic planning decisions and transforms them into real production plans. Oliveira and Santos (2017) argue that decisions on lot sizing are necessary to improve stock management and to reduce costs. High stock levels grow costs like maintenance, and low stock levels could delay demand attendance.

It stands out that the programming problem is in determining production lot sequencing to minimize the time and cost generated by lines set up in the production line. In this exchange of products, there is dependency between the previous items the setup time is considered dependant to the sequence and/or cost structure, entailing a simultaneous decision on sizes and sequences of production. According to Glock, Grosse and Ries (2014 apud Oliveira & Santos, 2017, p. 4) "the problem of lot dimensioning (LD) consists in determining the optimal size of production lots in order to minimize costs and attend the clients demand,

http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

receiving special attention of researchers due to its importance for global economy". Between the outstanding authors on literature regarding dimensioning and sequencing of production lots, exemplified by the General Lot-sizing and Scheduling Problem (GLSP) are: Drexl and Kimms (1997), Fleischmann and Meyr (1997), Haase and Kimms (2000), Meyr (2000), Allahverdi et al. (2008), Araújo et al. (2008), Jans and Degraeve (2008), Toso, Morabito and Clark (2009 apud Junqueira & Morabito, 2018), Ferreira et al. (2010), Clark, Almada-Lobo and Morabito (2010 apud Junqueira & Morabito, 2018).

Taking into account the variables used to calculate depletion time and methods for production lot dimensioning, two methods are analyzed as to their implications, respecting cases and peculiarities which would foment different models. That is, the Economic Lot of Shopping (ELS) or the model (Q, r).It must be highlighted that the leveling between produced and consumed value due to the number of competitors and today's uncertainty of demand became a challenge for industries.

The model of Wanke and Saliby (2005) presents a solution of the inventory control (Q, r) model with uniform distribution of demand and lead time.

The model (Q, r) considers the stock of new products and the long term learning of the characteristics on demand distribution in lead-time supply.

Deals with lot sizing and request point for uniform supply lead-time and demand, in a more applicable form than normal distribution due to presenting situations where any result have the same probability of occurrence.

Starting from this premise, Wanke and Saliby (2005), calculating the values of the function of probability density of supply lead-time demand, demand projection and the respective variance of demand on response time (X), can be done through the mathematical expressions (1), (2) and (3).

$$f(X) = \frac{1}{\left(\left((d_M - d_m) \times \left((T_M - T_m)\right)\right)\right)} \tag{1}$$

$$X = \frac{\left(\left((d_M - d_m) \times \left((T_M - T_m)\right)\right)\right)}{4} \tag{2}$$

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

$$S_x^2 = \frac{\left(\left((d_M - d_m)^2 \times (T_M - T_m)^2\right) + \left(3 \times (d_M + d_m)^2 \times (T_M - T_m)^2\right) + \left(3 \times (d_M - d_m)^2 \times (T_M + T_m)^2\right)\right)}{144} \quad (3)$$

In the expressions d_m corresponds to daily minimum demand and d_M to daily maximum, t_m represents minimum supply lead-time in days and t_M maximum supply lead-time, also in days.

The model treats the delimitation of inferior and superior limits both according to demand and resupply lead-time variability.

Regarding the product between demand and supply lead-time, the products of the coordinates of these vertices are $t_m * d_M$ and $t_M * d_m$, and the integration regions also depend on the size of the reorder point.

Depending on the size, according to Wanke and Saliby (2005) the level of service in the cycle must be calculated in one of the three possible integration regions:

1. Integration Region 1: $r \leq t_M \times d_m$
2. Integration Region 2: $r \geq t_m \times d_M$
3. Integration Region 3: $t_M \times d_m < r < t_m \times d_M$

The model of Sarkar et al. (2019) presents the setup time reduction and of the impact of security factors on stock resupply management on supply chain.

In other words, the supply chain model for reorder point considers the productive unit and retail to reduce lead-time and setup time, in order to obtain their impacts on total costs when lead-time demand is stochastic.

With lead-time depending on lot size and consisting in production time and setup time, with free distribution.

The model proposed by Sarkar considers a Two-echelon supply chain: provider or manufacturer and retailer that attend the market. And detects the event of manufacturing process anomaly through the decision variable 0.

The vendor (1st level): manufacturer works with stochastic lead-time (lead-time L(P,Q)) due to productivity oscillation (there is variability between the productive rates P_{min} and P_{max}).

http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

The buyer (2nd level: retailer) operates through the system (Q, S). A system of continuous revision. In this case the retailers always acquire a lot with equal amounts of the product in all dispatches, according to the resupply period.

However there is an impact related to lot size and consequently to production, being considered by Sarkar et al. (2019):

a) Average (DL(P, Q));
b) Standard Deviation ($\sigma\sqrt{L}(P,Q)$);
c) Lead-time depends on setup time and handling time. Both represented by parameter t_S.
d) The Lead time crashing cost also reduces t_s.
e) Setup crashing cost also reduces t_s.
f) The moment also considers the possibility of investments on minimizing setup cost and parts with manufacturing defects.
g) Retailer: there are delayed requests from the manufacturer. In this case there are security factors (k_1 and k_2) for the lots and the security stock (S).

The model considers for the vendor cost function (manufacturer) that the unitary production cost is in function of the production rate P ($/time) according to function C_p (P) presented by expression (4).

$$C_P(P) = \xi_1 P + \frac{\xi_2}{P} \qquad (4)$$

$P_{mín} > D.$

Which impacts on production lot size. Meaning that the bigger the lot more possible for the production rate to rise which is relevant to the factory since it can produce a surplus lot if the demand is inferior to the amount produced in the considered time period.

From the production rate it is also determined the average inventory, being applied the storage cost according to expressions (6) and (7).

$$\frac{h_v Q}{2}\left\{n\left(1-\frac{D}{P}\right)-1+\frac{2D}{P}\right\} \qquad (5)$$

$$custo\ de\ se\ manter\ o\ estoque = h_b \times \left(\frac{Q}{2}+S\right) \qquad (6)$$

With h_v for vendor and h_b equal to ($ / unit / time unit) buyer.

Another crucial point is in varying the storage cost.

http://www.ijmp.jor.br *v. 12, n. 9, Special Edition, December 21, IFLOG 2020*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

The mathematic expression (7), according to the authors, defines the total vendor cost and (8) the total cost of the supply chain.

$$TC_v = \frac{A_v D}{nQ} + \frac{h_v Q}{2}\left\{n\left(1-\frac{D}{P}\right) - 1 + \frac{2D}{P}\right\} + DC_p(P) + B_1 ln\left(\frac{\theta}{\theta_0}\right) + B_2 ln\left(\frac{A_{v0}}{A_v}\right) + \frac{\rho D\theta nQ}{2}$$

(7)

$$\begin{aligned} TC(Q,P,n,k_1,A_v,\theta) \\ &= (A_0 + nC_T)\frac{D}{nQ} + h_b\left(\frac{Q}{2} + k_1\sigma\sqrt{t_S + \frac{Q}{P}}\right) \\ &+ \frac{D\pi}{nQ}\left(\frac{\sigma}{2}\sqrt{t_S + \frac{Q}{P}}\left\{\sqrt{1+k_1^2} - k_1\right\}\right. \\ &\left. + \frac{(n-1)\sigma}{2}\sqrt{t_T}\left[\sqrt{1 + k_1^2\frac{t_2 + \frac{Q}{P}}{t_T}} - k_1\sqrt{\frac{t_2 + \frac{Q}{P}}{t_T}}\right] + \frac{nC_R(t_S)}{\pi}\right) + \frac{A_v D}{nQ} \\ &+ \frac{h_v Q}{2}\left\{n\left(1-\frac{D}{P}\right) - 1 + \frac{2D}{P}\right\} + DC_p(P) + B_1 ln\left(\frac{\theta}{\theta_0}\right) + B_2 ln\left(\frac{A_{v0}}{A_v}\right) \\ &+ \frac{\rho D\theta nQ}{2} \end{aligned}$$

(8)

In the expressions (7) and (8) there is an impact from the parameters Av (cost by setup) and from the amount of defective parts. The total vendor cost and the supply chain cost both rise from a higher lot size.

This dynamic of gains and losses in business and the need for allocating resources in the best possible way converge on the current problems of the decision-making process on costing systems. Besides, for Mantovani et al. (2019), the adequate management of processes inherent to logistics allows companies to obtain competitive advantages allied to cost reduction.

2.2.2. Cell Layout

Similar to the present study, Soares et al. (2011) performed a case study in a manufacturing cell of a company from the automotive sector. Among several studies on computational simulation, restructuring cellular layout seems useful to reduce in-house stock levels, increase resource productivity, reduce lead time, and adequate workforce on the production cell. Decker Junior et al. (2020) highlight that choices of layout configuration are fundamental to make feasible and raise a company's competitiveness. Thus, a cell is projected to attend a determining part (from raw material to finished product), using similar machines

http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

and tooling. Upon contemplating the manufacturing process and the material storage, there is special attention to the manufacturing cell, which according to Mancio and Sellitto (2017), mixes characteristics and layout advantages of processes and products, usually with a substantial reduction in crossing time and in-process inventory. Similar parts and pieces are grouped in number and volume of minimum production, for example, in families or subgroups organized by analytical methods.

Regarding the theoretical framework from Mancio and Sellitto (2017), cellular layouts are best suitable for medium volume and medium variety operations. However, the efficiency of cellular manufacturing will depend on the adequacy of the heuristics used in its planning. And according to Ekren and Ornek (2008), when the production sequencing suffers frequent and substantial changes it is encouraged to incorporate the virtual cellular layout concept. For Carvalho et al. (2019), through the implementation of a manufacturing cell, it is possible to do project a reduction in production time (in days), the potential gain in production time (in %), and the quantity of produced parts (by day). Besides the improvement in stock turnover and reduction in people involved in manufacturing. In other words, the manufacturing cell performance can be measured in multiple ways, such as: productivity, WIP levels, crossing time, average of delayed work, average of anticipated work, average time of work on waiting list, machine utilization, operator utilization, material handling costs, setup costs and inventory costs (Soares et al., 2011).

The relevance of the considerations and analysis of cellular layout are imperative to achieve less waste and to optimize the activities which aggregate value through the productive chain.

3. RESEARCH METHOD

The study contemplated the application of the simulation and modeling method in a manufacturing cell of a big auto parts manufacturer located on the interior of the São Paulo state, which will be referred as Company Alpha. For that, it was considered the simulation stages described by Chwif (1999), which contemplates the model’s conception, its implementation and analysis of the results (Figure 1).

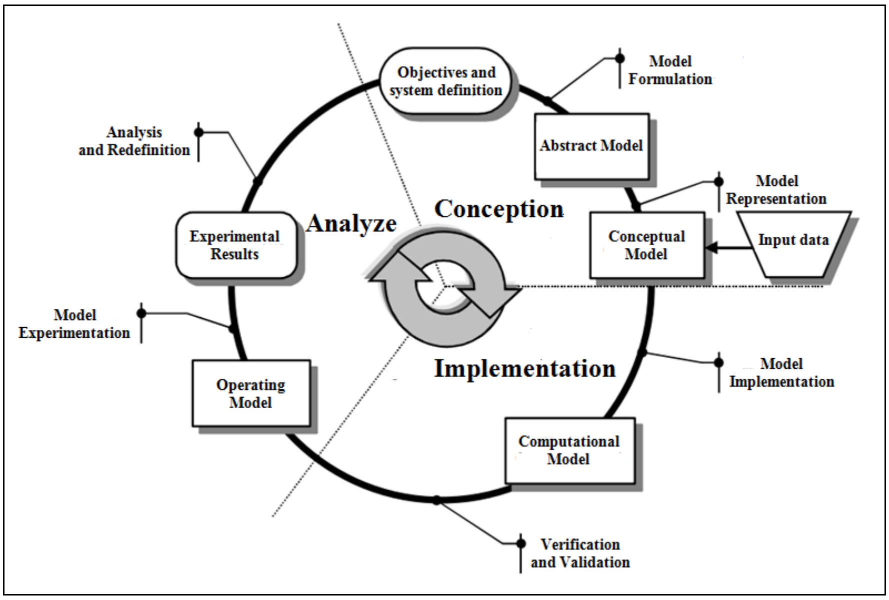

Figure 1: Life cycle of a simulation model
Source: Chwif, 1999, p.10

3.1. Conception

The first stage on constructing a simulation model involves its conception. Thus, it was defined as the objective of the problem representing a production system in a simulation software and the creation of improvement scenarios in lot dimensioning and inventory control.

For that, it was necessary to understand what parameters were fundamental for modeling, so a bibliographic research was performed. In the research, the authors consulted journal databases and scientific publications with recognized sources, national and international. In this first stage there were identified system parameters as depletion time, flow time and average stock. Once identified the parameters and information necessary to describe the system, the first abstract model was elaborated from the processes taking place inside the manufacture cell being studied, involving machining and component assembly, as well as material flow.

From this abstract model, new information’s were added relative to the studied case, that is, the input data collected. Choosing a specific case for application helps on approximating theory and practice. And in this case allows an interesting role of, not only creating an abstract model to evaluate the behavior of the parameters obtained from theory, but also that the application for more than one specific reality allows to explore atypical events in dynamic environments. For example, upon demand unpredictability in order to understand the behavior of production processes and stock management.

http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

It stands out that there is no pretense on exhausting the theme due to being a punctual and robust case, but to foment important analysis to future studies. Therefore much attention and care are given to generalizations or simplifications, and in no moment the scientific rigor is unvalued, being necessary to validate the case study (Yin, 2001; Ventura, 2007).

Some examples of utilized input data: number of suppliers, processing time of machine components and number of hours in a work shift. After collection and input of data, the next stage contemplated the model's implementation.

3.2. Implementation

The implementation stage, as mentioned by Chwif (1999), involves the conversion of the model to a simulation language, which is commonly deeply connected to computational language. For that, the software Plant Simulation was utilized, with its respective programming language. Plant Simulation was developed by Siemens PLM Software and utilized to help on modeling, simulation, analysis and visualization of production processes, material flow and logistic operations. The programming language utilized by the software is SimTalk II.

3.3. Analysis

Finally, the last step involved in the method was analyzing from the experimental or operational model. As the name suggests, this model is the result of the computational model validated by the consistency on representing the studied process and carries great value to creating scenarios (Chwif, 1999).

Five scenarios were explored in this step, altering variables like running machine speed, buffer presence and the increase of the dimension on the process running machine. From the obtained results for flow time and produced volume, it was indicated in which context the best result would be obtained, contributing to a more rationalized decision making.

4. RESULT ANALYSIS AND DISCUSSION

4.1. Model construction and generated scenarios

Figure 2 represents in scale the manufacturing cell used by this study with the work objects distributed on the frame of the Plant Simulation software from Siemens (Version 14.1, proprietary license from the School of Engineering of São Carlos (EESC/USP).

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 12, n. 9, Special Edition, December 21, IFLOG 2020
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

The constructed manufacturing cell model produces a subset of the product manufactured by Alpha company. The subset is assembled on workstation 3. The assembly is executed from the union of 8 components.

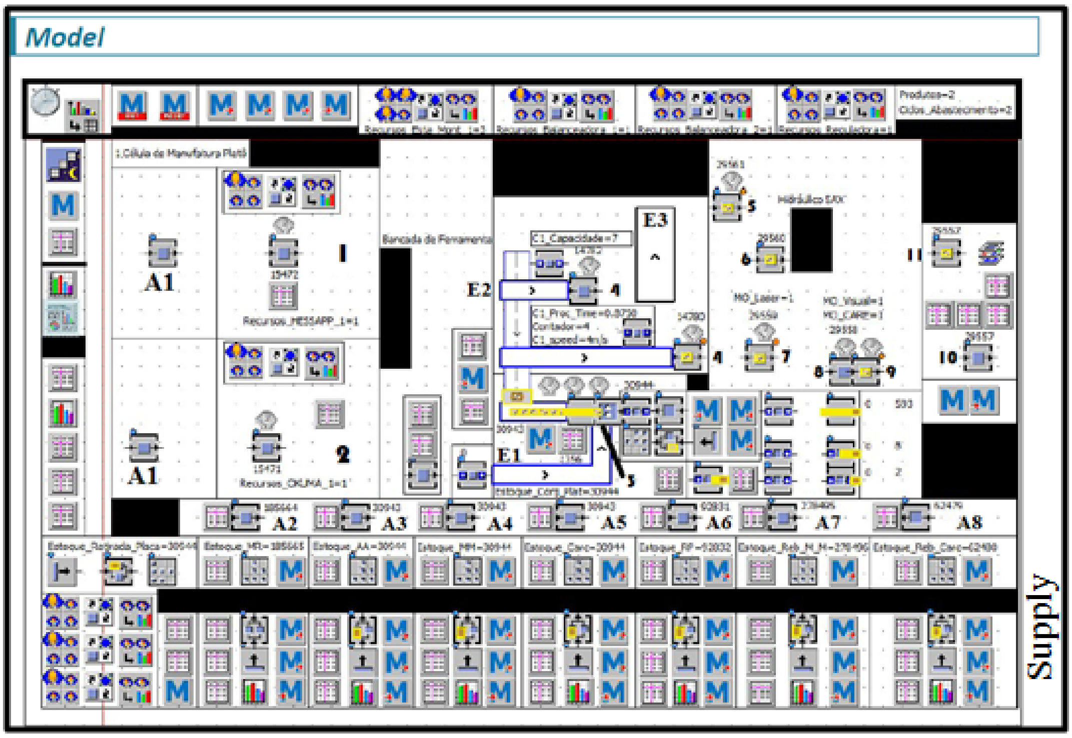

Figure 2: Layout of each Manufacturing Cell.
Source: Authors (2020).

The supply of components in the manufacturing cell is executed by the supply system A1, A2, A3, A4, A5, A6, A7 and A8. In order to replicate the system, the authors developed a routine in SimTalk II language, considering two subset models according to the material structure of the product on Table 1.

The production flow in the manufacturing cell, study object of this work, does not represent a problem with setup times dependent on the sequence, which motivated the authors to consider the model from Wanke and Saliby (2005) to scale the buffer after the assembly process.

In function of the foreseen demand of products A and B, considered by this study as 856 units per day each, and the planning horizon considered as 20 working days with an uninterrupted operation turn of 8.5 hours per day, the available amounts available for cell processing are found on Table 1. Figure 3 represents the saw tooth graph of the supply in question.

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br *v. 12, n. 9, Special Edition, December 21, IFLOG 2020*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

Table 1: Bill of Materials.

Supplier	Item	Quantity	Daily Supply
A1	1	1	1.712
A2	2	6	10.272
A3	3	1	1.712
A4	4	1	1.712
A5	5	1	1.712
A6	6	3	5.136
A7	7	9	15.408
A8	8	2	3.424

Source: Authors (2020).

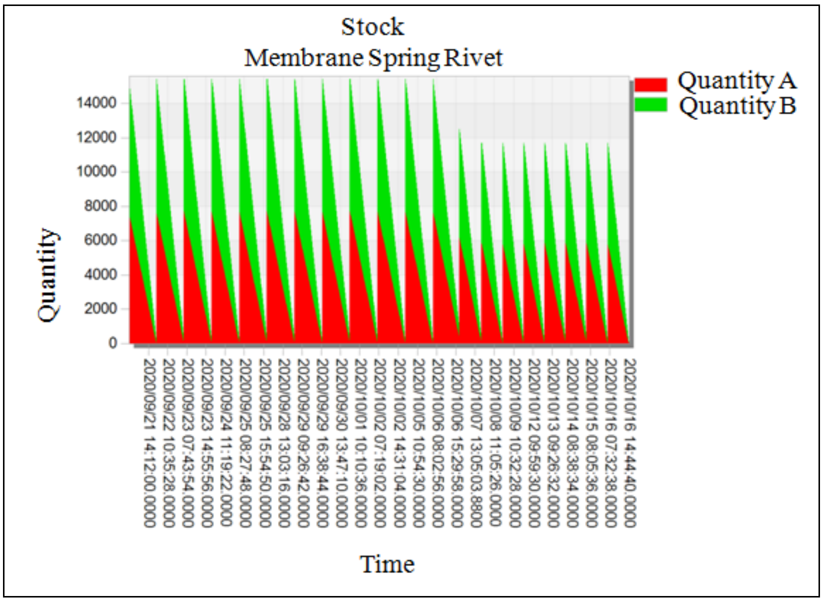

Figure 3: Saw tooth Graph from Item 7 (Supplier A7).
Source: Authors (2020).

Of the eight components from BOM only the Supply A1 component has a machining process, which can be executed in two similar machines with processing time of 17.88 seconds per item on both machines, as indicated by Figure 2.

After machining on machines 1 or 2 the item is transferred to assembly, workstation 3, through running machine E1. The assembly time is 15.5 seconds by set.

The production flow follows from the balancers (workstation 4) to stations 5, 6, 7, 8, 9 and 10. Regulator (15.78 seconds per item), SAX (load measuring machine - 18.69 seconds per item), engraving the laser identification and oiling of the set (13.03 seconds per item), final inspection and packing (12.83 seconds per item).

With the model design finished, with the correct position of the machines on the frame according to the layout of the cell used by the study, five simulation scenarios where generated:

- **1º scenario** – velocity of 1 m/s on the running machine C1 without assembly buffer and the number of items on C1 without definition;

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br *v. 12, n. 9, Special Edition, December 21, IFLOG 2020*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

- **2º scenario –** velocity of 1 m/s on the running machine C1 with assembly buffer and the number of items on C1 after buffer equal to 6;
- **3º scenario –** velocity of 3 m/s on the running machine C1 with assembly buffer and the number of items on C1 after buffer equal to 6 with a raise on volume of items during supply, according to Table 2;
- **4º scenario –** velocity of 3 m/s on the running machine C1 with assembly buffer and the numbers of items on C1 after buffer equal to 6;
- **5º scenario –** increase on the extent of the running machine C1 from 3 to 3.5 meters and raising the velocity from 3 to 4 m/s, with inclusion of buffers on the regulators and the supply buffer raising the amount of items in the running machine after the buffer from 6 to 7.

The best result, according to Table 2, is scenario 4 with a volume of 29.576 items and an assembly flow until the packing of 21.308 seconds. The graph on Figure 3 exhibits the increase on produced volume in addition to the reduction on flow time on assembling the kit's package.

According to Figure 2 the workstation 3 (Assembly) when liberating the set its operation becomes restricted due to the velocity of the running machines and the transport tables to the balancing machines. Before the inclusion of the buffer after assembly, due to the lack of space for set movement, limiting the space on the running machine C1, and the transporting table do not perform the transport operation, interrupting assembly while waiting for space liberation.

Table 2: Supply volume of the items on each scenario.

			Production Lot by product			
Scenario	**Produced Volume**	**Flow Time**	**1st week**	**2nd week**	**3rd week**	**4th week**
1	26.692	23,616	856	650	650	650
2	26.679	23,615	856	650	650	650
3	29.572	21,310	856	856	856 / 650	650
4	29.576	21,308	856	856	856 / 650	650
5	29.574	21,311	856	856	856 / 650	650

Source: Authors (2020).

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

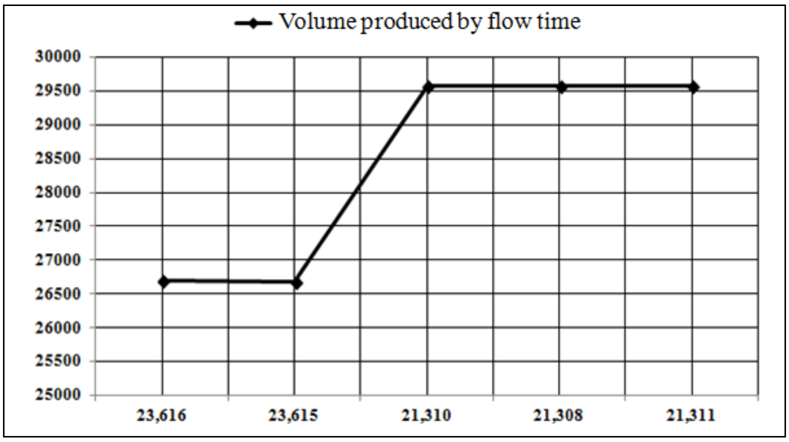

Figure 4: Variation of produced volume against reduction of flow time.
Source: Authors (2020).

The inclusion of a buffer regulates the flow so interruptions in the assembly won't be necessary, maintaining a more continuous production flow and raising produced volume as shown in Table 2.

From the construction model and flow reconfiguration with the buffer inclusion after assembly the authors applied the lot dimensioning procedure from the authors Wanke and Saliby (2005) to scale the item volume to be kept on the assembly buffer in order to maintain continuous flow without interruption with minimal stock.

The buffer calculation after assembly was accomplished according to expressions 2 and 3. Tables 3 and 4 show the results.

Table 3: Lot dimensioning assembly buffer.

Minimum daily demand	d_m	591 sets/day
Maximum daily demand	d_M	856 sets/day
Lead time of minimum resupply	t_m	0,58 days
Lead time of maximum resupply	t_M	1,30 days
Variance	S_x^2	1754,16
Standard Deviation	S_x	41,88

Source: Authors (2020).

Table 4: Expected demand by answer time (X).

Expected demand by answer time (X)		
Description	***Lead Time***	**Demand**
Response time (medium) with demand projection	0,94 days	678,24 / day
Response time (minimum) with demand projection	0,58 days	856,00 / day
Response time (maximum) with demand projection	1,30 days	1356,49 / day

Source: Authors (2020).

5. CONCLUSIONS

The achieved results, although preliminary, revealed the importance of simulation as a support tool for decision making in the process of lot dimensioning with emphasis on inventory cost reduction for industry 4.0.

ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

For complex environments, it is not a simple task to plan the production flow points which require buffer stages in order to maintain synchronism as well as dimensioning, , especially in environments with an elevated number of items being moved and processed, even if in a manufacturing cell.

The present work achieved its objective regarding the development of a model and its gauging, presenting preliminary results through the application of the Wanke and Saliby (2005) model with positive results regarding the raising of production volume whilst reduction of flow time.

REFERENCES

Biswas, S., & Narahari, Y. (2004). Object oriented modeling and decision support for supply chains. **European Journal of Operational Research, Amsterdam**, 153, 704-726.

Carvalho, P. S., Schneider, V. A., Parreira, L., & Chapoval Neto, A. (2019). Proposta de implantação de uma célula de manufatura: um estudo de caso em uma metalúrgica. **Gepros: Gestão da Produção, Operações e Sistemas, Bauru**, 14(4), 114.

Catelan, M. C. F., Araujo, S. D., Fiorotto, D. J., & Carvalho, D. M. (2020). Heurísticas para o problema de dimensionamento de lotes com máquinas paralelas flexíveis. **TEMA, São Carlos**, 21(2), 313-337.

Chwif, L. (1999). **Redução de modelos de simulação de eventos discretos na sua concepção: uma abordagem causal**. 151 f. Tese (Doutorado em Engenharia Mecânica) - Escola Politécnica, Universidade de São Paulo, São Paulo.

De Paula Ferreira, W., Armellini, F., & De Santa-Eulalia, L. A. (2020). Simulation in industry 4.0: A state-of-the-art review. **Computers & Industrial Engineering**, 149.

Decker Junior, C. D., Henning, E., Ferreira, J. C. E., & Zappelino, B. F. (2020). Comparação dos projetos fatoriais completo e fracionado em um modelo de simulação de eventos discretos em um sistema de manufatura para os leiautes celular e celular virtual. **Gepros: Gestão da Produção, Operações e Sistemas, Bauru**, 15(2), 23-57.

Ekren, B. Y., & Ornek, A. M. (2008). A simulation based experimental design to analyse factors affecting production flow time. **Simulation Modeling Practice and Theory, Amsterdam**, 16, 278- 293.

Gaziero, C., & Cecconello, I. (2019). Simulação Computacional do Fluxo de Valor: uma proposta de Integração da Indústria 4.0 e Lean Production. **Scientia Cum Industria**, 7(2), 52-67, 2019.

Goienetxea Uriarte (2018). Ainhoa; NG, Amos HC; URENDA MORIS, Matías. Supporting the lean journey with simulation and optimization in the context of Industry 4.0. In: **Procedia Manufacturing**. 586-59.

Hernandez, M. A. G., & Librantz, A. F. H. (2013). Improvement of the supply chain for the sugar cane exportation process employing discrete events simulation techniques. **Acta Scientiarum, Maringá**, 35(4), 637-643.

Hirsch-Kreinsen (2016). **Hartmut. "Industry 4.0" as Promising Technology: Emergence, Semantics and Ambivalent Character**.

http://www.ijmp.jor.br *v. 12, n. 9, Special Edition, December 21, IFLOG 2020*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

Junqueira, R. D. Á. R., & Morabito, R. (2018). Programação e sequenciamento das frentes de colheita de cana-de-açúcar: modelo e métodos de solução para problemas de grande porte. **Gestão & Produção**, São Carlos, 25(1), 132-147. DOI: https://doi.org/10.1590/0104-530x2647-16.

Kagermann, Henning et al. (2013). **Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group**. Forschungsunion.

Liao, Yongxin et al. (2017). Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal. **International journal of production research**, 55(12), 3609-3629.

Lugert, Andreas, Batz, Aglaya, & Winkler, Herwig (2018). Empirical assessment of the future adequacy of value stream mapping in manufacturing industries. **Journal of Manufacturing Technology Management**.

Mancio, V. G., & Sellitto, M. A. (2017). Sistemas flexíveis de manufatura: definições e quadro de trabalho para futura pesquisa. **Revista GEINTEC-Gestão, Inovação e Tecnologias, São Cristóvão**, 7(2), 3760-3773.

Morabito, R., & Pureza, V. (2010). **Modelagem e simulação**. In: Miguel, P. A. C. (Org.). **Metodologia de pesquisa em engenharia de produção e gestão de operações**. Rio de Janeiro: Elsevier, 165-194.

Negahban, Ashkan, & Smith, Jeffrey S. (2014). Simulation for manufacturing system design and operation: Literature review and analysis. **Journal of Manufacturing Systems**, 33(2), 241-261.

Oliveira, W. A., & Santos, M. O. (2017). Uma nova regra de ramificação para resolver o problema de dimensionamento de lote capacitado e programação com configurações dependentes de sequência. **TEMA**, São Carlos, 18(3), 515-529, DOI: http://dx.doi.org/10.5540/tema.2017.018.

Peixoto, E. C., & Pinto, L. R. (2006). Gerenciamento de estoques via previsão de vendas agregadas utilizando simulação. **Production (Online)**, 16(3), 569-581.

Sarkar, B., Guchhait, R., Sarkar, M., Pareek, S., & Kim, N. (2019). Impact of safety factors and setup time reduction in a two-echelon supply chain management. **Robotics and Computer-Integrated Manufacturing,** New York, 55, 250-258.

Scheidegger, Anna Paula Galvão et al. (2018). An introductory guide for hybrid simulation modelers on the primary simulation methods in industrial engineering identified through a systematic review of the literature. **Computers & Industrial Engineering**, 124, 474-492.

Silva, W. A. (2005). **Otimização de parâmetros da Gestão Baseada em Atividades (ABM) aplicada em uma célula de manufatura**. 2005. Dissertação (Mestrado em Engenharia de Produção) - Universidade Federal de Itajubá, Itajubá.

Soares, J. P. M., Lemos, F. De O., Araújo, C. L. K., & Hansen, P. B. (2011). A contribuição da simulação computacional para a análise sistêmica da reestruturação de layout e otimização de recursos na manufatura celular: estudo de caso em uma célula de uma empresa do ramo automotivo. **Produto & Produção (Online)**, [S. l.], 12(3), 49-68.

Soares, João Pedro M. et al. (2011). A contribuição da simulação computacional para a análise sistêmica da reestruturação de layout e otimização de recursos na manufatura celular:

http://www.ijmp.jor.br _v. 12, n. 9, Special Edition, December 21, IFLOG 2020_
ISSN: 2236-269X
DOI: 10.14807/ijmp.v12i9.1592

estudo de caso em uma célula de uma empresa do ramo automotivo. **Produto & Produção (Online)**.

Ventura, M. M. (2007). O estudo de caso como modalidade de pesquisa. **Revista SoCERJ**, 20(5), 383-386.

Wanke, P., & Saliby, E. (2005). Proposta para a gestão de estoques de novos produtos: solução do modelo (q, r) para a distribuição uniforme da demanda e do lead-time de suprimento. **Gestão & Produção**, São Carlos, 12(1), 1-20.

Yin. R. (2001). **Estudo de caso: planejamento e métodos**. 2. ed. Porto Alegre, RS: Bookman.