International Journal of Research Studies in Science, Engineering and Technology
Volume 4, Issue 8, 2017, PP 40-44
ISSN : 2349-476X

Application of Queue Theory in a Continuous Assembly Line for Setting Conwip Level

Edson Manica[1], Prof. Dr. Solange da Silva[2]

[1]*University (Membership): Pontifical University Catholic of Goiás - PUCGO; Academic Master's Program in Production Engineerin and Systems; State of Goias, Brazil;*

[2]*University (Membership): Pontifical University Catholic of Goiás - PUCGO; Professor Master´s Program in Production Engineering and Systems; State of Goias, Brazil;*

***Corresponding Author:** Edson Manica, University (Membership): Pontifical University Catholic of Goiás - PUCGO; Academic Master's Program in Production Engineerin and Systems; State of Goias, Brazil;*

Received Date: 21-11-2017 ***Accepted Date: 28-11-2017*** ***Published Date: 04-12-2017***

ABSTRACT

The queue theory and simulation tool, has helped companies to improve their processes by understanding the constraints of their systems. This article aims to present the study on a continuous assembly line power generators in a Brazilian manufacturer of electrical equipment in order, to identify how your bottleneck resource behaves, to then define the level of Constant Work in Process (CONWIP) system. The methodology was applied research, as sought solutions to the proposed problem. The result was the implementation of actions that have standardized volume CONWIP system at the level of just meet the demand scheduled for the day, reducing queues and also the cost of acquisition of raw materials.

Keywords: *CONWIP, Queuing Theory, reduction of WIP*

INTRODUCTION

High levels of work in process (WIP) borne from companies costs, take the flexibility of the production lines and hide production losses across the flow value chain. Alternatives come to make the most prepared manufacturing environments to demand fluctuations in the market and high volumes of WIP, as the systems of production and purchase orders Coordination (SCO). Lage at Junior. Al., (2008) the goal of a SCO is to achieve high level of customer service without increasing inventories; however, choose the system best suited for the production of customized items in practice it is still a challenge.

To Boonlertvanich (2005) between models of SCO, the CONWIP appears as an alternative to defining the ideal amount of WIP in the production flow of customized products. Boonlertvanich (2005) also says that when the given level of WIP is reached, new orders are not released before the current leave the system. However, to limit the issuance of new orders, you must understand the production flow behavior, identifying boundary points, which generate expected in the system.

Among the alternatives to identify standby generators in production flows, which automatically raise the WIP, the discrete event simulations, such as Theory of Queues (TF), assist in making strategic decisions, to guarantee a continuous and controlled flow in WIP levels. Andrade (2000) TF is one of the techniques of operations research, which deals with problemssystems jams where services are requested, however, are limited by inherent constraints of the system, which, because of this, can cause queues.

Given this context, this article aims to answer the following questions: - How TF can help to understand the bottlenecks resource behavior for making decisions about CONWIP levels of the system? You can reduce the WIP when you have a resource bottleneckon the continuous production line?

This article aims to present the study conducted between February and June 2017 in an assembly line of power generators in a Brazilian manufacturer of electrical equipment using the TF to understand the behavior of the arrival of components in the bottleneck resource the production line in order to define the CONWIP level system. The methodology was applied research, as sought solutions to the proposed problem. This study is relevant because, restrictions are present in all types of processes, from industrial to service, have studies on how to identify them and measures them, helps other researchers in their projects.

LITERATURE REVISION

In this section, topics related to CONWIP, bottleneck resource and queuing theory will be presented for the formation of the theoretical basis necessary to perform the experiment.

CONWIP

For Spearman et al. (1990) an effective and efficient production control system must be able to produce the right amount at the right time and at a competitive cost. These systems usually are divided into pushed and pulled production systems. According to Serene, et. al., (2011) the CONWIP is a hybrid control system of production, which can be seen pulled by the end of the line and pushed from start to end of the line. To Bonvik (1999) CONWIP is a production control strategy that limits the maximum number of shares allowed within a system at the same time. Spearman et al. (1990) also says that just as in the KANBAN method of inventory control, CONWIP limits the amount of WIP in the system, with the benefit of reducing costs and lead time. According to Vollmann et. al.

With the development of concepts and production systems, ways of reducing the lead-time (RT) of the products on the production line and therefore the WIP have been discussed. To Wiendahl (1995) TA is the time from start of the process until the completion of operations in the manufacturing script. According to yet Wiendahl (1995) TA operations comprises:

- Expected after the previous processing;
- Transport to the current work center;
- Queuing;
- Preparation;
- Processing and inspection.

For Sellito (2005) is measured, the TA is affected by randomness in the queue and processing. Kleinrock (1975) says that the process is in balance, the averages of arrivals and departures are equal rates during the period of analysis.

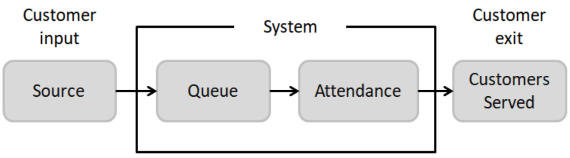
Bottleneck feature

Among the possible forms of restriction of a production system, the limited capacity of certain equipment to meet the planned demand, will define it as a bottleneck resource. For Goldratt & Fox (1997), the bottleneck is the feature that restricts the output of the production system, leading to the formation of queues between operations.

Theory of Queues

Andrade (2000) says that, especially from the 30s, research related to TF emerged with greater visibility. According Monks (1987), queuing theory is the quantitative approach to the analysis system that includes waiting lines or queues. Waiting lines can form when the system does not have sufficient capacity on average to meet the demand. This is because the arrival times and service times for customers are random and variable.

Figure 1 illustrates the structure of a queuing system in which the Source is the customer input (components, in the case of an assembly line); queue consists of customers waiting for service, not including customers in attendance; Service may consist of one or more service stations, where it analyzes the number of customers in the system (at any moment) or system state; Served customers are customers who have been through the service station and out of the system.



Source: *Adapted from Andrade (2002)*

Figure1. *Structure of a queue system*

According to Bronson (1985), the queuing system consists of a set of users, a set of servers and order in which users arrive and are processed.

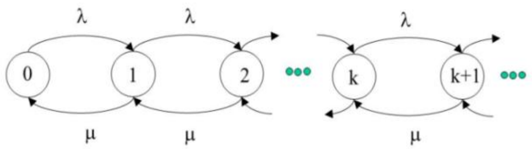
Monks (1987) says that the waiting lines can be formed even when the system (installation) has sufficient capacity, on average, to meet the demand. This is because the arrival times and service times for customers are random and variable.

It should be taken into consideration for the analysis of queues, a set of components and mathematical analysis to determine a balance between arrivals and departures of users as well as their care and standby so as not to cause inconvenience and loss to both users, as the company.

As Bronson (1985), queuing systems are characterized by five components: Model arrival of users, service model, number of operators, establishment of capacity to serve users and the order in which users are served. This author also states that the model of arrival of users is specified by the time between arrivals (λ). The service model is represented by the length of service (μ), ie, the time required to meet a user. System capacity indicates the maximum number of users, both those being served and those in the queues, this capability may be finite or infinite. Queuing discipline is the order in which users are served, this divided in two shapes, can occur on the basis of first-in, first-out (FIFO) or last-in, last out (LIFO). For the number of attendants, some concepts were defined as the number expected in the queue (Lq): Expected number of customers waiting for service. expected number in the system (L): Expected number of customers or waiting in line or not met. waiting time in the queue (Wq): waiting time of a customer waiting in queue. waiting time in the system (Wi): waiting time of a customer in the queue plus the time it is served.

M / M / 1 queue

Figure 2 illustrates the queuing model M / M / 1 model used mainly theoretical studies because it allows easily calculate all the attributes of a queue, facilitating analysis.



System Balance

⬆

service capacity> average number of customers seeking service

⬍

Occupancy rate <1.

Source: *Adapted from CHWIF & MEDINA (2010)*

Figure2. *Queue model M / M / 1*

According to Bronson (1985) equations of the model are based on certain key features:

- Forms of arrival to queue and service follow the Marcoviano model;
- Number of service channels to 1.

Also according to Bronson (1985), theexpressions that represent the theory are:

- Average number of customers in system: NS = λ / (μ - λ);
- Average number of customers in queue: NF = λ2 / [μ (μ - λ)];
- Average Number of Customers Being Served (Server Utilization Factor): ρ = λ / μ;
- Probability that there are n customers in the system: Q (n) = (1 - λ / μ) (λ / μ) n.

METHODOLOGY

For this experiment, we opted for the application of a model M / M / 1 queue, since the process being studied is a continuous production line, while the products are customized, all follow the same flow, through the same processes. The methodology was applied research therefore seeks to experiment with a solution to the question of research. The goal is to identify the bottleneck resource behavior, in order to define the CONWIP level within the system, improving the strategic planning and production control, reducing WIP.

Queue between operations - M / M / 1

Studied the production line is arranged in one row, continuously, through which the components pass getting the necessary changes to become finished product. As the parts are moved among the workstations, the same waiting in the queue to be processed at slower system operation, which is the production bottleneck. Due to the acquisition cost of certain equipment, only this workstation processes efficiently, the parts are transported by producing mat. Thus, during the shift lines are observed to be processed according to this restriction.

To begin the study, some measurements were performed in the production flow coming to the following information: the average frequency of arrival of the neck pieces is 1 / 5.9, that is, every 5.9 minutes piece is processed in the previous station and transferred to be processed in the station neck. The average processing rate of the bottleneck is 1 / 7.8, then every 7.8 minutes once the neck part is processed. After completing the measurements on the production line, with the aid of a spreadsheet, illustrated in

Figure 3, the simulation of 1000 pieces of arrivals on the neck feature (n = 1000) was performed, using the random function spreadsheet for and simulate entry of new components at the beginning of the production line in order to observe the behavior of the neck. The arrival rate (λ) at the bottleneck resource was set to 0,

n	time between arrivals (ri) RI =-ln (1-random ())/lambda	time attendance (si) You =-ln (1-random ())/µ	time of arrival (ai) Ai=Ai-1+Ri	beginning of attendance (bi) Bi=máx(ci-1 ; ai)	End of service (ci) Ci=Bi+Si	Queue time (wi) Wi=Bi-Ai	System time (ui) Ui=Ci-Ai	Idle time (hi) Oi=Bi-Ci-1	Temporal average (wmed)
			0		0				
1	4,533402128	4,829251574	4,5	4,5	9,4	0,0	4,8	4,5	0,0
2	3,567314217	8,859748039	8,1	9,4	18,2	1,3	10,1	0,0	0,6
3	6,33531003	9,614202378	14,4	18,2	27,8	3,8	13,4	0,0	1,7
4	0,997417126	1,45104176	15,4	27,8	29,3	12,4	13,9	0,0	4,4
5	3,114766152	7,488935344	18,5	29,3	36,8	10,7	18,2	0,0	5,6
6	1,279709294	2,072237609	19,8	36,8	38,8	16,9	19,0	0,0	7,5
7	11,02940852	9,054298417	30,9	38,8	47,9	8,0	17,0	0,0	7,6
8	1,277402509	0,128463422	32,1	47,9	48,0	15,8	15,9	0,0	8,6
9	7,853880509	0,050577438	40,0	48,0	48,1	8,0	8,1	0,0	8,5
10	1,071270234	2,57877408	41,1	48,1	50,7	7,0	9,6	0,0	8,4
11	5,576077574	2,495220229	46,6	50,7	53,2	4,0	6,5	0,0	8,0
12	0,048533214	1,485338211	46,7	53,2	54,6	6,5	8,0	0,0	7,9
13	13,85714008	2,96698545	60,5	60,5	63,5	0,0	3,0	5,9	7,3
14	7,50808055	0,871224215	68,0	68,0	68,9	0,0	0,9	4,5	6,7
15	0,427132898	3,221658581	68,5	68,9	72,1	0,4	3,7	0,0	6,3
16	0,732239145	1,709287968	69,2	72,1	73,9	2,9	4,6	0,0	6,1
17	2,224377218	6,100934323	71,4	73,9	80,0	2,4	8,5	0,0	5,9
18	1,517651256	1,878253604	73,0	80,0	81,8	7,0	8,9	0,0	6,0
19	1,008671966	3,150081309	74,0	81,8	85,0	7,9	11,0	0,0	6,1

Source: *Author (2017)*

Figure3. *Simulation in spreadsheet*

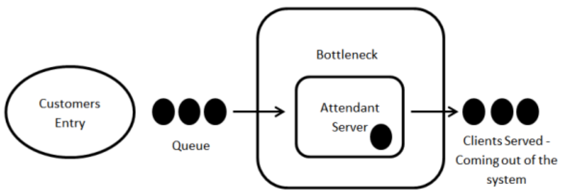
As illustrated in Figure 4, the simulation spreadsheet, possible to measure the average waiting time in the WIP queue preceding the bottleneck resource (UI), and the system mean time (WI), or lead-time components the production line.

Ui (average):	862,3886
WI (average):	869,8733

Source: *Author (2017)*

Figure4. *Average time queue system and*

The conceptual model illustrated in Figure 5, is the arrival of parts between work stations, visually showing the M / M / 1 queue studied the process in which there is a bottleneck resource.



Source: *Author (2017)*

Figure5. *Model mimi1 the study process*

Results And Discussions

With the experiment, it was possible, by simulating a queue M / M / 1 understand the resource bottleneck behavior of the power generation assembly line.

From the data, it was observed that the average time queue (IU), was 862.3886 seconds (14.37 minutes), and the average time of the whole system as u (WI) was 869.8733 seconds (14.49 minutes). This indicates that the average time that each component in the queue waiting to be processed on the neck feature is similar to the time to perform all the other operations of the assembly line. With an understanding of these data, it can be said that the volume of WIP observed on the assembly line, is approximately twice the volume required to meet the daily demand of production, the bottleneck resource, makes a queue is formed in operations precede, bringing the WIP, as stated Goldratt & Fox (1997) in their publications.

From the experiment, some actions were implemented to make the controlled amount of WIP on the assembly line, as well as suggests Spearman et al. (nineteen ninety). Among stocks, defined as the volume of CONWIP the production line will be the total of components needed to meet the daily demand of finished product. To ensure this control, sensors are installed which control the flow of the production line, limiting the WIP, the volume defined by default. Another action was the acquisition of equipment similar to the neck equipment, but manual operation. Although the processing time of the equipment is 40% in relation to the neck, gave a reduction in line, therefore the WIP observed between operations. Thus, the volume of CONWIP been standardized, making the programming of controllable production,

CONCLUSIONS

This article aimed to answer the following questions - How TF can help to understand the bottlenecks resource behavior for making decisions about CONWIP levels of the system? You can reduce the WIP when you have a resource bottle neck on the continuous production line?

This research allowed us to confirm that the application of queuing theory is extremely effective for understanding how bottlenecks features behave, enabling the measurement of the losses arising from such restrictions and provide reliable data for decision making in the case of this study, sensor installation on the assembly line and the acquisition of new equipment. Even with a resource bottleneck on the production line, the level of WIP was reduced, thus answering the research question.

A limitation of this study was to varying demand production occurred during the measurement period, requiring that measurements be interrupted at times due to lack of orders to be produced. For future work, we suggest the study of demand variation impacts on the volume of raw material stock, as there is a history of consumption and such variations may lead to excess or lack thereof.

REFERENCES

[1] Andrade, E. L. (2000). Introdução à pesquisa operacional. Rio de Janeiro: Livros Técnicos e Científicos Editora S.A.

[2] Andrade, E. L. (2002). Introdução à pesquisa operacional. 2. ed. Rio de Janeiro: LivrosTécnicos e Científicos Editora S.A.

[3] Bonvik, A. M. (1999). How to control a lean manufactuing system. Available at: http://web.mit.edu.

[4] Boonlertvanich, K. (2005). Extended CONWIP KANBAN System - Control and Performance Analysis. Ph.D. thesis, Georgia Institute of Technology. Available at: www.smartech.gatech.edu.

[5] Bronson, R. (1985). Pesquisa operacional. 1. ed. São Paulo: McGraw-Hill do Brasil.

[6] Chwif, L.; Medina, A.C. (2010). Modelagem e simulação de eventos discretos: teoria eaplicações. São Paulo: ed. dos autores. Goldratt, E.; Fox, J. (1997). A meta: um processo de aprimoramento contínuo. São Paulo: Educador.

[7] Kleinrock, L.. (1975) Queueing Systems. New York: John Wiley & Sons.

[8] LAGE Junior, M.; Godinho F. M. (2008). Adaptações ao sistema KANBAN: revisão, classificação, análise e avaliação. Gestão & Produção, v. 15, n. 1.

[9] Monks, J. (1987). Administração da produção. São Paulo: McGraw-Hill.

[10] Sellitto, M. (2005). Medição e controle de desempenho estratégico em sistemas de manufatura. Ph.D. thesis, PPGEP-UFRGS. Available at: www.producao.ufrgs.br

[11] Sereno, B.; Silva, D. S. A.; Leonardo, D. G.; Sampaio, M. (2011). Método híbrido CONWIP/KANBAN: um estudo de caso. Revista Gestão & Produção, São Carlos, v. 18, n. 3, p. 651-672.

[12] Spearman, M. L.; Woodruff, D. L.; Hopp, W. J. (1990). CONWIP - A Pull Alternative to KANBAN. International Journal of Production Research, v. 28, n. 5, p. 879-894.

[13] Vollmann, T.; Berry, W.; Whybark, D.; Jacobs, F. (2006).Sistemas de planejamento & controle da produção para o gerenciamento da cadeia de suprimentos. Porto Alegre: Bookman.

[14] Wiendahl, H. (1995). Load-oriented manufacturing control. Berlim: Springer Verlag.

Citation: *M. Edson and d. Solange, "Application of Queue Theory in a Continuous Assembly Line for Setting Conwip Level", International Journal of Research Studies in Science, Engineering and Technology, vol. 4, no. 8, pp. 40-44, 2017.*