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Simulation of Paired-Cell Overlapping Loops of Cards with Authorization (POLCA) System in an Automotive Component Manufacturing Company

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Abstract: Now a days in Indonesia, automotive component manufacturing local companies are competing really hard. One of the component local companies is PT STLJ, it is a Make-to-Order (MTO) company that is using push production system with job shop mechanisms. In such environments, push system cannot accommodate the company's characteristic, leads to large number of backorder and Work-in-Process (WIP). Here, an alternative system called Paired-cell Overlapping Loops of Cards (POLCA) is suggested and tested in order to give a better solution for the MTO and job shop environment. POLCA is a hybrid push-pull production system that can control the flow of material in shop floor. The objectives of this study are to describe the procedure of developing POLCA simulation model and to compare its performances with the current system. Based on the simulation result using ProModel Simulation Software, it is known that POLCA System has better performance than the current system. The number of backorder is reduced by 2%, meanwhile the number of WIP is reduced by 93%.

Key words: Production system, job shop, make-to-order, POLCA, simulation

INTRODUCTION

In Indonesia, the automotive industries are growing rapidly. Automotive industries contributed 11% to total Gross Domestic Product (GDP). Many automotive companies are investing in Indonesia such as Toyota, Mitsubishi, Honda, etc. Along with the growth of the automotive industry, the growth of automotive component manufacturing industries are also increasing rapidly. This year, there are 50-70 new automotive component manufacturing factory in Indonesia with the total investment around 6 trillion rupiahs (Tempo, 2016).

However, a large number of players in the field of automotive component manufacturing industries makes local company compete each other. Also, ASEAN countries agreed to establish ASEAN Economic Community (AEC). AEC is the economic integration between ASEAN countries, ASEAN is seen as a single market and production base a highly competitive region with equitable economic development and fully integrated into the global economy (Invend in ASAN, 2017). AEC makes local Industries compete not only with the other local products but also with import products.

In order to survive and win the competition, the company needs to maintain its performance. One of the local component manufacturing companies that is struggling to satisfy its costumer is PT STLJ. Currently, PT STLJ is a Make-to-Order (MTO) company that is using push production system with job shop mechanisms. There are 17 products of PT STLJ that give 80% of demand which are stay fuel tank, guide tube, stay luggage, guide vapour vent tube, etc. Because PT STLJ uses push system while the company characteristic is MTO those products faces 2 problems a high number of Work-in-Process (WIP) and backorder. To solve those problems, simulation of Paired-cell Overlapping Loops of Cards with Authorization (POLCA) was conducted in this research.

The objectives of this research are to describe the procedure of designing POLCA simulation model and to compare the performance measure of POLCA System with the current system. The current system model and the POLCA System model were constructed using ProModel Simulation Software.

Literature review: POLCA is a hybrid push-pull production system combining best features of push systems and pull system. It manages process sequences at production floor. The flow of material is controlled using POLCA cards and High Level Material Requirement Planning Authorization (HL/MRP). HL/MRP is similar to MRP system. The difference is that HL/MRP works in cells level where every process within cells is assumed as a black box (Krishnamurthy and Suri, 2009).

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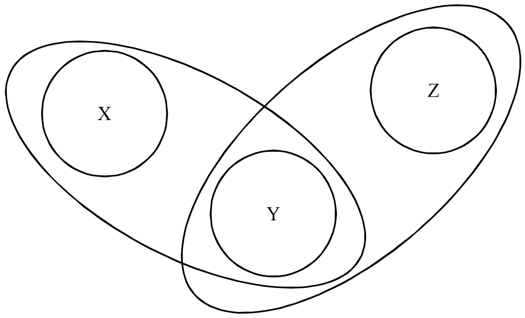

Fig. 1: POLCA cards loops

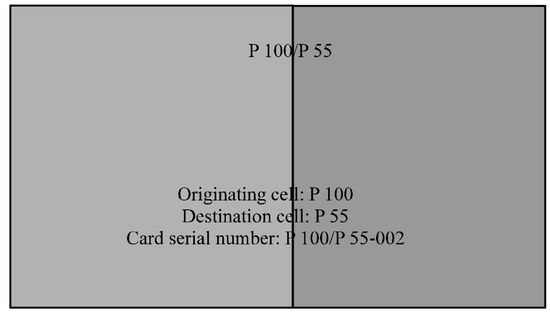

Fig. 2: POLCA card

As an example, it is known that there is a product that has routing process X-Y-Z (Fig. 1). When the product is scheduled by HL/MRP then the first cell, X can only start if the next cell, Y, send X/Y card. Each POLCA card represent empty capacity signal. After cell X finishing the job, then the product is sent to cell Y together with X/Y card. At cell Y, the product and X/Y card have to wait Y/Z card in cell Y. When cell Z has empty capacity, then cell Z will send Y/Z card to cell Y. If cell Y has both X/Y and Y/Z cards, then production process in cell Y can be done. This process shows overlapping mechanism in POLCA system. The production process will continue as explained until production volume is achieved. The number of POLCA cards can be calculated by using Eq. 1 as by Krishnamurthy and Suri (2009):

$$N_{X/Y} = (LT_X + LT_Y) \times \frac{Num_{X/Y}}{D} \quad (1)$$

Where:

$N_{X/Y}$ = Required card number of POLCA cards for paired-cell X and Y
LT_X = Lead time of cell X, include setup time, process time and waiting time
LT_Y = Lead time of cell Y, include setup time, process time and waiting time
D = Scheduling period
$Num_{X/Y}$ = Total demand of paired-cell X and Y (in quantum)

Quantum size represents unit numbers that allowed to be produced by each cell after get POLCA card. Quantum of each POLCA card can be determined freely. But there are trade-offs to be considered:

- If the quantum is too large, then the number of POLCA cards will be too small and makes infrequent and possibly lumpy signals of available capacity to the upstream cell
- If the quantum is too large, then the number of POLCA cards will be too large and it will be difficult to control all of them

In general, transfer batch and production batch is numbers that acquired from quantum multiplication. Figure 2 shows an example of POLCA card which contains information: originating cell name and its colour which is P100 and the colour is yellow, destination cell name and its colour which is P55 and the colour is blue, card serial number: P 100/P 55-002, it means the second card of P 100/P 55. Those information are used for visualization thus it becomes easy to control the flow of material.

According to Table 1, HL/MRP is used to manage material flow between two cells. In HL/MRP there are 6 main columns: order number, filled by customer order number, material availability, filled by material information and status, earliest start time, filled by allowable date to start process, route in cell, filled by machine name that used within cell and its process time, destination cell, filled by destination cell name, required POLCA card, filled by type and number of POLCA cards. The number of cards can be calculated by Eq. 1.

POLCA mechanism is not only occurred between cells. There is another approach where POLCA mechanism can be used between machines. It can be seen in olsen engineering company study case as by Krishnamurthy and Suri (2009). Besides that POLCA can be implemented in industry that has layout process without changing its initial layout, where POLCA mechanism can be applied between groups of machines as by Vandaele *et al*. (2008). This group of machine in process layout is machines that located closely because they have similarity in process. In this research, we use the theory as by Vandaele *et al*. (2008) because PT STLJ is a job shop manufacturing company and has process layout. Therefore, a group of machine can be defined as a POLCA cell.

Table 1: Example of HL/MRP as by Riezebos (2010)

Release list cell: A (released on: 08/08/2016)

			Route in cell a (process time)				Required POLCA card	
Order number	Material availability	Earliest start time	1	2	3	Destination cell	Number of cards	Type
001	OK	9/8/2016	M1 (10')	M2 (15')	-	B	1	A/B

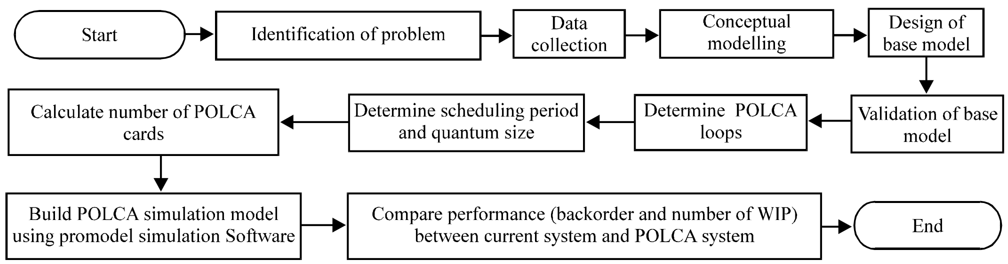

Fig. 3: Methodology

MATERIALS AND METHODS

Figure 3 explains the methodology used in this research which is developed based on Krishnamurthy and Suri (2009) and Ching *et al*. (2015). After problem identification, the real data on PT STLJ shop floor was collected such as routing files, lead time of each cell, number of demand and planning period. Current system model and POLCA System model were constructed by using ProModel Program. After running the simulation, the result of base model (current system) performance was compared to the result of POLCA System performance. The performance measures are backorder number and WIP number. The number of backorder is the number of residual demand that's not done yet. WIP number represents the number of semi-finished products in the production floor. The procedure of designing POLCA simulation model is as follows:

Determine POLCA loops: This is an example to determine POLCA loops using a product called A1. The sequence of cells in production process of A1 is P 100, 55 and 70. Therefore, the POLCA loops are P100/P55 and P 55/P 70.

Determine scheduling period and quantum size: Based on the actual data, the scheduling period is 19 h or 68,400 sec and the quantum size is 500 units.

Calculate number of POLCA cards: Number of POLCA cards can be defined using Eq. 1. The POLCA card is used for a certain loop. The POLCA cards of loop P 100/P 55 will be calculated as an example. There are some parameters that have to be determined first which are:

Lead time for each cell includes setup time, process time and waiting time: For example, product A1, 6, 9 and 17 are processed in P 100. The lead time in P 100 for processing A1 is 120 sec, A6 is 150 sec, A9 is 36 sec and A7 is 142 sec. The total lead time for P 100 is 448 sec. The average lead time for P 100 is 448 seconds divided by 4 which is 112 sec. Therefore, the lead time of P 100 is 112 sec. Lead time for other cell is calculated also with that process as lead time of P 100. Assume that lead time of P 55 is 150 sec.

Demand in quantum: For example, the demand of loop P 100/P 55 is 7000 units and the quantum size is 500 units; therefore the demand in quantum of loop P 100/P 55 is 7000 units divided by 500 units which is 14 units. Based on the calculation using Eq. 1, the number of P 100/P 55 card is 1 (one) card:

$$N_{P100/Pss} = (LT_{100} + LT_{ss}) \times \frac{Num_{P100/Pass}}{D}$$

$$N_{P100/Pss} = (112 + 150) \times \frac{14}{68.400} =$$

$$0.0536 = 1card$$

RESULTS AND DISCUSSION

The simulation of current system is based on the actual condition (push system). There are 8 cells that is used to produce STLJ products as in Fig. 4 which are press 40 ton (P40), press 63 ton (P63), press 25 ton (P25), press 55 ton (P55), press 70 ton (P70), press 100 ton (P100), Welding (WL) and Spot Welding (SW). If there is an order, the variable of demand will increase, the entity of product will be sent to the first cell correspond to its

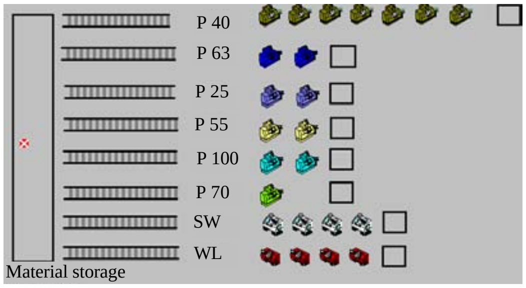

Fig. 4: POLCA Simulation Model

routing file and it will increase the variable of WIP. If the process in the first cell is done, the entity will be sent to the second cell although the cell is full and it will go on until the whole processes are done. If the process is finished, it will decrease the variable of WIP and it will increase the variable of finish goods. The backorder variable is calculated using Eq. 2 and 3:

$$\text{If FG} \geq \text{DM,them BO} = \text{BO} \quad (2)$$

$$\text{If FG} < \text{DM,them BO} = \text{BO} + \text{DM} - \text{FG} \quad (3)$$

Where:

FG = The number of total finish goods
DM = The number of total demand
BO = The number of total backorder

However, the simulation of POLCA System works differently because it combines push and pull system. If there is an order, the product entity will not be sent to the first cell until the second cell sends a free capacity signal. The capacity of each cell is represented by a variable called vCount, the maximum value of vCount is determined by quantum. If the value of vCount is zero, then the cell has free capacity. If vCount of the seccell is zero then it will allow the first cell to work by receiving the product entity from the material storage. Each entity that enters the cell will increase the vCount value. If the value of vCount reaches the limit it will be reset to zero. If the process in the first cell is done, the entity will not be sent to the sec cell until the third cell sends a free capacity signal and the processes will continue as explained until the last cell. If the process is finished, it will decrease the variable of WIP and it will increase the variable of finish goods. The backorder variable is calculated using Eq. 2 and 3. Based on the simulation results of 75 replications with a run length of 760 time units using ProModel, the average number of backorder and WIP can be seen in Table 2.

Table 2: Performance result of push system and POLCA System

Type of system	WIP (units)	Backorder (units)
Current	16,143	11,625
POLCA	1,126	11,400

Table 3: Waiting time of current system and POLCA System

Type of system	Average total time in system (time units)	Waiting time in system (time units)	Waiting time (%)
Current	278.89	277.37	99.5
POLCA	181.04	49.55	27.4

Table 4: Required capacity

Cells	Required capacity (units)	Available capacity (units)	Required number of additionalcapacity (units)
P 40	10	7	3
SW	8	4	4
P 63	3	2	1
P 25	3	2	1
P 55	3	2	1
P 100	3	2	1
WL	7	4	3
P 70	1	1	0

The number of WIP using current system is higher than using POLCA system. There are 15,017 units of gap between 2 systems. POLCA system can reduce WIP by 93%. The number of WIP is affected by the bottleneck cell. In POLCA System, POLCA card represent empty capacity signal as pull feature. That feature can avoid the production process to produce a product that has to be processed in bottleneck cell. Therefore, the number of WIP is short. Meanwhile, the number of backorder using current system is also higher than using POLCA system. There are 225 units of gap between 2 systems. POLCA system can reduce backorder by 2%. Due to the rules of POLCA System, the product cannot enter the system if destination cell of the next cell is still processing. It makes the waiting time in POLCA System shorter than the current system and lead to shorter lead time with higher output. Table 3 shows comparison of waiting time between current system and POLCA System.

The average total time and waiting time in POLCA System are 181.04 and 49.55 time units, both are smaller than the current system which are 278.89 and 277.37 time units. The gap of waiting time percentage between current system and POLCA system is 72.1%. But the reduction percentage of backorder is only 2%, due to the lack of capacity in PT STLJ. In POLCA system, the cells must at least have the capacity to meet required output in a given planning period with 10-15% spare capacity (Krishnamurthy and Suri, 2009). Therefore, additional machines are needed to run POLCA System optimally. Table 4 contains the required number of additional capacity, almost all cells need additional capacity except P70.

CONCLUSION

The research was conducted in an automotive component manufacturing company which is PT STLJ. PT STLJ is a Make-to-Order (MTO) company that is using push production system with job shop mechanisms. The simulation models were constructed using the ProModel software. The procedure of developing POLCA simulation model is explained in the methodology section. Based on the simulation result, POLCA system has better performance than the current system (push system). The number of WIP and backorder in POLCA system are smaller. The reduction percentage of WIP number is 93%. But the reduction percentage of backorder number is only 2%. PT STLJ needs to add 10-15% spare capacity to meet the requirement.

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