Influence of Inventory and Work in Process Adjustment Time on Production Target Achievement of D Minus 1 Production Scenario: A Case Study of Hospital Bed Production

Susanto Sudiro
Magister Teknik Mesin
Universitas Pancasila Jakarta
Jl Borobudur No 07 Menteng , Jakarta Pusat 10320,Indonesia
susantosudiro@yahoo.co.id

Sha'ri Mohd Yusof
Razak School of Engineering and Advanced Technology
Universiti Teknologi Malaysia Kuala Lumpur
Level 7, Razak Tower Jalan Sultan Yahya Petra 54100 Kuala Lumpur
shari@fkm.utm.my

Revino
Post Graduate Program
Institut Sains dan Teknologi Nasional Jakarta
Jalan Duren Tiga Pasarminggu, Jakarta Selatan 12760, Indonesia
oniver10@yahoo.com

Abstract

A company produces hospital beds for global market with tight delivery schedules. On the production line is often constrained by the uncertainty of inventory and work in process (WIP) availability and has been used excessive resources which is losing company competitiveness. To achieve on time delivery (OTD) applied D Minus 1 production scenario with process sequences are welding, painting and assembly scheduled respectively on D-2, D-1 and D0 day. D minus 1 is activity to provide the WIP buffer downstream as a supply of materials for the upstream process which is carried out periodically with a one-day cycle so that the demand for product delivery can be completed. This scenario modelled as dynamic system which is set as cyclic process with period one day to shipping time. Use production dynamic factors can be simulated production control which is able to achieve OTD. Those factors are function of inventory adjustment time (IAT), Finish inventory adjustment time (FAT) and WIP adjustment time (WAT).Using those factors in the production line can be shown effect of the IAT, FAT, WAT to the level of accurate and precision of the process to the production target, which is can be used for achieve OTD succeed.

Keywords
D minus 1, hospital beds, system dynamic, on time delivery, inventory adjustment time.

1. Introduction

This Paper is part of a research on modelling of work in process (WIP) planning and control multi-product production of hospital beds for anticipate demand of this products in Indonesia. Data from the Ministry of Health

Republic of Indonesia (2015) in 2015 ratio of hospital bed per 1000 population(Fig 1(a)) is 1.21 and in 2014 to 2015 have been bought 39,403 beds, it is mean growth of this business was 0.097 per 1000 population(Fig 1(b)).

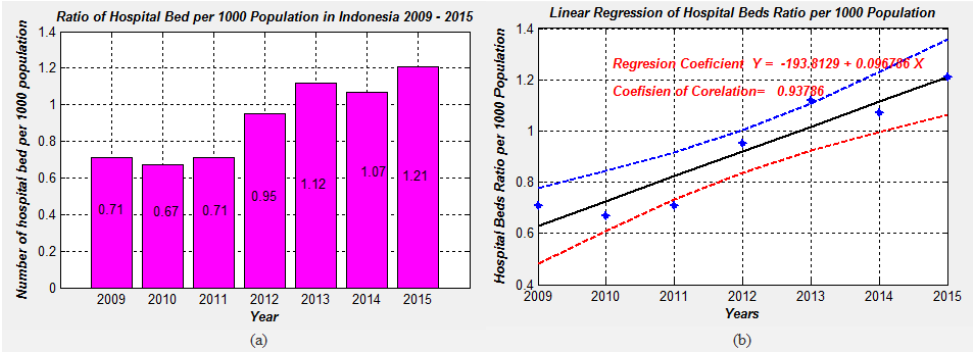


Figure 1. Ratio of hospital beds per 1000 population and regression of the growth, Ministry of Health Republic Indonesia, 2015

According to potential demand for hospital beds in Indonesia are subject to a manufacturing company in Yogyakarta Indonesia. Currently this company is undertaking major efforts to reach the highest level in its class, in addition to the outstanding company indeed.

The targeting market segment is export and domestic market area. For the domestic market the company provides any services for the private sector and to the government. Market responds are tremendously significant, the further impact is company has to serve the very diverse of kind of its products, volume, time and shipment destination to serve from single customers or orders in the form of projects.

To anticipate the significant business growth, the company implemented ERP SAP system (runs since 2013), but the result is not as well as expected. Especially in the production floor, the information in every aspect of production in production floor not real time available. The operating speed of the ERP SAP system is rather slow moving than production time, production information always late to be processed and the impact is being waste in the production floor rise up drastically and make frustrate peoples which operating ERP SAP (Sudiro et al., 2017).

The components have been reached assembly station but the information of the components still left behind, almost no data of the components have been issued or received in SAP data base, even the finish good have been received in the warehouse but without any transaction document. The worst case is in the end of the years, financial departments cannot close the report, the huge differences of the stock on all production unit and very difficult to balance this stock differences. Cumulative stock differences in year 2014 is nearly 1.2 million US $ and 2.8 million US $ in 2015, this is make huge loses for the company (Sudiro et al., 2017).

To achieve customer satisfaction the company tries to apply a new production scenario D Minus 1 (Sudiro et al., 2015) to integrated all activities carried out between production planning and scheduling, production facilities, production dispatching and production execution (ISA 95, 2000) in order to provide services that meet customer demands.

The objective of this study is to support D minus 1 production scenario with model production control which is has ability for shows adjustment time of any production factors (inventory, finish inventory and WIP) could affect production system. By these factors can be predicted behavior of production system and than can be chosen the best value of inventory adjustment time (IAT), finish inventory adjustment time (FAT) and WIP adjustment time (WAT) in order to succeed produce the goods as already planned and go to on time delivery (OTD) to achieve highest level of customer's satisfaction.

2. Literature Review

Many enterprises have practiced the lean thinking paradigm to enhance the efficiency of their business processes. In recent years, an agile manufacturing paradigm has been underlined as an alternative to, and possibly an improvement on, leanness. Christopher and Towill (2001) have described that lean concepts work well where demand is relatively stable and predictable where product diversity is low. In contrast, when customer requirement for variety is high and volatile, a much higher level of agility is required. Helo (2000) defined agile manufacturing as the capability of reacting to unpredictable market changes in a cost-effective way, simultaneously prospering from the uncertainty. In many manufacturing companies, dynamically changing markets are demanding more differentiated products in lower volumes and within less production lead time. Any uncertain conditions challenge the dynamic response of manufacturing systems. Enterprises have to deal with high seasonal rise and fall in demand. Frequent changes of product designs and complex products need quicker response times in ramp-up to volume. To stay

competitive in this 21st century global industrialization, companies require responsive manufacturing systems that can react to unpredictable market changes as well as launch new products economically and efficiently. Responsive manufacturing systems yield shorter production lead time, minimal inventory build-up and related cost, better overall dynamic system behavior and thus lead to excellent customer satisfaction.

Fong (2005) has been describe production control model as shown in figure 2 and figure 4. Figure 2 shows of a single-stage production control system the objective is to reach a particular inventory value (i.e., desired inventory, INV*) of a single-stage production system subjected to a particular customer demand. Given a new program launch of product, the management policy is to determine a set of system parameters such that the production will meet the target inventory level within a reasonable settling time. The production inventory is the accumulation of a difference between the production rate (PR) and the shipment rate (SR) during a certain shipment time (ST). The shipment rate is calculated from dividing the total inventory level by the average shipment time. The production rate (PR) is given by the desired production rate (DPR). The desired production rate (DPR) represents the rate at which the units of product are to be made to the inventory.

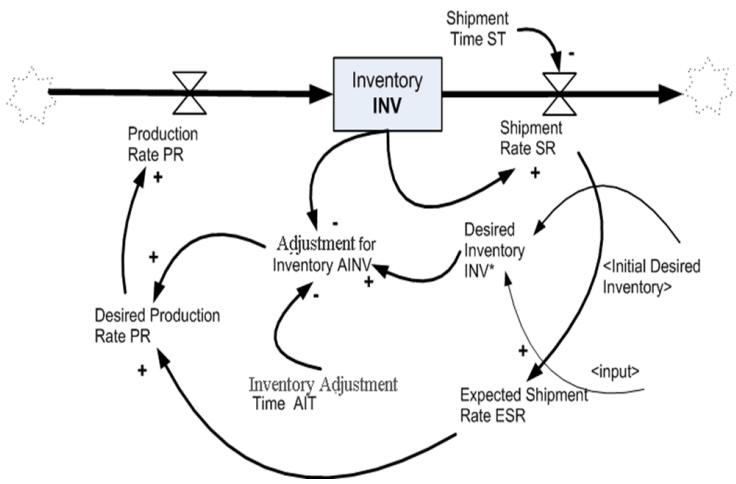
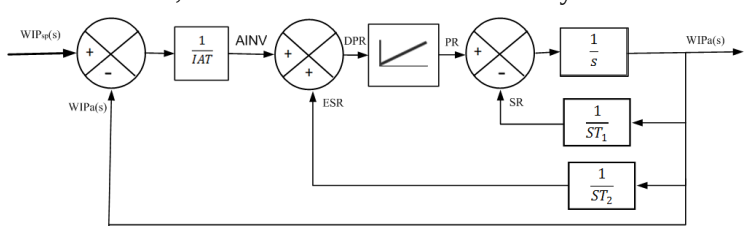


Figure 2. A single-stage production control system, Fong (2005)

There are two fundamental decision rules to determine the desired production quantity. First, production should replace the expected shipment rate (ESR) from the inventory. Second, if there is any discrepancy between the desired inventory INV* and the actual inventory INV, the production rate should be controlled by either making more than ESR or making less than ESR while the inventory level is below or above the target value respectively (i.e., AINV). Hence, DPR is the sum of ESR and AINV. The adjustment for the inventory AINV generates the negative (balancing) "inventory control" feedback loop as shown in Fig.3. AINV is a linear adjustment in the discrepancy between INV* and INV over the inventory adjustment time (IAT). Sterman (2000) describes this adjustment time as the time constant for the particular feedback loop. The IAT represents how fast the production system reacts to correct the discrepancy of inventory level. In the later section, we show that IAT of this single-stage system model only represents a portion of the entire system time constant of the actual transfer function. This time delay is sometimes so short relative to the dynamics of interest, we can assume that there is no delay so that it is acceptable to let ESR = SR.



WIPsp(s) =INV*= demand inventory = input reverence value of inventory

WIPa(s)= INV= inventory=output from the system

SR = Shipment rate	**ESR = Expected shipment rate**
ST1 = Shipment rate for SR	**ST2 = Shipment time for ESR**
AINV = Adjustement Inventory	**IAT = Inventory adjustement time**
PR = Production rate	**DPR=Demand Production Rate**

Figure 3. Complete BD representation of a single-stage production system, Fong (2005)

We further modify the single-stage model to become a two-stage production control system by adding to the receding stage of production a "work-in-process control" feedback loop and related causal loop variables as shown in Fig.4. There are two stock elements found in this model accumulate the work-in-process (WIP) roduction units and its finished inventory (FI) units. WIP accumulates the difference between production start rate (PSR) and production completion rate (PCR) during a certain production lead-time (LT). The finished inventory (FI) determines the stock level between production completion rate (PCR) less shipment rate (SR) over an average shipment time (ST). There are two balancing feedback loops found to adjust the work-in-process (WIP) and the finished inventory (FI). Similar to the single-stage model, there is a linear adjustment between desired work-in-process (WIP*) and WIP over a specified work-in-process adjustment time (WAT) as the adjustment for work-in-process (AWIP). Likewise, there is an adjustment for finished inventory (AFI) between desired inventory (DI*) and FI over a specified finished inventory adjustment time (FAT). In addition, the desired production completion rate (DPCR) is the sum of AFI and expected shipment rate (ESR). Similarly, the desired production rate (DPR) is calculated by adding AWIP and desired production completion rate (DPCR). In this model, the desired work-in-process (WIP*) is the product of DPCR and the expected lead time (ELT). It is assumed that expected lead time is equal to lead time (ELT=LT), and that there is no time delay between shipments such that ESR = SR.

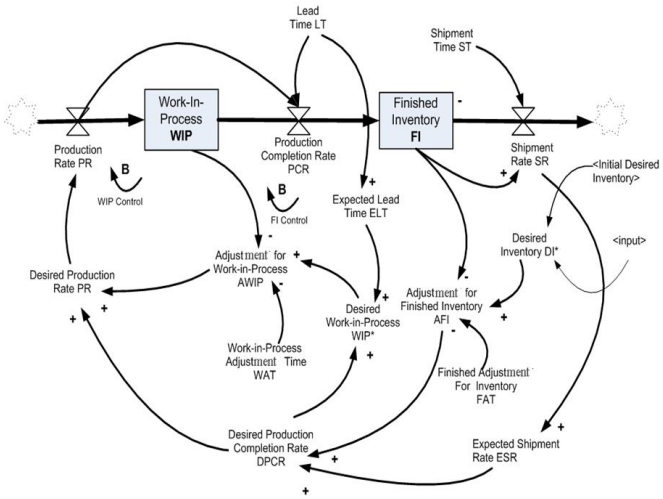


Figure 4. A two-stage production control system, Fong(2005)

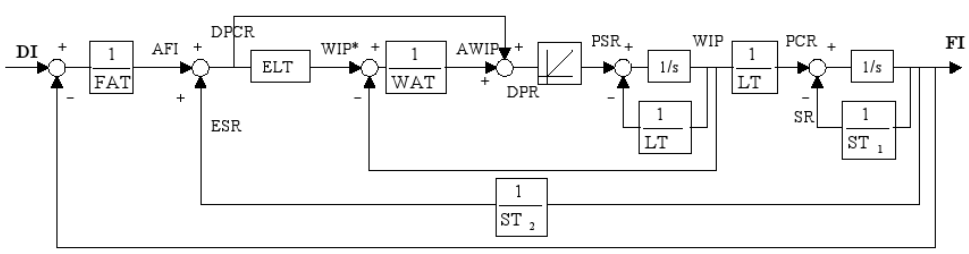


Figure 5. Complete BD representation of a two-stage production system, Fong(2005)

Response of both system for each input references show in equation (1) for single stage and equation (2) for two stage control system. This respon are output of control system for total production planning horison time use shipping time(ST) and this different with model D minus1which is base on daily production. For case in this study this equation is modified for fullfil model D minus 1 and the system control is used for controlling daily production and repeating until reach shipping time.

Response of single stage control system:

$$y(t) = K\left(1 - e^{-t/\tau}\right); \qquad \text{With} \qquad \lim_{t \to \infty} y(t) = K \tag{1}$$

With proportional gain is $K = \frac{\tau}{IAT}$ and time constant is $\tau = \left(\frac{1}{ST_1} - \frac{1}{ST_2} + \frac{1}{IAT} \right)$

Respon of two stage control system:

$$y(t) = K\left[1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sin\left(\omega_d t + \tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}\right)\right] \tag{2}$$

For steady state condition

$$\lim_{x\to\infty} y(t) = K = \frac{\left(\frac{1}{FAT}\right)\left(\frac{1}{LT}\right)\left(1+\frac{LT}{WAT}\right)}{\omega_n^2} \tag{3}$$

$$\omega_n = \sqrt{\left[\left(\frac{1}{LT}+\frac{1}{WAT}\right)\left(\frac{1}{ST_1}-\frac{1}{ST_2}+\frac{1}{FAT}\right)\right]}$$

$$\zeta = \frac{1}{2\omega_n}\left[\frac{1}{LT}+\frac{1}{WAT}+\frac{1}{ST_1}\right]$$

$$\tau = \frac{1}{\zeta\omega_n}\frac{2}{\left[\frac{1}{LT}+\frac{1}{WAT}+\frac{1}{ST_1}\right]}$$

3. Methodology

Methodologies used in this study is modeling production scenario in the shop floor use D minus1 model for producing hospital bed in the production line. For each product planned to be produced in the production plant provided 3 machines with the flow of process is starting from welding, painting and assembly. This machine pair planned to produce product as order demand using shipment time as the planning horizon.

To setup production planning and scheduling (PPS) activity the PPS is modeling and controlled as classical control system, also for this system created mathematical model for production. Base on the model control system is used Fong (2005) model for responsive manufacturing system and for this study is choose single stage and two stage control system. Fong systems are modeling for production system for total shipment time and this is different with D minus 1 model which is base on daily production. For this study Fongs model is modified for one day production and than setup mathematical periodic function and make process repetition until production time reach shipment time.

To setup mathematical model of D minus 1 production scenario is used Heaviside function. By this mathematical function is set production experiments use ANOVA and production factors which is used are IAT, FAT, WAT and LT for make prediction of production process model behavior.

4. D Minus 1 Production Scenario

Model D minus 1 production scenario is shown in Fig. 6a. The ” Day 0” being time scheduled to assembly the finished goods. Day - 1 is day scheduled on the upstream buffer WIP materials supply, consecutively implemented for every upper stream of the workstations buffer. Raw components supplied in lot and downsize in batch in WIP buffer to supply the welding stations, welding buffer in batch supply to paint shop and feed queuing in hanger. Coming out from paint shop, the components are arranged in racks, trolley or box in batch of WIP buffer. This batch materials is sent to assembly station together with standard components supply from warehouse arranged in kiting form.

Timing scheme of this model is shown in Fig. 6b. In time D - 2 must be available WIP buffer as feeding material to welding plant. The result of welding process is WIP buffer, this complete WIP buffer must be available feed to paint shop, and result of paint shop are finish components which is fed to assembly line.

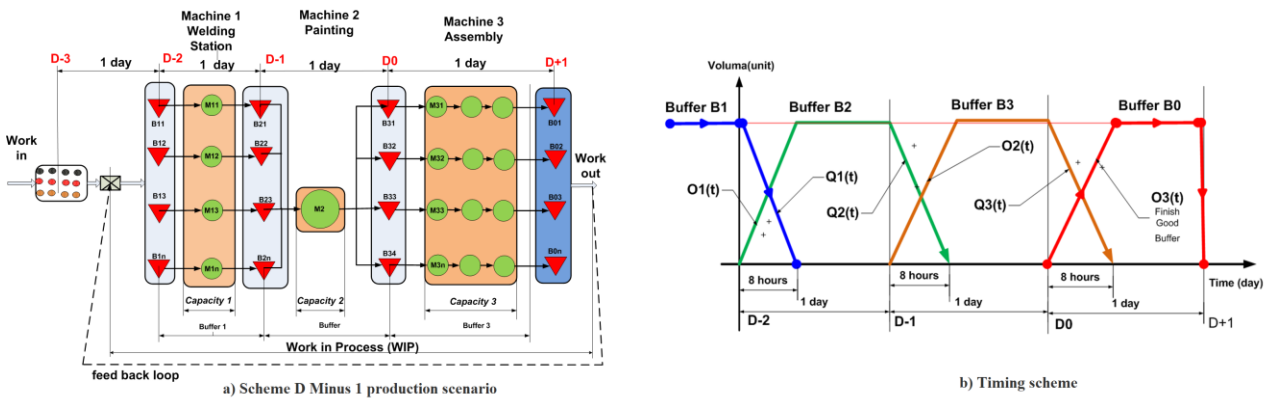


Figure 6. D minus 1 production scenario (Sudiro et.al, 2015)

The sequence diagram of manufacturing execution (MES) for mode D minus 1 is shown in fig 7 (Sudiro et.al, 2017). In this model assembly process (M_3) start 2 days behind M_1 and 1day behind M_2. In the first day has available WIP buffers in B_1 of raw components to build a kind of product and ready fed to M_1. In this day for this kind of product station M_2 and M_3 is in waiting state. In the day second has available WIP buffer in B_2 and ready fed to M_2, together with M_1 , M_1 and M2 in production state but M3 is still in waiting state. In the day third has available WIP buffer in B_3 and ready fed to M_3. All WorkCentre's M_1, M_2 and M_3 is in production state. In the day forth and so on all the Working Center's is in production state until job scheduled is finish. The production command signal send from production dispatcher as a task in feature of MES.

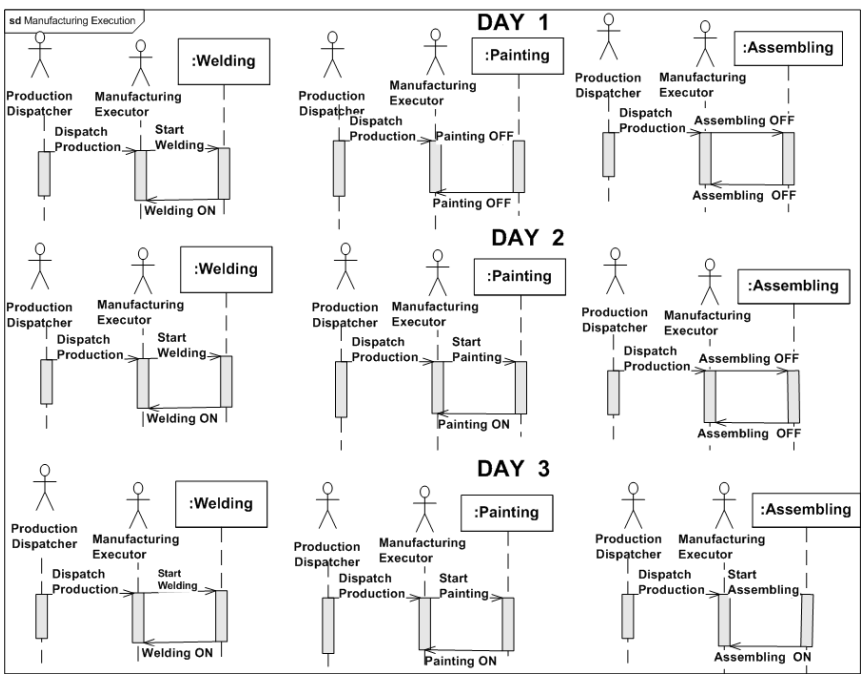


Figure 7. Sequence Diagram of Manufacturing Execution (Sudiro et.al, 2017)

5. Production Planning And Scheduling Frame Work

5.1 Production Planning Horizon

D minus 1 model production is cyclic planning production process (Groenevelt et al, 1996) using planning horizon is shipping time (ST). Production scenario of the model using multi stage production process. For every production stage use same effective processing time with a period is shipping time minus number of stage minus 1, it is mean for production scenario using 3 stage of production the effective processing time is ST – 2 day (Fig 8).

The process is begin for the first stage, and the last stage can be start after all the stage behind has work. For the case of single product hospital bed production is used 3 stage production consists welding, painting and assembly so assembly process start at the third day and welding process finished 2 days earlier then assembly process.

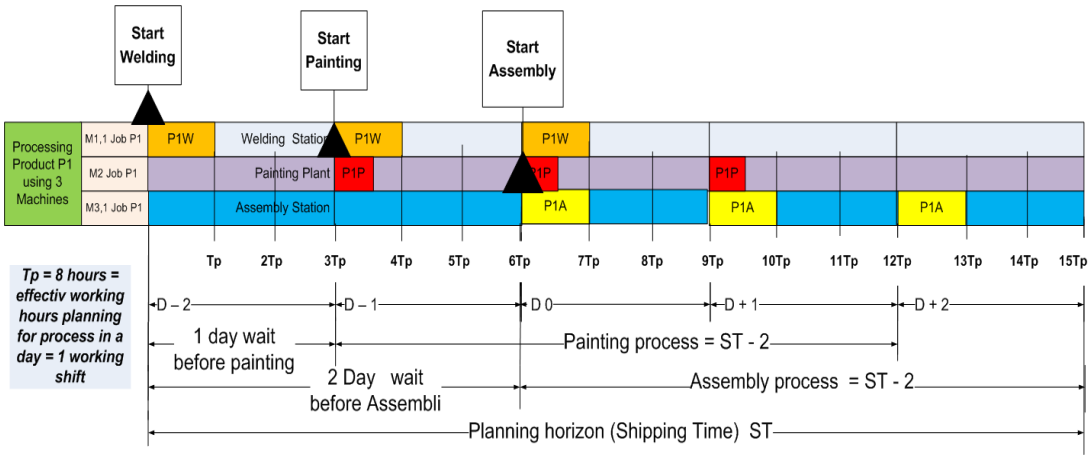


Figure 8. D minus 1 planning horizon.

5.2 Planning Production Schedule

Production schedule is setup used mathematical Heaviside function H(t) (Legua et al, 2008):

$$H(t) = \begin{cases} 0 \xrightarrow{for} t \le 0 \\ 1 \xrightarrow{for} t > 0 \end{cases} \tag{4}$$

Using D_{di} as the stimulus and ST is total planning horizon. General time respond Dp at time t for every number of period k of period Td can be determine as:

$$Dp(t,k) = D_{di}(H(t - kT_d) - H(t - kT_d - T_d)) \tag{5}$$

k=1, 2, 3,……ST = number of period

By equation (5) can be determined day to day production schedule in each work stations as seen in equation 6,7, 8 each is respectively schedule for welding, painting and assembly :

$$Dpk(t,k) = D_{di}(H(t - (k-1)T_d) - H(t - (k-1)T_d - T_d)) \tag{6}$$

$$Dpc(t,k) = D_{di}(H(t - kT_d) - H(t - kT_d - Td)) \tag{7}$$

$$Dpa(t,k) = D_{di}(H(t - (k+1)T_d) - H(t - (k+1)T_d - T_d)) \tag{8}$$

Base on equation 6, 7, 8 have been creating module use Matlab for setup production schedule with output as shown in table 1. This is table of production activity for deliver order of 160 units product hospital bed Supramak 73006, with daily production 40 units with shipping time 6 days production period date is 2÷8 February 2017 (holidays were ignored).

Table 1. 73006 Supramak Bed Production Schedule

	01-Feb-2017	02-Feb-2017	03-Feb-2017	04-Feb-2017	05-Feb-2017	06-Feb-2017	07-Feb-2017	08-Feb-2017
Supply	40	40	40	40	0	0	0	0
Weld	0	40	40	40	0	40	0	0
Paint	0	0	40	40	0	40	40	0
Assembly	0	0	0	40	0	40	40	40
Realization	0	0	0	0	0	0	0	0

5.3 Modification of Single-Stage Fongs Production Models

The single-stage production control step response to the equation (1) is for inventory scenario using the total time of ST transmission time, whereas the D minus 1 scenario is based on daily production with the effective time of T_p production of 8 hours. To get the production model in accordance with the D minus 1 scenario then a single stage control model is modified using the Heaviside function.

This model will be used at each work station by superposition of the daily production of each workstation and the total inventory of each process can be set. The modifications from production to the total delivery time into daily production are by changing the total time constant τ and proportional gain *K* of equation (1) using the ST_1 value with the set one-day rate into the daily time constant. The daily time constant of each workstation is:

$$\tau_{pk} = \left(1 - \frac{1}{ST_2} + \frac{1}{IAT_{pk}}\right) \tag{9}$$

$$\tau_{pc} = \left(1 - \frac{1}{ST_2} + \frac{1}{IAT_{pc}}\right) \tag{10}$$

$$\tau_{pa} = \left(1 - \frac{1}{ST_2} + \frac{1}{IAT_{pa}}\right) \tag{11}$$

$\boldsymbol{\tau_{pk}}$ = time constant in the welding process

$\boldsymbol{\tau_{pc}}$ = time constant in the painting process

$\boldsymbol{\tau_{pa}}$= time constant in the assembly process

IAT_{pk} = IAT for welding process

IAT_{pc} = IAT for painting process

IAT_{pa} = IAT for assembly process

$$K_{pk} = \frac{\tau_{pk}}{IAT_{pk}} \tag{12}$$

$$K_{pc} = \frac{\tau_{pc}}{IAT_{pc}} \tag{13}$$

$$K_{pa} = \frac{\tau_{pa}}{IAT_{pa}} \tag{14}$$

K_{pk} = Proportional gain of welding process

K_{pc} = Proportional gain of painting process

K_{pa} = Proportional gain of assembly process

The supply and release scenario at the welding station is provided in accordance with the total demand distributed to the D_d daily demand which must be complied with ST delivery time. The amount of output from the welding portion at all times to meet the ST delivery time for a one-stage production model with daily production time using the Heaviside method of production equation is:

For welding process is

$$O_{pk}(t) = \sum_{k=1}^{ST-2} D_d K_{pk} (H(t-(k-1)) - H(t-(k-1))\,\mathrm{e}^{(-t+(k-1))/\tau_{pk}}) - D_d H(t-k) \tag{15}$$

For painting process is

$$O_{pc}(t) = \sum_{k=1}^{ST-1} D_d K_{pc} (H(t-k) - H(t-k)\,\mathrm{e}^{(-t+k)/\tau_{pc}}) - D_d H(t-(k+1)) \tag{16}$$

For assembly process is

$$O_{pa}(t) = \sum_{k=1}^{ST} D_d K_{pa}(H(t-(k+1)) - H(t-(k+1))e^{(-t+(k+1))/\tau_{pa}}) - D_d H(t-(k+2)) \tag{17}$$

5.4 Modification of Two-Stage Fongs Production Models

Response of two-stage production control in equation (1) is for WIP scenario and inventory scenario using total time based on ST is different from scenario D minus 1 which uses daily production scenarios. To get the production model according to scenario D minus 1 then the two stage control model is modified using the Heaviside function. This model is used as a combined production control model of WIP and inventory. The first stage is used for WIP and the second is for inventory. This model illustrates the daily output at the assembly station. Modifications from production to total delivery time into daily production are done by changing the dynamic characteristics of the output system. The modified factor ie the natural frequency (ω_n) and the damping ratio (ξ) , both are found in equations (2), in this case the daily use of ST_1 is daily rate of 1 day. The change results in an equation:

$$\omega_n = \sqrt{\left[\left(\frac{1}{LT} + \frac{1}{WAT}\right)\left(1 - \frac{1}{ST_2} + \frac{1}{FAT}\right)\right]} \tag{18}$$

$$\zeta = \frac{1}{2\omega_n}\left(1 + \frac{1}{LT} + \frac{1}{WAT}\right) \tag{19}$$

The supply and output scenario of the production system according to the total demand distributed to D_d daily demand that must be fulfilled to comply with ST shipping time. The number of releases from the system at all times satisfies the ST delivery time at the two-stage production model for the daily production time formulated using the Heaviside method is:

$$O_{pa}(t) = \sum_{k=1}^{ST} D_d K(H(t-(k+1)) - H(t-(k+1)) \frac{e^{\zeta\omega_n(-t+(k+1))}}{\sqrt{1-\zeta^2}} \sin(\omega_d(t-(k+1)) + \tan^{-1}(\frac{\sqrt{1-\zeta^2}}{\zeta})) - D_d H(t-(k+2)) \tag{20}$$

Two-stage output model with D minus 1 scenario for total demand of 120 units with 5-day delivery time using output process equation (20) is shown in Fig.9.

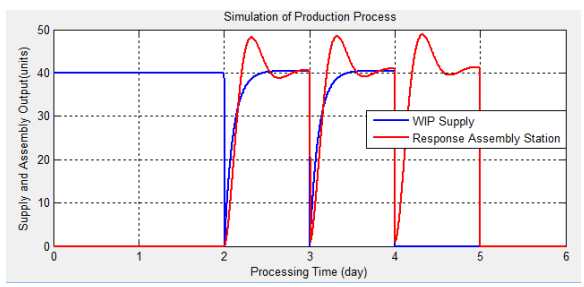


Figure 9. Two-stage daily output model of D minus 1

6. Production Process Simulation

6.1 Simulation of Single-Stage Production Process

For two level and three factor simulation of single-stage system use factors shipping time 5-day and 7-day delivery time, IAT is 1 and 4 days for produce 120 and 200 units beds are shown in Fig. 10 and the simulation results are shown in Table 2. Table 2 show shipping time ST_1, expected shipping time ST_2 and IAT is significance production process, with low IAT faster production process reach the production target (Fig. 10), high IAT slower or maybe any delay will be happen in the production line. Total production planned in this case is 120 and 200 units for shipping time 5 and 7 day, for both production scenario daily production demand is 40 units. Use modification equation (16) to D minus 1 scenario for example is painting process with IAT 0.08 day, ST_1 is 1day, expected shipping time ST_2 is 0.9 day, simulation result show in Fig. 11.

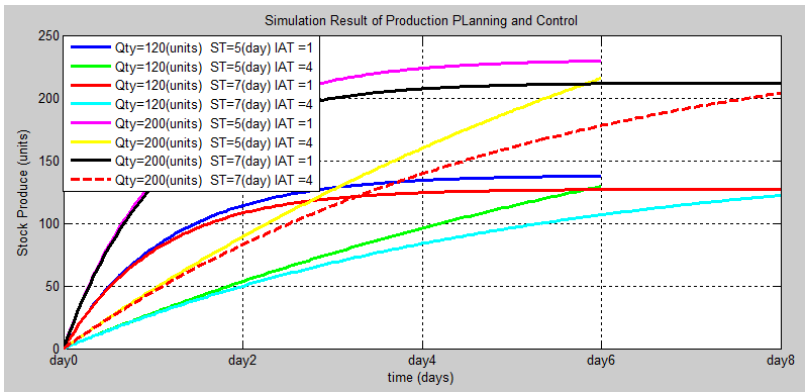


Figure 10. Single-stage production simulation for two level and three factors production experiments

Table 2. Effect of experiments factor to precision of time target for single-stage system

	Variance	Ftest	P-Value	***=Significant
A=Demand Shipment (day)	0	Inf	0	***
B=Expected for Transfer Time(day)	0.4568	6.3093	0.2412	p>0.05
C=Inventory Adjustment Time(day)	29.4165	10.2070	0.1931	p>0.05
Interaction AB	0	Inf	0	***
Interaction AC	2.4652e-32	1.1691e+32	1.1102e-16	***
Interaction BC	1.1926	2.4166	0.3639	p>0.05
Error	2.8820	1	0.5000	p>0.05

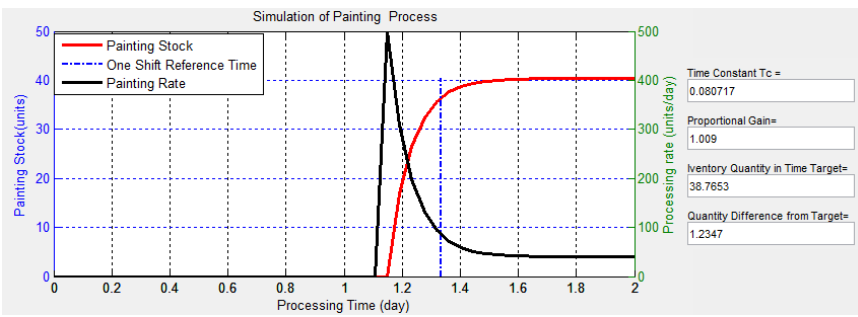


Figure 11. D minus 1 of daily painting process, ST_1 = 1 day, ST_2 = 0.9 day, IAT = 0.08day

Time finish inventory target for this case is 8 hours in this case is in1.37day (Fig.12, one shift reference time line). At this time have finish 38.7653 units, for 40 units targets process delay for 1.2347 units. This delay caused delay of inventory finish start received in the painting buffer container. Inventory start at 1.17 day (Fig.12, painting stock line), painting process need one cycle for completing process in the production line before component finish. To avoid delay is needed wright adjustment time for inventory.

Complete scenario of D minus 1 production scenario for daily productions is 40 units bed, for all the process, welding, painting, and assembly with supply of raw components supply is show in Fig. 12.

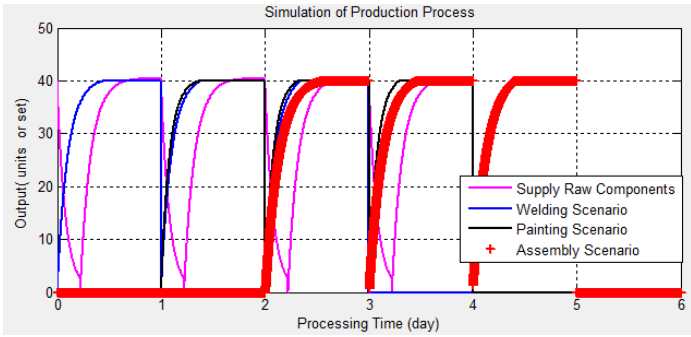


Figure 12. D minus 1 Production scenario for 120 beds, ST 5 day, Dd 40 units, IAT 0.01day

6.2 Simulation of Two-Stage Production Process

In the case of two-stage production system is planned total of 120 units (D_d is 40 units) delivery time is 5 days. For two level and three factor simulation is used LT 1.5 and 2 days, WAT 0.05 and 0.3 days, FAT 0.1 and 0.5 days, simulation results are shown in table 3 and Fig. 13. Simulation result show all experiments factor are have significant effect to the production process and to reach production target must be adjust all factors closely to the process.

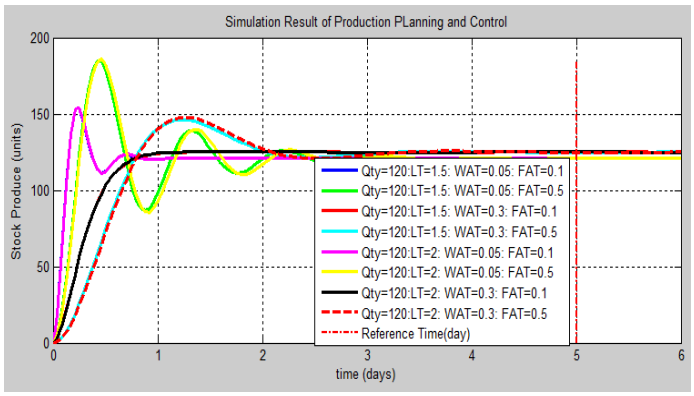
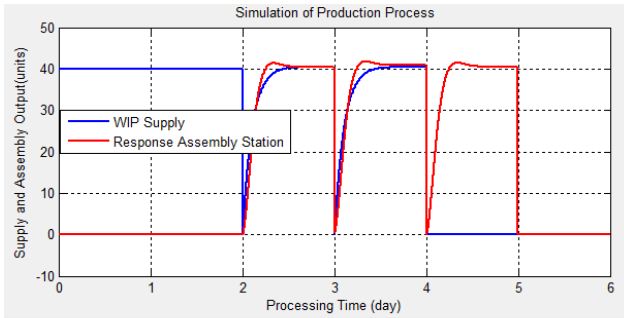


Figure 13. Two-stage production scenario for 120 beds, ST 5 days, D_d 40 units

Table 3. Effect of experiments factor to precision of time target for two-stage system

	Variance	Ftest	P-Value	***=Significant
A=Lead Time Day	0.0169	1.3413e+03	0.0205	***
B=WIP Adjustment Time	0	Inf	0	***
C=Finished Inventory Adjustment Time	9.1156	2.4835	0.4398	p>0.05
Interaction AB	0	Inf	0	***
Interaction AC	0.0129	1.7512e+03	0.0179	***
Interaction BC	3.9443e-31	5.7397e+31	1.1102e-16	***
Error	22.6390	1	0.5000	p>0.05

On simulation using WAT = 0.05, FAT = 0.1 (Fig. 14) found stable system response at 514 minutes and over shoot reached 2.2464%. The result of this simulation shows a 34 minute delay and over shoot only 1 unit. The average process cycle time is 12.85 minutes, relativ close to the takt time. The factors of production factors in this system may be recommended for use even though there should be more time, but this time value is less effective on the system.



Time Constant, Settling time, Over Shoot and Peak Factor of Dynamics Response

	Dynamics Value
WAT	0.0500
FAT	0.1000
LT	0.7000
Time Constant (minutes)	128
Settling Time (minutes)	514
Over Shoot (%)	2.2464
Peak (units)	41
Target (units)	40
Bias (units)	1

Figure 14. D minus 1 production scenario for 120 beds, ST 5 day, Dd 40 units, WAT 0.05 day and FAT 0.1 day

7. Conclusion

This study is to support model D minus 1 production scenario with systematic production planning and scheduling (PPS). The result of the study have gained influence of any production factors that is inventory adjustment time (IAT), finish inventory adjustment time (FAT) and WIP adjustment time (WAT) in order to control process stability to succeed produce the goods as already planned and go to on time delivery (OTD) to achieve highest level of customer's satisfaction.

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Biography

Susanto Sudiro is Lecture in Magister of Mechanical Engineering Program at Pancasila University, Jakarta Indonesia. He earned B.S. in Mechanical Engineering from ISTN Jakarta, Masters in Mechanical Engineering from ITB, Bandung Indonesia and Doctor of Philosophy from UTM Kualalumpur Malaysia. He joined Pancasila University in 1990 and currently supervising many research projects both at B.S. and master level in topics relating to Quality Management, New Product Development, Lean Manufacturing, and Machine Tools Design. He has done research projects in new product development with some Hospital Bed Manufacturer e.g. MAK (Mega Andalan Kalasan) from Indonesia and FranceBed from Japan. He spent more than 15 years implement Good Manufacturing Practices in Medical Devices base on ISO 13485 Quality System for Regulatory Purposes. He also has experience in regulation system to make hospital bed product comply with Indonesian National Regulation (SNI) and European Medical Devices Regulation (CE mark). His research interests include new product development, project management, jig and fixture design, manufacturing, simulation, optimization, reliability, scheduling, and lean.

Dr Sha'ri has a degree in Industrial Engineering from University of Miami and a Masters of Science in Integrated Quality Systems from University of Birmingham and Doctor of Philosophy with a focus on TQM for small manufacturing business from the University of Birmingham. He is a Registered Professional Engineer with the Board of Engineers Malaysia (BEM) and a Senior Member of the American Society for Quality (ASQ). He is now a Professor of Quality Engineering and Management in UTM. He joined UTM in 1990 and currently supervising many research projects both at PhD and master level in topics relating to Quality Management, Robust Quality Engineering, Sustainability, Lean Manufacturing, and Industrial Engineering. Dr Sha'ri has published over 100 papers in national and international journals and conferences. Besides writing, he has been involved in training a number of organizations including Proton, IWK, Hitachi Chemical, Mitsubishi in various topics of Quality Engineering, ISO 9001, Industrial Engineering, and Project Management. He is currently heading a research project on developing a theoretical framework for lean adoption in Malaysian companies.