SUDEIJ
Sustainable Urban Development and Environmental Impact
SUDEIJ 2(1): 1–20
ISSN 3062-8997

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Simulation of hybrid push/pull production system for cost reduction and resource optimization in sustainable automotive manufacturing

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Received Date: January 15, 2025 Revised Date: February 2, 2025 Accepted Date: February 28, 2025

ABSTRACT
Background: The rapid development of the automotive industry requires an efficient production system to minimize costs and optimize resources. PT Moreen JBBK, an automotive component manufacturer, previously relied on a push production system based on demand forecasts. However, discrepancies between forecasted and actual demand led to excess inventory and increased storage costs. To address this issue, a hybrid push/pull production system was introduced, aiming to balance inventory levels while maintaining production efficiency. **Methods**: This study employs a discrete event simulation method using Arena software to analyze the impact of implementing a hybrid push/pull production system at PT Moreen JBBK. The research utilizes company data from October 2016 to compare the efficiency of different production scenarios. **Findings**: Findings indicate that adopting a hybrid push/pull production system significantly reduces inventory costs while preventing backorders. The system modifies the upstream process by transitioning from forecast-based production to a pull system that aligns with actual demand. Meanwhile, the push system remains in use for raw materials and semi-finished components to ensure production continuity. Additionally, worker and machine utilization decreased, allowing the company to reallocate resources for other product lines, thereby enhancing production capacity. **Conclusion**: The study concludes that implementing a hybrid push/pull production system provides PT Moreen JBBK with a competitive advantage by reducing operational costs without compromising demand fulfillment. However, this system requires careful inventory tracking and employee adaptation. In the long run, reduced storage costs lead to substantial savings. **Novelty/Originality of this article**: The novelty of this research lies in its application of hybrid push/pull production to an SME automotive manufacturer in Indonesia, demonstrating its effectiveness in reducing costs and improving resource utilization. This study contributes to the broader development of the automotive industry, supporting economic growth through optimized production strategies.

KEYWORDS: simulation; arena; hybrid production system; discrete event simulation.

1. Introduction

According to the Central Bureau of Statistics (BPS), the manufacturing or processing industry sector is the leading sector that provides the largest contribution to Gross Domestic Product (GDP) and has an impact on Indonesia's economic growth (Badan Pusat Statistik, 2016). In general, the sectors of the Indonesian economy experienced an overall increasing trend (Badan Pusat Statistik, 2016). In 2016, the cumulative growth of the manufacturing industry sector to the Gross Domestic Product (GDP) amounted to 4.61

Cite This Article:
Muhammad, H., & Kusumastuti, R. D. (2025). Simulation of hybrid push/pull production system for cost reduction and resource optimization in sustainable automotive manufacturing. *Sustainable Urban Development and Environmental Impact Journal, 2*(1), 1-20. https://doi.org/10.61511/sudeij.v2i1.2025.1730

percent until the third quarter of 2016 (Badan Pusat Statistik, 2016). The processing industry itself is described by the Central Bureau of Statistics (BPS) as an economic activity that carries out activities to convert basic goods (raw materials) into finished or semi-finished goods and/or from less valuable goods into higher value goods, either mechanically, chemically with machines or by hand (Badan Pusat Statistik, 2016). The performance of the Indonesian economy in the third quarter of 2016 against GDP based on constant prices increased by 3.20 percent from Rp. 2,353,522.9 billion to Rp. 2,428,722.3 billion. Meanwhile, the contribution of the manufacturing industry sector to GDP in the third quarter of 2016 amounted to Rp. 511,165.2 billion or 19.90 percent. (Badan Pusat Statistik, 2016). Within the manufacturing industry is the automotive industry or transportation equipment sector (Zhang, 2006). The contribution of the motor vehicle industry to gross domestic product (GDP) in the third quarter of 2016 has the potential to increase after reaching the highest level in the second quarter of 2016 since the last three years (Gabungan Industri Kendaraan Bermotor Indonesia, 2016). Data from the Central Statistics Agency (Badan Pusat Statistik/BPS) shows that the transportation equipment sector, which includes motorcycles, cars, and other transportation equipment, recorded the sharpest growth since 2013, growing by 8.39% in the second quarter of 2016 (Gabungan Industri Kendaraan Bermotor Indonesia, 2016).

In the automotive industry, two-wheeled vehicles still occupy the position with the highest demand (Ministry of Industry, 2016). According to Minister of Industry Airlangga Hartarto, the motorcycle population in Indonesia reached 90 million units or more than one-third of Indonesia's population of 250 million (Tempo, 2016). This number shows that motorcycles are still the main alternative for people to carry out their activities amid the availability of public transportation that has not been maximized. In the last five years, the motorcycle industry in Indonesia has shown a significant increasing trend with an average production of more than 7 million units per year (Tempo, 2016). The Ministry of Industry is also optimistic that the growth trend of the domestic motorcycle industry will increase consistently in the coming years (Tempo, 2016). Domestic motorcyle production wholesale and export can be seen in Table 1.

Table 1. Domestic motorcyle production wholesale and export

	Production	Wholesale	Export
2010	7,395,390	7,369,249	29,395
2011	8,006,293	8,012,540	30,995
2012	7,079,721	7,064,457	77,129
2013	7,736,295	7,743,879	27,135
2014	7,926,104	7,867,195	41,746

This is also solidifies Indonesia's position as the third largest motorcycle producer in the world after China and India. On the other hand, the Ministry of Industry emphasizes the importance of optimizing research and development (R&D) activities in the country, so that the national motorcycle industry is able to develop products that meet the needs of domestic and international markets. (Tempo, 2016). Along with the development of the automotive industry, production demand in the domestic component industry has also increased (KPMG Consulting, 2014). The component industry is a force that supports the motor vehicle industry (Tempo, 2016). The Ministry of Industry states that the development of the motor vehicle industry has a wide-ranging multiplier effect, from creating economic activity in component assembly and manufacturing activities, to driving economic activity in the distribution sector and after-sales service activities (Tempo, 2016).

In addition, the importance of the proportion of local components to the automotive industry is also an important concern. With more local components, the motorcycle industry in Indonesia can provide more jobs. So far, two million workers have been absorbed (Tempo, 2016). According to the Ministry of Industry, the local content of the average motorcycle made in Indonesia or the Domestic Component Level (TKDN) has reached 85 percent. If the local component industry is strong, this will reduce dependence on imported components and thus save foreign exchange. Therefore, the motorcycle assembly industry is asked increase guidance to Small and Medium Industries (SMIs) in the field of components in order to increase their productivity and also improve the quality of their products so that they can be accepted in the vehicle manufacturing industry (Hernandez-Matias et al., 2006).

The implementation of a production system that can optimize productivity is a challenge faced by every manufacturer. Currently, with the level of competition getting higher with increasingly differentiated consumer demand, low costs, and also high quality are important factors to win the competition (Jeroen & Reinot, 2010). In meeting market demand, the implementation of the right production system will be able to increase production effectiveness which will have an impact on reducing production costs (Jeroen & Reinot, 2010). The application of the right production system will also have an impact on whether or not the goods reach consumers in the fastest possible time and at a low cost (Jeroen & Reinot, 2010). The discussion of production systems will also be related to inventory, production costs, responsiveness to consumer demand, and also the flexibility of the production process. Competition in today's manufacturing industry is not only in quality and cost, but also in terms of production speed (Rasmussen & Walden, 1999). By implementing the right production system, production costs can be reduced, and productivity and efficiency can be increased (Pinedo & Chao, 1999).

Many experts have conducted research related to the integration of push and pull production systems (Takahashi & Nakamura, 2004; Spearman & Zazanis, 1992; Deleersnyder et al., 1989) Each of these manufacturing systems has advantages and disadvantages. The general result and conclusion is that combining these two methods is more beneficial (Hochreiter, 1999). In most cases it is found that, when the two systems are integrated, the disadvantages can be avoided and the advantages of each system can be strengthened (Ghrayeb, et al, 2008). A push/pull hybrid system is an integration of the conflicting performance characteristics of both push and pull systems to obtain better system performance. This hybrid system is commonly found in assamble-to-order environments (Ghrayeb, et al, 2008). In this environment, raw materials can be transformed into semi-finished products, at which point downstream operations are controlled by customer orders (Ghrayeb, et al, 2008). Therefore, in a hybrid push/pull system, upstream production stations are controlled by push production, while production from downstream production stations is controlled by pull production systems (Cochran & Kaylani, 2008).

PT Moreen JBBK is a domestic manufacturer of motorcycle automotive components. This company is also included in the manufacturing industry sector which has the largest contribution to GDP. Therefore, performance improvement at PT Moreen JBBK is expected to contribute to the growth of the automotive industry as well as the Indonesian economy. Currently PT Moreen JBBK carries out its production activities with a push system by making a Master Production Schedule (MPS) and Material Resource Planning (MRP) based on forecasting demand from its customers. The problem faced by PT Moreen JBBK is that the demand forecast that has been made is different from the actual demand. As a result, the overall operational costs have also increased due to the inventory in the system that has accumulated. This condition makes it necessary to analyze the production system at PT Moreen JBBK to optimize the production system which is expected to increase productivity and also reduce existing inventory levels.

2. Methods

This research generally aims to analyze a production system applied in a manufacturing company through discrete event simulation and apply the concept of hybrid production system (Jacobson et al., 2013). The hybrid production system has been stated to reduce the weaknesses of each of the basic production systems, namely push and pull, which makes it appropriate to be applied in this research (Yen Huang, 2011). To see the impact of the implementation, a case study was conducted at PT Moreen JBBK, an automotive component manufacturer that implements a push production system. The problem that generally occurs in manufacturers who implement push production systems is the high amount of inventory due to the gap between actual and forecast demand. This problem also occurs at PT Moreen JBBK, and by applying the concept of a hybrid system, it is expected to minimize these shortcomings. Judging from these objectives, this research is included in descriptive research which aims to find out more about things and describe or describe the characteristics of a particular thing (Malhotra, 2007). Judging from its scope, this research is a case study research, because researchers want to describe the real conditions of a company (REM Assoicates Management Consultant, 2014; Cooper & Schindler, 2011).

This research will use simulation software, Arena Simulation Software Version 14, developed and released by Rockwell Automation (2010). Arena uses the SIMAN language to help users build alternative strategies for existing work systems to improve their performance. A model is built by dragging & dropping modules into the model window, connecting the modules with connectors to show the flow of entities through the simulated system, and giving the modules further details using dialog boxes or worksheets (Law, 2007). Verification is concerned with determining whether the assumptions have been translated into the computer program correctly. The verification method is done by debugging the computer program simulation, or if using Arena simulation system software there is already a verification feature (Kumar et al., 1993). With this system, researchers can find out whether the program that has been built is correct or not. Validation is the process of determining whether the basic model has approached or can describe the real system in achieving research objectives (Ip et al., 2002). Validation in this research will compare the value added time of each process in the real production system and the base case simulation model to be built. The validation is done by creating a confidence interval from the base case model. If the parameters contained in the real system are in the confidence range of the model results that have been built, then the model can be said to be valid. The alpha value used in general is 5-10%. This is due to the availability of sufficient data determining the level of confidence is at the level of 5-10%. With this number, this research is expected to represent real conditions more accurately.

3. Results and Discussion

3.1 Production system of PT Moreen JBBK

PT Moreen JBBK is a manufacturer of automotive components for motorcycle manufacturers in Indonesia. It was established in 2012 and currently has 70 employees. This company acts as a tier two subcontract company of an automotive manufacturer in Indonesia. As shown in Figure 1, this company will receive requests for component manufacturing from a component manufacturer whose products will be used to produce for automotive manufacturers. Position of PT Moreen JBBK in the automotive industry can be seen in Figure 1.

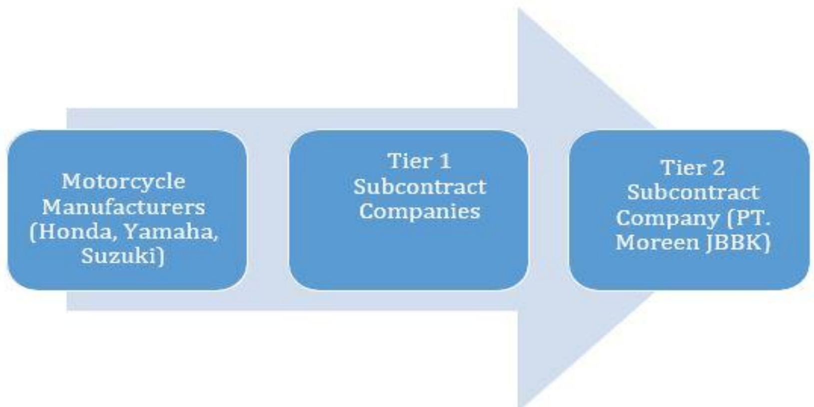


Fig. 1. Position of PT Moreen JBBK in the automotive industry

The products of PT Moreen JBBK include components that are used to make a part of a motorcycle unit. The uses of these products, such as components for making motorcycle footrests, motorcycle exhaust support components, and other components. The research will focus on one product, namely the Sidestand Assy Bracket because it is the product that has the largest contribution to the company's revenue compared to other products owned, which is around 30% of the total revenue. Thus, it is expected that improvements in the production process of the product can have a major impact on the company.

Figure 2 shows the production product structure of the Side Stand Assy Bracket product. This product consists of three components, two of which are made in the same factory (make), and one component is procured by ordering (buy) from a third party. The product a component used to make a footrest on a motorcycle unit. Side stand bracket assy production hierarchy chart can be seen in Figure 2.

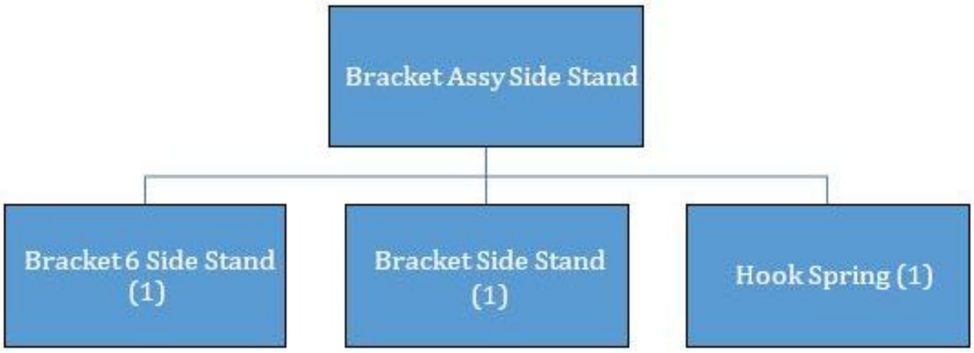


Fig. 2. Side stand bracket assy production hierarchy chart

PT Moreen JBBK produces automotive components by stamping and welding process. There is a mold called dies, which is used to form a steel plate (raw material) into the desired component shape. The molding process using these dies will be carried out at the stamping process stage. After that, for products that require the joining of several components, it will go through the welding process. In producing Bracket Assy Side Stand products, the components of Bracket 6 Side Stand and Bracket Side Stand will be produced through a stamping process from raw materials. After that, the two components will be combined with the subcontract component, Hook Spring, through the welding stage.

PT Moreen JBBK gets forecasts from its clients for each product 3 months before the production month. After that, it continues to plan the production capacity and production schedule of each product. The production carried out by PT Moreen JBBK is push from each process. The manufacturing can be divided into 4 parts of the process, namely: (1) Production from raw materials into 6 Side Stand Bracket components with stamping process. (2) Production from raw materials into Side Stand Bracket components by stamping process. (3) Procurement of Hook Spring components from third parties (subcontract). (4) Combining the three components of Bracket 6 Side Stand, Bracket Side Stand, and Hook Spring into Bracket Assy Side Stand through a welding process. The type of production strategy used by PT Moreen JBBK is a repetitive strategy, because it has a mold in the form of dies that are standardized and can produce in large quantities. In addition, at PT Moreen JBBK there are also components formed with several dies that can be combined into another product. This is a characteristic of the repetition production strategy.

Based on interviews with the managerial staff of PT Moreen JBBK, implementing a minimum inventory policy (safety stock) of twice the fulfillment of the largest possible demand for semi-finished goods inventory and also finished goods inventory. However, because PT Moreen JBBK uses a push production system with production targets based on demand forecasts, sometimes the actual demand that occurs is not the same as the forecast. Therefore, there is a problem in the form of inventory levels in the production system that exceed the desired inventory level.

3.2 Research assumptions in the base case scenario

There are assumptions applied to the simulation model of this research in order to focus the desired research point from the actual situation. Assumptions of research data limitations in reflecting the actual situation: (1) The data used is production and demand data for the October 2016 period. Because in that month there was the most demand. (2) This simulation only uses data and runs for a month due to the limitations of Arena simulation software in building simulation ranges. (3) Process time (production capacity) is obtained from the amount of working time per day (8 hours per day) in seconds divided by the amount of production per day. The time obtained within the scope of one month is then entered into the input analyzer to determine the distribution to be used in the process module in Arena. (4) It is assumed that the server is always busy because during working hours the production process will continue, so the arrival of the entity is arranged so that the server is never empty. Production will stop when the production quantity has reached the production target. (5) Production simulation is carried out on one product which is the focus of research, namely Bracket Assy Side Stand. (6) The number of simulation replications was carried out 10 times based on the rule of thumb in conducting simulations. (7) This base case simulation will be run with a simulation setting Replication length or replication length for 21 days, where one day has 8 hours.

This is based on the number of days and working time during October 2016. This research will use base time units in the form of days, to make it easier for researchers to see the results of the average daily inventory contained in the system. (8) Holding cost will be calculated by multiplying the product value in rupiah by the holding cost fraction of 20% (this proportion is based on the journal of Cachon & Olivares (2010) which states that the average storage cost of the automotive industry is 20%, and has been proposed to the management of PT Moreen JBBK and received approval to be used in the simulation) and then divided by the number of days in a year, namely 365. The result will be the holding cost per unit of product per day. (9) The amount of holding cost per month will be calculated by multiplying the average amount of inventory per day by the results of the calculation in assumption point 7 and multiplying by the number of days in a month, namely 31 days. (10) Based on information from PT Moreen JBBK, the value of each semi-finished component and finished goods is IDR 15,000 for finished goods Bracket Assy Side Stand, IDR 3,810 for Bracket 6 Side Stand components, IDR 9,559 for Bracket Side Stand components, and IDR 279 Hook Spring components. (11) The alpha value used in the model validity test is 5%.

3.3 Base case simulation model

The base case model will represent the current production process and demand for Side Stand Bracket Assy products at PT Moreen JBBK. This production system implements a push production system, because production will be carried out continuously on the basis of demand forecasts obtained from customers (Azadeh & Ghaderi, 2006). As explained in the production process, PT. Moreen JBBK produces and orders semi-finished components and stores them as inventory of semi-finished goods (WIP), namely Bracket 6 Side Stand, Bracket Side Stand, and Hook Spring. After that, the WIP components will be removed to be combined in the manufacture of finished goods (finish good) in the welding process and will be included in the finished goods inventory. Production will continue until the production target is achieved. Demand that arises will be met by taking finished goods from the finished goods inventory. The amount that cannot be fulfilled at the time of demand will be backordered and the amount will be added to the next demand.

This base case simulation model will be built with Arena computer software that refers to the simulation model of previous researchers, Marshudi & Shafeek (2014), which has been described in the theoretical basis. The simulation model describes a push production system that has a component combining process in it with a batch module. However, the difference between this base case simulation model and the previous research model is that, because PT Moreen JBBK runs the stamping and welding process simultaneously, the simulation model is divided into several parts. First is the part that produces and procures

WIP components that will be put into inventory. Second, the joining process is carried out by taking the available WIP inventory. This is depicted in this model by using the same inventory variables for the reduction and addition. That way, the merging stage can run concurrently with the component production stage without waiting for the process to start. The process of taking components from WIP inventory will replace the merge or batch module found in the reference simulation model from Marshudi & Shafeek (2014). In addition, there is also a part of the model that describes the actual daily demand from the client. This demand will be fulfilled by reducing the amount of inventory in the finished goods inventory. The addition of this set of actual demand modules is intended to be able to see the movement of inventory in the system during the simulation period.

The simulation process starts from the create module contained in each part of the model based on the production process at PT Moreen JBBK which has been described previously. There are five create modules in the base case simulation model that has been built. First, the create module in the production process of the Bracket 6 Side Stand component named BRK6 describes the raw material that enters the system to be processed into a Bracket 6 Side Stand component. The incoming entity will go through the BRK 6 stamping process module. After there is a decide module called shape checking which describes checking the production results of components that will be assigned to the BRK6 production quantity and adding semi-finished goods inventory to the assign module called Inventory 1. The true/false probability of the decide module is 99.9% true because based on interviews, it is very rare for errors to occur at the stamping stage. After that, there is a decide module that is intended to see whether the production quantity has reached the set production target or not. If not, the entity will return to the stamping process module indicating that production will continue. If so, the entity will go to the hold module which will hold production. This process indicates that production will stop when the production quantity has reached the production target.

Second, the create module in the production process of the Bracket Side Stand component named BRK SS describes the raw material that enters the system to be processed into a Bracket Side Stand component. The incoming entity will go through a process module called stamping BRK SS which will then go through the decide module which has the same probability as in the production process of the Bracket 6 Side Stand component. The entity of BRK SS will be assigned as the production quantity of BRK SS and will add semi-finished inventory to the assign module named Inventory 2. After that, the entity of BRK SS will go through the same flow as the BRK6 entity where production will be stopped or held with the hold module when it reaches the production target.

Third, there is a create module called Hook Spring. This module describes the receipt of Hook Spring components based on scheduled arrivals from third parties that will be assigned to semi-finished inventory in the Inventory 3 assign module. The time and number of entity arrivals are determined through the arrival data of goods obtained from the historical data of PT Moreen JBBK. The setting is done by using the schedule arrival feature in Arena software.

Fourth, there is a create module called BRK ASSY SS. This module describes the production process of the welding stage. The incoming entity will be assigned to reduce the inventory of each required component, namely Bracket 6 Side Stand, Bracket Side Stand, and Hook Spring. This inventory reduction assign process describes the welding stage that will take its components from each of the required component inventories as previously described. Next, the entity will go through a process module called welding FG. After that, the entity will go through the decide module which has a true probability of 98%. This is based on the results of interviews that states that the accuracy of the welding production process is around 98%. The flow of the BRK ASSY SS entity will also follow the flow of the BRK 6 and BRK SS entities where production will stop when the production target has been reached.

Fifth, there is a create module called Demand that describes the actual demand per day from clients. The number of entities that enter the system is set with a daily arrival schedule to describe the actual demand that occurred in October 2016. This illustrates the number of shipments of goods from PT Moreen JBBK to clients that will be sent per day. Each entity that appears will reduce the inventory of finished goods, with an assign module called Reduction Inventory 4. But before that, there is a decide module where when the number of requests exceeds the amount of finished goods inventory available, it will go through the record module and be recorded as a backorder. Researchers built a simulation model like this, because PT Moreen JBBK performs stamping and welding processes at the same time and requests will be fulfilled through taking finished goods from the finished goods inventory.

There are several variables in this model. The production target variable is determined based on the demand forecast per month received by PT.Moreen JBBK from its clients. Then the number of production targets will follow the number of demand forecasts per month obtained. In the inventory variables BRK 6, BRK SS, Hook Spring, and BRK ASSY SS there is an initial value in the form of the amount of inventory from the previous period's production results. In addition, there are variables of Total Production of BRK 6, BRK SS, and BRK ASSY SS. This variable will serve to see how much has been produced and will be the determining factor when the system will stop producing when it has reached the same amount as the production target variable.

After the model is built, a verification and validation stage is needed to determine whether the model can represent the real situation. Model verification is done by checking the model through the check model feature in Arena software. That way, it can be seen whether or not there are errors or errors in the model system that has been built. The results of this verification show that the model that has been built by researchers has no errors. The model validation process is carried out by comparing the process time or value added time of each part of the model concerned with production activities with the actual average process time for one month. The validation results of the base case simulation model can be seen in Table 2.

Table 2. Validation of base case simulation

Replication	Production of Bracket 6 Side Stand	Bracket Production Side Stand	Welding Process
1	18.34857	18.1583	21.1634
2	18.14764	18.3955	21.3496
3	18.18543	18.2235	21.0501
4	18.33262	18.2457	21.2847
5	18.35513	18.1551	21.4445
6	18.22814	18.0999	21.5185
7	18.29407	18.4290	21.3229
8	18.47813	18.5405	21.0538
9	18.07958	18.4440	21.1430
10	18.21183	18.5347	21.5682
Mean	18.2661	18.3226	21.2899
Var	0.013845851	0.02714264	0.034350375
Stadev	0.037210014	0.052098598	0.061779514
t	2.262	2.262	2.262
Lower limit	18.18194502	18.2047752	21.15013535
Upper limit	18.35028312	18.44046926	21.42962587
Average actual time	18.18702752	18.20804263	21.33190245

From the table 2, the average actual time of each process is in the calculation of the confidence interval with an alpha of 5%. The result of the confidence interval of the value added time of the Bracket 6 Side Stand production process is [18.18194; 18.35028] seconds and the average actual value added time is 18.18702 seconds, so the simulation model has been valid in describing the production process of the Bracket 6 Side Stand component. In addition, the other two production processes can also be described validly in the simulation model, looking at the confidence interval and the actual average value added time of the

Bracket Side Stand production process and welding process respectively as follows; [18.2047752; 18.440469] seconds with an actual average time of 18.208042 seconds and [21.15013535; 21.42962587] with an actual average time of 21.33190. That way the base case simulation model has been valid in describing the real state of the three production processes.

The total holding cost of this base case simulation is Rp. 2,635,446 for a month with the amount of inventory of each component and finished goods in the system as shown in Table 3. The cost uses the average amount of inventory from the results of 10 simulation replications that have been carried out. Average inventory per day of each component and finished goods can be seen in Table 3.

Table 3. Average inventory per day of each component and finished goods

Replication	BRK Inventory 6	BRK SS Inventory	FG Inventory	Hook Inventory
1	3,248	3,755	7,228	6,242
2	3,161	3,787	7,407	6,298
3	3,167	3,748	7,256	6,225
4	3,166	3,791	7,546	6,276
5	3,162	3,715	7,242	6,135
6	3,178	3,761	7,457	6,196
7	3,148	3,793	7,379	6,312
8	3,161	3,744	7,467	6,239
9	3,167	3,728	7,436	6,085
10	3,214	3,743	7,541	6,256
Average	3,177	3,756	7,396	6,226

3.4 Alternative scenario 1

In this alternative scenario, the amount of finished goods inventory will be reduced, because the average amount of finished goods inventory in the base case appears to have the highest amount compared to other components. In addition, given that the value of the finished good is the highest, it is desirable to avoid a large buildup of finished goods inventory, as this can increase holding costs. The excessive amount of inventory results from the implementation of production that refers to production targets based on demand forecasts. Meanwhile, the actual demand that occurs is often different from the forecast that has been obtained. The difference is what then accumulates and over time if accumulated will be a large amount. This alternative scenario will use a hybrid model in the PT Moreen JBBK production system for Side Stand Assy Bracket products. In this hybrid production system, the inventory for finished good will be replenished when there is a reduction in inventory with the amount corresponding to the demand. So that production will be triggered by actual demand like a pull system. On the other hand, production for semi-finished components (WIP) will be carried out in the same flow as the base case model, namely the push production system, thus forming a hybrid push/pull production system.

The simulation of this alternative model will still use the same Arena software simulation model, but there are additional variables in the form of inventory targets. This variable serves to attract the production of finished goods so that the amount produced can adjust to the actual demand by maintaining a predetermined inventory level. For example, when the inventory target is set at 5,000 units, when the actual demand appears at 800 and will be taken from the finished goods inventory of 5000 units, the inventory will be 4,200 units. With an inventory target of 5000 units, the system will produce 800 units to reach the inventory target. In this model, the inventory target will be set at the initial inventory of finished goods, which is 5,070 units. In addition, by setting an inventory target, over production can be prevented because production will depend on the actual demand, not on the production target. There is a change in the decide module called target checking 3 which originally the total production quantity variable will adjust to the production target replaced by the FG inventory quantity which adjusts to the inventory target variable. In addition, there is a configuration change in the hold 3 module, which originally functioned to hold production that had reached the monthly production target, which was replaced with a scan condition feature where the amount of FG inventory was smaller than the FG inventory target. This change functions so that the system produces again when there is a reduction in finished goods inventory.

The difference test results of alternative model 1 are significantly different from the base case model. This is inferred from the absence of 0 values in the upper and lower limit intervals of the test results as shown in Table 4. This difference test parameter uses the total holding cost to look collectively at the amount of storage in the system, both semi-finished goods and finished goods. In addition, by using cost parameters, the economic value of the scenario results that have been applied can be shown. The simulation results of alternative model 1 have an average total cost of IDR 2,531,060 which is smaller than the average total cost of the base case model by IDR 104,386 or 4% of the initial cost. This reduction in total storage costs shows that a production system that refers to inventory targets can reduce storage costs and can prevent excessive over-production that occurred in the previous production system at PT Moreen JBBK. The results of the alternative 1 model difference test can be seen in Table 4.

Table 4. Results of the alternative 1 model difference test

Scenario 1 (In IDR)			
Replication	Total Storage Cost Base Case (X)	Total Storage Cost of Alternative Model 1 (Y)	X - Y
1	2,604,027	2,523,196	80,831
2	2,637,704	2,500,495	137,209
3	2,597,740	2,523,220	74,520
4	2,673,901	2,564,774	109,127
5	2,591,180	2,538,897	52,283
6	2,651,290	2,539,859	111,430
7	2,628,617	2,528,462	100,155
8	2,650,353	2,511,444	138,909
9	2,641,754	2,531,026	110,728
10	2,677,900	2,549,231	128,669
Mean	2,635,447	2,531,060	104,386
StDev	28,661	17,478	26,741
Lower Limit	88,048		
Upper Limit	120,725		
Significantly Different			

3.5 Alternative scenario 2

After looking at the results of alternative model 1, there are shortcomings in the form of inventory piling up on semi-finished components. This happens because the production of semi-finished components still uses the production target, while the amount produced in the production of finished goods is not the same as the production target. In alternative model 2, the amount of inventory of semi-finished components will be reduced by limiting production to the inventory target that will be set. Based on interviews with PT Moreen JBBK, the ideal amount of inventory is 2 times the daily demand of 4,000 units. This amount will be the inventory target for semi-finished components, namely Bracket 6 Side Stand and Bracket Side Stand. This model will use the same configuration as alternative model 1, but there is a change in the decide module called target checking and target checking 2 which originally had a configuration of the total production amount of the two components referring to the production target, in this model it is changed to the inventory variable of the two components which will refer to the predetermined inventory target. The number of production targets set using the ideal amount of inventory according to PT. Moreen JBBK is 4,000 units. In addition, there is a change in the hold module in the semi-finished component production part model, which is a scan condition where the total inventory of BRK 6 and

BRK SS is smaller than the target inventory of the two components. This change aims to allow the simulation model to restart production when there is a decrease in inventory. The production system in alternative scenario 2 uses a hybrid push/pull production system (Kaylani, 2014). However, on the push side, the production of semi-finished goods, it no longer uses the production target reference in its production, but uses the inventory target.

The results of the difference test for the alternative scenario model 2 and the base case can be said to be significantly different as shown in table 5. This is concluded from the absence of a value of 0 in the upper and lower limit intervals of the test results. Similar to the difference test in alternative 1, this difference test parameter also uses the total storage cost or holding cost to see the collective amount of storage in the system, both semi-finished goods and finished goods. The simulation model results in alternative scenario model 2 have an average total storage cost of Rp 1,710,851 which is smaller than the average total cost of the base case model of Rp 924,595 or 36% of the original cost. This decrease in storage costs indicates that the alternative scenario model 2 is considered effective in reducing the burden of storage costs on PT Moreen JBBK. The results of the alternative 2 model difference test can be seen in Table 5.

Table 5. Results of the alternative 2 model difference test

Scenario 2 (In IDR)			
Replication	Total Storage Cost Base Case (X)	Total Storage Cost of Alternative Model 2 (Y)	X - Y
1	2,604,027	1,597,571	1,006,456
2	2,637,704	1,740,858	896,846
3	2,597,740	1,580,783	1,016,956
4	2,673,901	1,797,561	876,340
5	2,591,180	1,723,741	867,439
6	2,651,290	1,736,346	914,943
7	2,628,617	1,702,877	925,740
8	2,650,353	1,742,960	907,393
9	2,641,754	1,751,565	890,189
10	2,677,900	1,734,251	943,649
Mean	2,635,447	1,710,851	924,595
StDev	28,661	65,027	48,512
Lower Limit	894,954		
Upper Limit	954,236		
Significantly Different			

3.6 Alternative scenario 3

This model is a development of alternative scenario 2. In this model, the inventory level of finished good will be reduced to the ideal inventory level, the same as the inventory level of semi-finished components, which is 4,000 units. The inventory of finished goods at the beginning of the October 2016 period was 5,070 units. Inventory reduction will be carried out by producing finished goods again when the inventory amount has reached or is less than 4,000 units. Therefore, at the beginning of the period, there is no production activity until the inventory level of finished goods reaches 4,000 units or lower. This model will use the basic configuration of alternative model 2, but there is a change in the target inventory variable FG from 5,070 units to 4,000 units. The results of the difference test of alternative model 3 can be seen in Table 6.

The results of the difference test for the alternative scenario model 3 and the base case can be said to be significantly different as shown in Table 6. This is concluded from the absence of a value of 0 in the upper and lower limit intervals of the test results. Similar to the t-test in alternatives 1 and 2, this t-test parameter also uses the total storage cost or holding cost to see the collective amount of storage in the system, both semi-finished goods and finished goods. The simulation model results in alternative scenario model 3 have an average total storage cost of Rp 1,523,133 which is smaller than the average total cost of the base case model of Rp 1,112,313 or 43% of the original cost. This decrease in storage costs indicates that this alternative scenario model 3 is considered effective in reducing the burden of storage costs on PT Moreen JBBK.

Table 6. T-test results of alternative model 3

Scenario 3 (In IDR)			
Replication	Total Storage Cost Base Case (X)	Total Storage Cost of Alternative Model 1 (Y)	X - Y
1	2,604,027	1,532,049	1,071,978
2	2,637,704	1,514,013	1,123,691
3	2,597,740	1,555,368	1,042,372
4	2,673,901	1,521,444	1,152,457
5	2,591,180	1,507,838	1,083,342
6	2,651,290	1,526,601	1,124,688
7	2,628,617	1,530,197	1,098,420
8	2,650,353	1,520,159	1,130,195
9	2,641,754	1,516,194	1,125,560
10	2,677,900	1,507,472	1,170,429
Mean	2,635,447	1,523,133	1,112,313
StDev	28,661	13,427	36,493
Lower Limit	1,090,016		
Upper Limit	1,134,611		
Significantly Different			

3.7 Analysis of scenario results

In the analysis of PT Moreen JBBK's production system for the Side Stand Assy Bracket product, there is a problem in the form of high inventory in the system due to the application of the push production system which is applied based on demand forecasts. In solving these problems in the alternative scenario model, researchers try to implement a hybrid push/pull production system with various policies in each alternative (Takahashi & Nakamura (2004). After comparing the three alternative scenarios with the total storage cost parameter at each replication, the third alternative is able to meet demand for a month with the lowest total storage cost. A comparison graph of the total cost of each model can be seen in Figure 3.

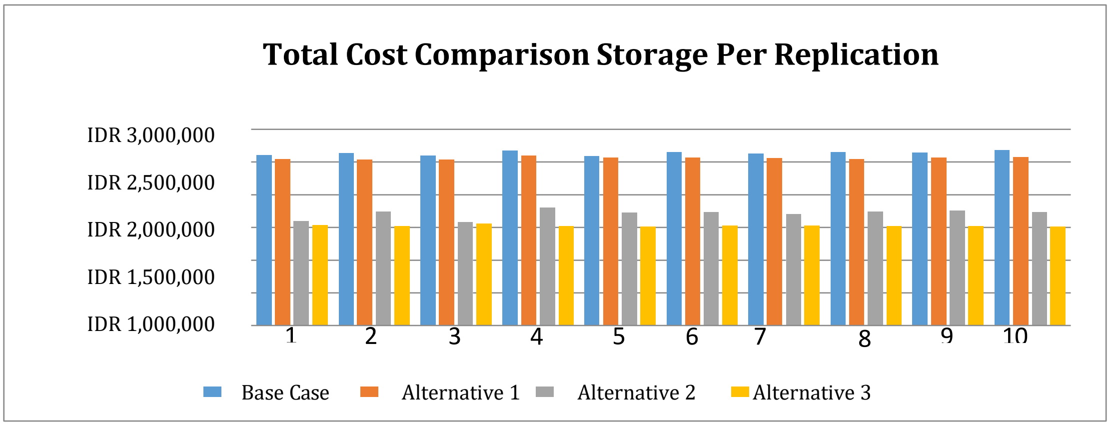


Fig. 3. Comparison chart of total cost of each model

Assuming that the conditions in this research period can describe the state of the company for a year, the implementation of the hybrid push/pull production system of PT Moreen JBBK can achieve savings in holding costs for a year from the three alternative scenarios of Rp 1,252,632 in the first scenario, Rp 11,095,143 in the second scenario, and Rp 13,347,759 in the third scenario as shown in Figure 4. This decrease in inventory cost is a parameter that can indicate improvements in the production system, especially in solving the problems previously experienced by PT Moreen JBBK regarding the accumulation of inventory in the system. Through the T-test results, it can be seen that the three scenarios are able to reduce storage costs significantly. The graph of the amount of savings for each alternative model can be seen in Figure 4.

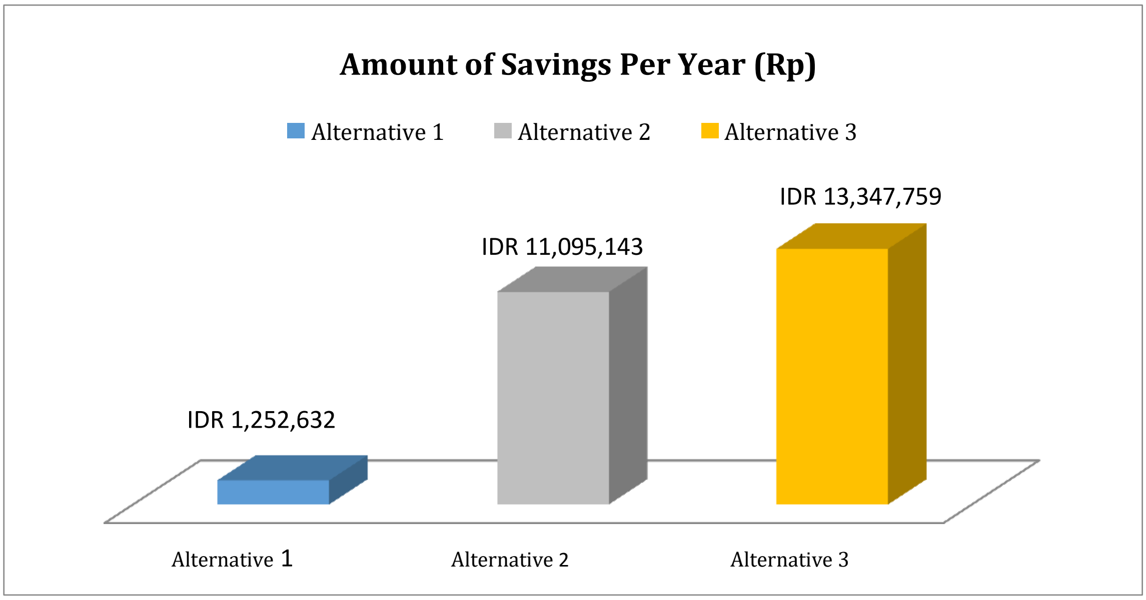


Fig. 4. Graph of the amount of savings for each alternative model

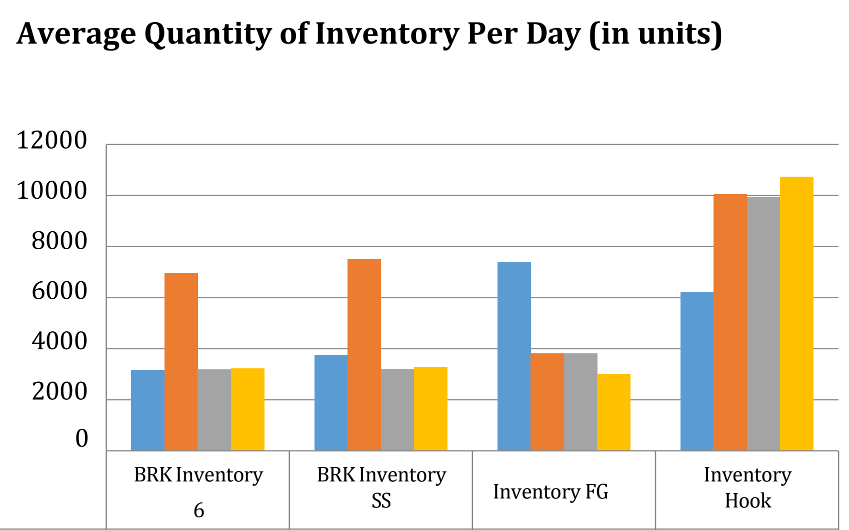
Shown in Figure 5, the simulation results for the average daily inventory of finished and semi-finished goods in the system. The first scenario focuses on reducing the amount of inventory by implementing a pull production system in the production of finished goods because the base case shows a high level of finished goods inventory. The result of the implementation was a reduction in the amount of inventory accumulated in the finished goods section, but an increase in the inventory of semi-finished goods in the system.

This resulted in a modest decrease in total storage costs. Seeing this, in the second alternative scenario, a reduction in the inventory of semi-finished components is carried out by setting an inventory target. The results of implementing this policy resulted in a much greater reduction in storage costs compared to the first scenario. In the third scenario, the inventory level for finished goods was reduced to a lower point.

The original inventory level referring to the initial inventory of 5,070 units was lowered to 4,000 units, in accordance with the ideal amount of inventory according to PT Moreen JBBK. The results of the policy were able to reduce the average amount of inventory per day to a lower point, and were able to fulfill every demand that occurred during the study period. This makes the policy in the third scenario the one that is able to reduce storage costs by the largest amount of reduction and still fulfill demand in that period. A comparison graph of average inventory per day can be seen in Figure 5.

The implementation of a hybrid push/pull production system for Side Stand Bracket Assy products also has an impact on the utilization of workers and production machines. There is a decrease in the utilization of workers and production machines for stamping and welding processes. However, the remaining production capacity of workers and production machines due to this decrease in utilization can be allocated to the production process of other products at PT Moreen JBBK. This is possible because the production machines used by PT Moreen JBBK can be used to produce other products, by replacing molds or dies on each machine. So this decrease in utilization is expected to be used in increasing the overall productivity of PT Moreen JBBK. The conclusion of this scenario analysis is that the implementation of a hybrid push/pull production system is successful in significantly reducing storage costs in the production of Side Stand Assy Bracket products at PT Moreen

JBBK. However, policy adjustments are needed in the production of semi-finished goods components to produce the maximum reduction in storage costs.



	BRK Inventory 6	BRK Inventory SS	Inventory FG	Inventory Hook
Base Case	3177	3756	7396	6226
Alternative 1	6943	7515	3810	10052
Alternative 2	3185	3214	3810	9922
Alternative 3	3222	3289	3019	10736

Fig. 5. Comparison chart of average inventory per day

4. Conclusions

PT Moreen JBBK as a manufacturer of automotive components has been implementing a push production system in its production process with reference to demand forecasts from customers. However, in the application of the production system, there is a problem in the form of a gap between actual demand and demand forecast which has an impact on the accumulation of finished goods. Seeing this problem, a hybrid push/pull production system is applied which has been stated by many researchers, which can maximize the performance of the production system by combining the push and pull systems. The results of the analysis of the performance of the production system at PT Moreen JBBK and the application of the hybrid push/pull production system to the production of Side Stand Assy Bracket products through simulation, showed a significant decrease in storage costs.

The implementation of a hybrid push/pull production system for the production of Side Stand Assy Bracket products at PT Moreen JBBK is carried out by changing the upstream production system, namely the incorporation of semi-finished components into finished goods (finish good) which originally used a production target based on demand forecasts, to a pull system whose production will adjust to actual demand. That way, the gap between production targets and actual demand, which has been a problem so far, can be resolved. Meanwhile, production for raw materials to semi-finished components is still carried out with a push system to maintain demand fulfillment with a not so long lead time. So, with the implementation of this hybrid push / pull system, PT Moreen JBBK can reduce inventory costs (holding costs) without causing backorders against actual demand. In addition, with the implementation of this system, PT Moreen JBBK has an impact in the form of decreased utilization of workers and machines. However, it can be used as an added value to production at PT Moreen JBBK by allocating the remaining resource utilization to produce other products. This is possible, because at PT Moreen JBBK the production machines used can be used to produce other products by changing the dies used. In the end, allocating the utility can increase the production capacity of PT Moreen JBBK or can be a time and cost capital to add product lines.

By implementing this hybrid production system, PT Moreen JBBK can achieve competitive advantage from operations management with a strategy of competing on cost. PT Moreen JBBK can reduce operating costs while maintaining the value desired by its customers, namely the fulfillment of demand itself. However, the implementation of this hybrid production system requires adaptation to workers and also the inventory recording system. The push/pull hybrid production system requires more thorough and actual inventory recording. Every time there is demand and reduced inventory in the finished good inventory, it is necessary to record the amount of inventory reduction which will be a reference in the previous production process. It takes time to adapt and train employees to implement the new production system. But in the long run, with proven savings in storage costs, the company will get a large amount of savings on its production costs.

From the results of the simulation analysis of alternative scenarios with the total storage cost parameter, it is the third scenario that is able to reduce the total storage cost of the production of Side Stand Assy Bracket products at PT Moreen JBBK with the highest amount of savings. The third alternative scenario is a scenario that uses a hybrid push/pull production system, with a policy of setting inventory target limits at the semi-finished component production stage and decreasing inventory levels on finished goods (finish good) and then using a pull production system that refers to actual demand. Based on the results of the scenario simulation analysis, the researcher suggests applying the third alternative scenario to the production of Side Stand Assy Bracket products at PT Moreen JBBK. Through this research, it is hoped that it can improve the performance of SMEs of automotive manufacturers in Indonesia. That way the automotive industry will be able to develop and with the development of one of the industrial sectors in Indonesia, it is expected to contribute to overall economic growth.

Acknowledgement

The authors gratefully acknowledges the reviewers for their valuable critiques and insightful recommendations, which greatly improved this manuscript. Additional thanks are extended to colleagues and mentors who provided guidance and support throughout the research process.

Author Contribution

Conceptualization, H.M.; Methodology, H.M.; Formal analysis, H.M.; Investigation, H.M.; Resources, H.M.; Data curation, H.M.; Writing – original draft preparation, H.M.; Writing – review and editing, H.M.; Supervision, R.D.K.

Funding

This research did not receive funding from anywhere.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

Not available.

Conflicts of Interest

The authors declare no conflict of interest.

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