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COST OPTIMIZATION IN DISRUPTION CONDITIONS: A CASE STUDY IN SMALL MEDIUM ENTERPRISE

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ABSTRACT

Purpose: The objective of this study was to design a cost optimization model that offers production improvement for SMEs.

Theoretical framework: Several studies related to production system disruption management have been conducted, with the majority focusing on large companies. However, small and medium enterprises (SMEs) have limitations compared to large companies. Repairability is considered for cost optimization.

Design/methodology/approach: This research designed a cost optimization model that offers production improvement with repairability process for SME.

Findings: There is a need for repairability given the disruption caused by defective products in SMEs. There is a clear difference in total profit between the current state without repairability and proposed conditions with repairability. SMEs suffer massive losses in the absence of repairs, assuming they do not consider repairing defective products with a production defect rate of approximately 15%. The current state produces many downgraded products. However, repairability still needs to be improved to increase profits.

Research, Practical & Social implications: The study implied that there is a need to consider repairability for product defects at SMEs, especially those with a 15% product defect rate. The use of the proposed model optimizes profit and is designed to increase production capacity based on product improvements. Repairability was considered in this research, considering that SMEs are more susceptible to disruptions compared to large companies.

Originality/value: The novelty of this paper is adding process repairability to the cost optimization model for SMEs in the textile sector, then considering the product downgrade under the conditions in SMEs.

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OTIMIZAÇÃO DE CUSTOS EM CONDIÇÕES DE DISRUPÇÃO: UM ESTUDO DE CASO EM PEQUENA MÉDIA EMPRESA

RESUMO

Propósito: O objetivo deste estudo foi projetar um modelo de otimização de custos que ofereça melhoria de produção para PMEs.

Referencial teórico: Vários estudos relacionados à gestão de disrupção do sistema produtivo foram realizados, sendo a maioria focada em grandes empresas. No entanto, as pequenas e médias empresas (PMEs) apresentam limitações em relação às grandes empresas. A reparabilidade é considerada para otimização de custos.

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Desenho/metodologia/abordagem: Esta pesquisa desenhou um modelo de otimização de custos que oferece melhoria de produção com processo de reparabilidade para PME.
Constatações: Existe a necessidade de reparabilidade dada a perturbação causada por produtos defeituosos nas PME. Existe uma clara diferença no lucro total entre o estado atual sem reparabilidade e as condições propostas com reparabilidade. As PME sofrem prejuízos massivos na ausência de reparações, assumindo que não consideram reparar produtos defeituosos com uma taxa de defeitos de produção de aproximadamente 15%. O estado atual produz muitos produtos degradados. No entanto, a reparabilidade ainda precisa ser melhorada para aumentar os lucros.
Implicações de pesquisa, práticas e sociais: O estudo sugere que há uma necessidade de considerar a capacidade de reparo de defeitos de produtos nas PMEs, especialmente aquelas com uma taxa de 15% de defeitos de produtos. A utilização do modelo proposto otimiza o lucro e visa aumentar a capacidade produtiva a partir de melhorias no produto. A reparabilidade foi considerada nesta pesquisa, considerando que as PMEs são mais suscetíveis a interrupções em comparação com as grandes empresas.
Originalidade/valor: A novidade deste trabalho é adicionar a reparabilidade do processo ao modelo de otimização de custos para PMEs do setor têxtil, considerando então o rebaixamento do produto nas condições das PMEs.

Palavras-chave: Gerenciamento de Disrupção, Pequena Média Empresa, Produto de Reparação.

OPTIMIZACIÓN DE COSTOS EN CONDICIONES DE DISRUPCIÓN: UN ESTUDIO DE CASO EN UNA PEQUEÑA MEDIA EMPRESA

RESUMEN
Propósito: El objetivo de este estudio fue diseñar un modelo de optimización de costos que ofrezca una mejora productiva para las PYMES.
Marco teórico: Se realizaron varios estudios relacionados con la gestión de la disrupción en el sistema productivo, la mayoría enfocados a grandes empresas. Sin embargo, las pequeñas y medianas empresas (PYMES) tienen limitaciones en comparación con las grandes empresas. La reparabilidad se considera para la optimización de costos.
Diseño/metodología/enfoque: Esta investigación diseñó un modelo de optimización de costos que ofrece mejoras en la producción con proceso de reparabilidad para las PYMES.
Hallazgos: existe la necesidad de reparabilidad dada la interrupción causada por productos defectuosos en las PYME. Existe una clara diferencia en el beneficio total entre el estado actual sin reparabilidad y las condiciones propuestas con reparabilidad. Las PYMES sufren pérdidas masivas en ausencia de reparaciones, suponiendo que no consideren reparar productos defectuosos con una tasa de defectos de producción de aproximadamente el 15%. El estado actual produce muchos productos degradados. Sin embargo, la reparabilidad aún debe mejorarse para aumentar las ganancias.
Implicaciones de investigación, prácticas y sociales: el estudio sugiere que es necesario considerar la capacidad de reparación de defectos del producto en las PYME, especialmente aquellas con una tasa de defectos del producto del 15%. El uso del modelo propuesto optimiza el beneficio y tiene como objetivo aumentar la capacidad de producción a partir de mejoras en el producto. La reparabilidad se consideró en esta investigación, considerando que las Pymes son más susceptibles a las interrupciones en comparación con las grandes empresas.
Originalidad/valor: La novedad de este trabajo es añadir la reparabilidad del proceso al modelo de optimización de costes para las pymes del sector textil, considerando entonces la degradación del producto en las condiciones de las pymes.

Palabras clave: Gestión de la Disrupción, Pequeña Mediana Empresa, Producto de Reparación.

INTRODUCTION

Competition in the industrial world in producing products and services is increasing. Every manufacturing industry makes various changes to achieve the best (Singgih et al., 2021). Competition exists naturally between companies, especially in the SME sector, so that each makes the most of the resources it has and, under normal circumstances, grows by making greater use of the resources it has (Sutrisno, Fachrunnisa, & Widodo, 2022). SMEs are crucial to achieving industrial and economic growth because they foster a certain level of competition that improves the kind and quality of goods and services offered, meets the needs of the local market for a variety of services, and lessens reliance on the external market for these goods and services, both in developed and developing nations (Saud, Neamah, & Sabbar, 2022). According to Gunasekaran et al. (2011), SMEs account for 45 percent of total employment opportunities and 33 percent of gross domestic product (GDP) in developing countries. It is often perceived as an engine that drives innovation, economic growth, employment, and social mobility (Ayyagari, Demirgüç-Kunt, & Maksimovic, 2011). The characteristics of SMEs to obtain maximum profit are quite complex because various problems related to complex optimization require the use of many complicated procedures (Prabowo, Singgih, Karningsih, & Widodo, 2020). However, SMEs have limited resources and capabilities due to the complexity of the company (Kamarudin, Aslan, & Rajiani, 2018).

Innovation in manufacturing can take many different forms, from new technology and supply chain changes to product and process improvements (Vijayakumar & Chandrasekar, 2022). During the production process, disruptions such as defective products and machine breakdowns are almost impossible to avoid. The manufacturing sector suffers more as it generates more waste when executing production processes (Qureshi et al., 2022). Consequently, the entire organizational plan tends to be distorted, causing shortages of goods and unfulfilled customer demands (Hishamuddin, Sarker, & Essam, 2012). Yu & Qi (2004), stated that some of the disruptions that occur in the production process that cause deviations from plans, like unforeseen events, changes in system parameters, new boundaries, and considerations. However, to control and reduce the negative impacts, efforts are needed to revise the existing plan. Effective and efficient measures, make it possible to assess whether the implementation actions are the expected results (Azzemou & Noureddine, 2021). This process is referred to as disruption management. Sometimes disruption is unavoidable and causes changes to the corporate environment. The company needs to manage the risk of disruptions effectively. According to Yang et al. (2005), Disruption management is an effort to carry out the restore process after experiencing a disruption.

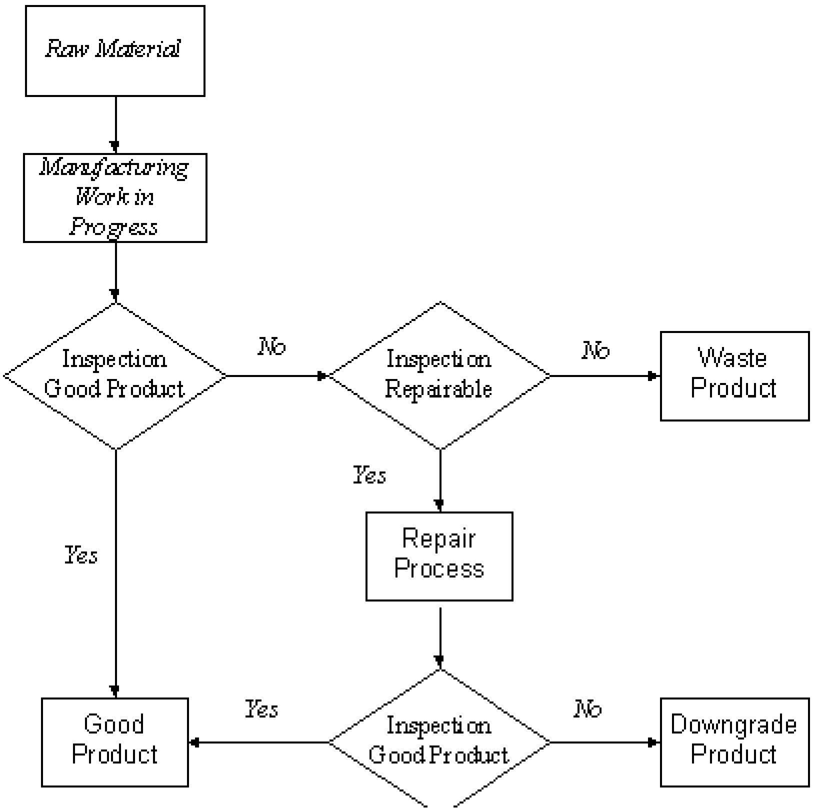
Disruption management increases productivity and production capacity and reduces waste such as defects in the production system (Zhu, Li, & Mishra, 2023). Musulin et al. (2012), emphasized the need for a dynamic and reactive, online approach that meets standards and provides accurate information concerning plant activities and changing conditions. Fernández et al. (2015), researched the monitoring approach in 3 criteria, namely predictive ability (predictive or reactive), sources of observed events (resources or orders), and generalization of processes that take into account the ability to apply different monitoring models possessed by the various application domain. Some of the approaches reviewed in existing studies do not apply to industries that produce several defective products. A small industry has several differences compared to large companies regarding costs, human resources, environment, government policies, etc. These differences influence the willingness to develop in SMEs. This research designed a model that offers product improvement to SMEs and focuses on optimizing costs when there is a disruption in the SMEs' production system, namely defective products, to obtain maximum profit. One of the most crucial metrics for assessing the performance of business units is profit. Profit is simply defined as positive earnings from business activities or investments (Baghaee, Hossein, & Sepasi, 2023). This research also detects scenarios involving defective products in SMEs.

LITERATURE REVIEW

Disruption management was first used in aviation companies, where flight disruptions frequently result in massive cost losses (Yu & Qi, 2004). The successful application of disruption management led to increased interest in applying disruption management to other fields. Yang et al. (2005) studied the problem of recovering production plans that are disrupted due to accidents such as power failure, market change, machine breakdown, supply shortage, worker no-show, and others. Researchers have studied the disruption management problem faced by single production plants. Lee & Yu (2008) studied the scheduling problem on parallel machines in a disruptive environment by minimizing the total of weighted completion times. Lin & Gong (2006) analyzed the machine damaged product with economic production quantity (EPQ) in a single stage production system. Chiu et al. (2007) used the EPQ model with Poisson distribution of machines to determine the optimal production time. They developed the total inventory cost using EPQ with and without details in a single-stage production system. Schmitt & Snyder (2012) developed an inventory model that considers unreliable suppliers and reliable but expensive suppliers.

Hishamuddin et al. (2012) developed a mathematical model for single fault recovery in a single-stage single production system. Figure 2.1 is a conceptual model for an inventory production system with disruption. The study considered back orders as well as lost sales options. This study considers back orders as well as lost sales. Then they extended the concept of transportation disruption in a two-stage production system (Hishamuddin, Sarker, & Essam, 2013). Here is the optimal production lot size (Q) proposed, where A is the setup cost for each cycle ($/setup), P is the production rate (units/year), and H is the annual inventory holding cost ($/unit/year). An extension of the problem covering demand uncertainty and process reliability to single-stage production inventory systems was investigated by Paul et al. (2014). In order to deal with problems in production inventory systems, the study came up with a recovery model and a dynamic solution approach. Paul et al. (2014) carried out a case study in a pharmaceutical company with the limitation that defective products were rejected or categorized as waste goods. However, in SMEs, the products that are rejected are still being inspected, after which they will be repaired (Sohal, Nand, Goyal, & Bhattacharya, 2022). This research focuses on defective items by taking into account the product and repair costs. A case study was carried out on a glove textile company involved in mass production. The repaired product is either good, a downgrade, or a waste item. A conceptual model for repaired products is shown in Figure 1. This system is based on product repairs with additional inspections to boost production capacity.

Figure 1. Product repair conceptual model



Source: Prepared by the authors (2023)

MATERIAL AND METHODOLOGY

The following is a model for minimizing costs adapted from Hishamuddin et al. (2012) and Paul et al. (2014) mathematical model. The adapted mathematical model considers repair products based on economic production quantities for systems under ideal conditions to match the SME situation. It also reduces equations for production systems involving defective products.

Total Cost Formulation

In this section, the cost equation was developed by considering SMEs and product repair. The research carried out by Paul et al. (2014) reported that all defective products were rejected. This causes a burden on the company's costs because SMEs have several limitations, such as capital and human resources, resulting in additional defects. Therefore, product repair enhances production capacity. The following are the cost calculations made by Paul et al. (2014). Setup costs are calculated as the cost per setup (A) multiplied by the number of adjustments during recovery (M). The following is a setup cost equation (1) where A denotes the setup cost for each cycle and M is the number of cycles in units of time. Holding costs (H) are described as expenses associated with keeping unsold inventory. The holding cost is determined by multiplying the total investments made during the recovery period, where H is the holding cost per unit, Q and P are the production lot size and rate, respectively.

$$\text{Set-up cost} = A.M \qquad (1)$$

$$\text{Annual holding cost} = \frac{Q}{2} H \frac{D}{Pq} \qquad (2)$$

Production cost (Cp) is the expense incurred to manufacture one product. The total cost of production is obtained by multiplying the production cost per unit by the total amount produced. In Equation (3), the derivation is applied to the model with total product quantity per unit of time (Pq). Rejection cost (Crj) is the expense caused by the rejection of the product. It is determined by multiplying the unit rejection cost by the total number of items rejected. Changes were made in Equation (4) due to some considerations regarding improved products. Inspection costs (Ci) are incurred for conducting product inspections. It is obtained by multiplying the cost of the inspection by the total number of products. In Equation (5), the derivation is applied to the model with Pq, which is the total product quantity per unit of time. Inspections are carried out on all products manufactured. The formulation model for the total cost (TC) in equation (6), applied in this study, is based on the research carried out by Paul et al. (2014), summing up the setup, production, inspection, rejection, holding, backorder (B) and lost sales cost (L).

$$\text{Production cost} = C_p Pq \tag{3}$$
$$\text{Rejection cost} = C_{rjt} q_{jt} \tag{4}$$
$$\text{Inspection cost} = C_i Pq \tag{5}$$
$$TC = A.M + [C_p + C_i](Pq) + [C_{rj}](q_j) + i + H + B + L \tag{6}$$

This research considered the product repair level and the repair cost charged per repaired product. The repaired products are divided into three, namely repaired products at full price (q_{k1}) with a quality of 90% or higher, and those that are not repaired. However, it decreased (q_{k2}) in quality to relatively 80% to 90%, and finally, those that were rejected (q_j) were reduced by 70% or even less. The repair cost per unit (Crp) is obtained from the materials used, labor costs, and also product inspection after being repaired. Equation (7) is a formulation for calculating the repair cost.

$$\text{Repair cost} = [C_{rp} + C_i](q_{k1} + q_{k2}) \tag{7}$$

Backorders and lost sales costs were not considered in this calculation. This is because SMEs are different from large companies with full commitments to delay. Because SMEs do not lease warehouses, holding costs are not calculated. In this formulation (8), it was assumed that interest costs are included in each cost.

$$TC = A.M + [C_p + C_i](q_i + q_j + q_{k1} + q_{k2}) + [C_{rj}](q_j) + [C_{rp} + C_i](q_{k1} + q_{k2}) \tag{8}$$

Total Revenue Formulation

The following equation (9) is the equation for calculating total revenue (TR) derived from Paul et al. (2014). Total revenue is the sum of the selling price of the excellent product and the repaired product. Authentic products are obtained from the cost of goods manufactured, which is the markup (m_1) and the selling price per product by adding repair products with good quality. Meanwhile, the downgraded product's price is obtained from the markup (m_2) of the cost of manufactured goods. As a result, the resold rejected product price is calculated using the markup (m_3) production price for the rejected products.

$$TR = m_1(\mathrm{Cp} + \mathrm{Ci})[\mathrm{q_i} + \mathrm{q_{k1}}] + m_2(\mathrm{Cp} + \mathrm{Ci})[\mathrm{q_{k2}}] \tag{9}$$

Total Profit Formulation

Equation (11) for a total profit (TP) is adapted from Paul et al. (2014) calculation of the total difference between TR and TC. The following formulation shows the necessary steps to obtain TP.

$$\text{Max} \quad \mathrm{TP} = \left[m_1(\mathrm{Cp} + \mathrm{Ci})[\mathrm{q_i} + \mathrm{q_{k1}}]) + m_2(\mathrm{Cp} + \mathrm{Ci})[\mathrm{q_{k2}}] + m_3(\mathrm{Cp} + \mathrm{Ci})[\mathrm{q_j}]\right] - \left[\mathrm{A.M} + (\mathrm{C_p} + \mathrm{C_i})[\mathrm{q_i} + \mathrm{q_j} + \mathrm{q_{k1}} + \mathrm{q_{k2}}] + (\mathrm{C_{rj}})[\mathrm{q_j}] + (\mathrm{C_{rp}} + \mathrm{C_i})[\mathrm{q_{k1}} + \mathrm{q_{k2}}]\right] \tag{10}$$

RESULTS AND DISCUSSION

Case Study

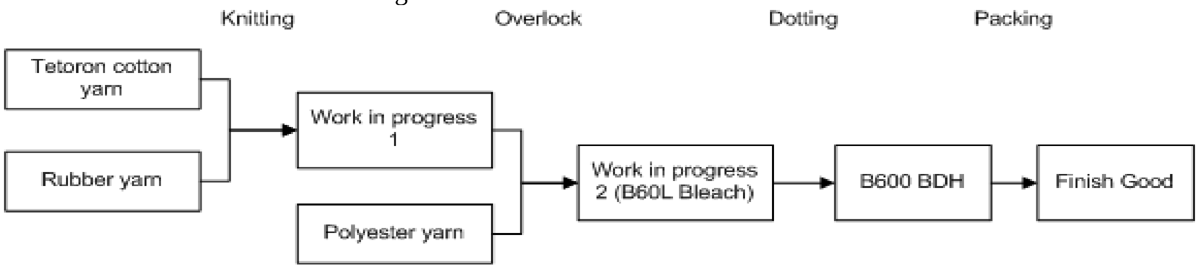
Case studies need to be carried out to validate the mathematical model. A case study was conducted at a knitted glove company that produces dotting and ziet thread gloves as well as several other types. The study was carried out on a medium-thick glove production line with dark spots, namely the B600 BDH line. A good quality glove product is shown in Figure 2.

Figure 2. Good Quality Knitted Glove Product

Source: Prepared by the authors (2023)

Figure 3 shows the glove production process. This procedure involves processing raw materials, such as cotton and rubber yarns, using a knitting machine. Next, the knitting is transferred to the overlock process to form the glove's wrist using a rubber band and polyester thread. Gloves are put on the dotting machine to form the dot spots on the fingers. Finally, the gloves are wrapped in plastic using a packing machine and placed in a sack. The proposed approach is to do an inspection and repair process after every section. However, after the interview and the data provided by the company, the authors narrow down the proposed approach after the knitting process. Authors do this because most of the defects are in the knitting process, and repairs are possible and cost almost nothing.

Figure 3. Knitted Glove Production Process



Source: Prepared by the authors (2023)

The production process at this glove company has a defect rate of 15%. Disruptions of machines are commonly encountered during the production process, thereby leading to defective products. Besides, once a fault is detected in the engine, it takes a while to repair and restart the machine. Disturbances in machines are bound to occur at any time. Under the proposed approach stated, the costs incurred during the disruption of these defective productions are optimized. This disruption was handled by obtaining information and data related to the production line, and historical data, and consulting with company managers. The data obtained are robust and significant to the research. Table 1 shows the data obtained per month.

Table 1 - Cost Data Per Month in The Glove Textile Industry

Data	September	October	November
Production cost (Cp)	Rp. 12.516 /dz	Rp. 12.694 /dz	Rp. 13.385 /dz
Inspection cost (Ci)	Rp. 3.167 /dz	Rp. 3.167 /dz	Rp. 3.065 /dz
Rejection cost (Crj)	Rp. 173 /dz	Rp. 173 /dz	Rp. 173 /dz
Repair cost (Crp)	Rp. 347 /dz	Rp. 347 /dz	Rp. 347 /dz
Good Product Prices	Rp. 18.500 /dz	Rp. 18.500 /dz	Rp. 19.500 /dz
Product Repair Prices	Rp. 15.000 /dz	Rp. 15.000 /dz	Rp. 15.300 /dz
Product Reject Prices	Rp. 6.250/dz	Rp. 6.418 /dz	Rp. 6334 /dz
Demand (D)	52.150 dz	53.350 dz	43.250 dz
Mark-up 1 (m1)	1,14176	1,12936	1,14909
Mark-up 2 (m2)	0,92575	0,91570	0,90159
Mark-up 3 (m3)	0,385728	0,391823	0,373245

Source: Prepared by the authors (2023)

Production cost (Cp) is derived from raw materials, labor, electricity, equipment, and interest costs. Inspection cost (Ci) is incurred for conducting product inspection. It consists of labor and equipment costs. Rejection cost (Crj) is incurred from the process of rejecting products, such as labor, equipment, and additional expenses. Repair costs (Crp) are incurred based on the repairs made to certain items, such as equipment, additional raw materials, and labor costs. Demand (D) is described as a customer request for product B600 BDH in 1 month. Mark-up 1 (m_1) is the markup number obtained from a good product's selling price compared to the total cost price of 1 dozen products. Mark-up 2 (m_2) is the markup number obtained from the downgraded product's selling price compared to the total cost price of 1 dozen products. Mark-up 3 (m_3) is the markup number obtained from the selling price of defective or rejected products compared to the total cost price of 1 dozen of products. This is because the product is damaged and unrepairable, or the costs incurred are greater than the production of new goods. The following limitations and assumptions were applied based on the case studies.

Setup Cost = 0 (this occurred because the company failed to take into account the 24 hours of work and setup costs).

q_i = [min q_i, max q_i]	Defect $q_i \leq 10\%$
q_j = [min q_j, max q_j]	Defect $q_{k1} \leq 10\%$
q_{k1} = [min q_{k1}, max q_{k1}]	Defect $q_{k2} \geq 10\%$; Defect $q_{k2} \leq 20\%$
q_{k2} = [min q_{k2}, max q_{k2}]	Defect $q_j \geq 20\%$
$q_i + q_{k1} + q_{k2} \geq D$	$q_i \geq 0$
$q_i + q_j + q_{k1} + q_{k2} \leq Pq$	$q_j \geq 0$
$q_{k1} \geq 0$	$q_{k2} \geq 0$

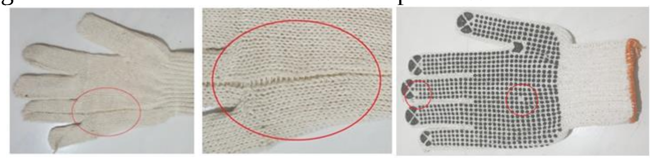
An example of a repairable defect is shown in Figure 4. This defect is relative between 10% and 20%. Another example of a defect in this type of product is a pinhole. This small hole is fixed by sewing it with a production machine or manually using a needle and thread. Based on the interview with the head of the production in the company, a re-paired product's quality is improvable.

Figure 4. Repairable Defects in Gloves With Good Quality

Source: Prepared by the authors (2023)

Another example of a defective product is shown in Figure 5. The defect is between 10% and 20%, although the product experienced a decline in quality. This deterioration is in the form of additional, faintly visible stitches or larger pores on the glove. The repair process, in this case, is like the one in Figure 3. This is fixed by sewing it with a production machine or manually using a needle and thread. Some examples of defects in a product are pinholes, mismatched stitches in gloves, and slightly untidy dotting seeds.

Figure 5. Defects In Gloves That Were Repaired With a Decrease In Quality



Source: Prepared by the authors (2023)

Figure 6 shows an example of a defective product that is unrepairable. These defects include large holes, inappropriate dotting, incorrect finger counts, or any defects relatively greater than 20% of the product. Therefore, to reduce these losses, the products are usually collected and resold at a lesser price.

Figure 6. Defects in Rejected Gloves

Source: Prepared by the authors (2023)

Solutions were made and later compared with the results obtained from the case study, shown in Table 2. In addition, the information in Table 2 was obtained from the company before the equations for the proposed approach were utilized. This is actual data for q_i, q_{k1}, q_{k2}, and q_j, where q_i is the quantity of a good product, q_{k1} is a defective product that has been repaired and has the same quality as a good product, q_{k2} is a defective product that has been repaired, however, there has been a decline in its quality, and q_j is the rejected product. In October, companies experienced an increase in demand; therefore, their products were higher than those manufactured in September and November. Total profit (TP) was obtained using Equation (10) in Tables 1 and 2. However, in October, it was less because several companies received downgraded products.

Table 2 – Monthly Data From Case Study

Data	September	October	November
q_i	46.875 dz	52.480 dz	43.034 dz
q_{k1}	250 dz	327 dz	300 dz
q_{k2}	4.760 dz	6.211 dz	5.710 dz
q_j	3.040 dz	2.938 dz	2.747 dz
Total Profit (TP)	IDR 33.424.007	IDR 29.954.082	IDR 30.866.111

Source: Prepared by the authors (2023)

Compared to the proposed mathematical model, the total profit (TP) value is relatively perfect, with the largest differences recorded in October. This is because q_i, q_{k1}, q_{k2}, and q_j

realized in October have the most significant difference. Table 3 shows the comparison between the unrepairable, ideal repairable, and current states. Following the data, the percentage of good products (divided by the total product quantity) is 85%, which implies that the defect rate is 15%.

Table 3 – Optimal Data Per Month on The Glove Textile Industry

Data	September	October	November
q_i	47.274 dz	54.306 dz	44.141 dz
q_{k1}	250 dz	250 dz	250 dz
q_{k2}	4.700 dz	4.700 dz	4.700 dz
q_j	2.700 dz	2.700 dz	2.700 dz
Total Profit (TP)	IDR 39.490.547	IDR 44.965.496	IDR 39.490.547

Source: Prepared by the authors (2023)

The analysis of these results was carried out using Equation (10). Table 3 shows that October has a higher value than September and November. Table 1 shows that the Demand (D) recorded in October has the highest value. Furthermore, q_{k1}, q_{k2}, and q_j were obtained by referring to the data in Table 2. The optimal results for q_i, q_{k1}, q_{k2}, and q_j are shown in Table 3. The Total Profit realized in October was more significant than those in September and November. This was due to the high demand in October. Based on Tables 2 and 3, the comparison of the total profits obtained is as follows.

Table 4 – Comparison on Total Profit Models

Total Profit	September	October	November
Without Repair	- IDR 23.424.419	- IDR 44.267.146	- IDR 40.038.068
Current State	IDR 33.424.007	IDR 29.954.082	IDR 30.866.111
Proposed Condition	IDR 39.983.420	IDR 41.257.887	IDR 39.490.551

Source: Prepared by the authors (2023)

Table 4 shows the comparisons for the total profit results. Conditions without repairs are a production process that does not consider repairing defective products because they were rejected. This implies that the SME suffers massive losses in the absence of repairs, supposing it does not consider repairing defective products. This is because the industry has a production defect of approximately 15%.

In the proposed state, products that had defects were repaired. However, under the current state, the total profit earned in September and November is like the proposed conditions compared to October. This was due to the differences in the number of requests (D) that occurred monthly. The proposed condition had a more significant total profit because it has the optimal solution for the quantity produced. Conversely, companies in the current state produced many downgraded products, as shown in Table 2. This is because they had more significant quantities of defective products. These companies seek to boost production, which causes several defective products that need to be repaired. On the contrary, the companies under the proposed conditions need to boost good products and reduce the downgraded ones.

Discussion

Disruptions during production processes are almost inevitable. These disruptions can sometimes be corrected so that overall production costs can be significantly reduced. Hishamuddin et al. (2012) developed a model for disruption in the product inventory system, and a recovery model that determines optimal production quantities to minimize costs was designed. This model was later developed further by Paul et al. (2014) and aimed to restore production schedules as quickly as possible after a disruption. Previous studies [7,14,16,17] have reported that products with defects were immediately rejected, while in several other industries, especially in SMEs, they were still considered for repairs. SMEs has several limitations compared to big company, which affect the willingness to develop. This makes it difficult for SMEs to spend significant funds to develop. However, adjustments are needed for SMEs to withstand big companies. This research developed a conceptual model for the production process with repair product consideration and a cost optimization model that considers the repair process of defective products with a case study in knitted gloves SME.

Based on the case studies, there is a need for improvements to boost profit. Companies need to embrace improvements to boost profits following a defect level of approximately 15%. The goods produced have three levels of quality, namely “good product quality”, “downgrade product”, and “defective product”. Good product quality has a defect rate of 10%. Downgraded products, on the other hand, range between 10% and 20%, while rejected items exceed 20%. The downgraded product has a lower selling price than a good quality product; however, it is still more profitable than reproduction or rejection. Products above 20% are either non-repairable or cost more than the profit. Current states have a lesser total profit than the proposed condition because the quantity produced is not optimal. Referring to Table 4, industries with high defect rates still need to embrace the improvement process.

Table 4 shows the comparisons for total profit results between conditions without repair, the current state, and the proposed condition. There is a clear difference in total profit without repair between the current state and proposed conditions. SMEs suffers massive losses in the absence of repairs, assuming it does not consider repairing defective products with a production defect rate of approximately 15%. There is a difference in October due to the quantity produced. As shown in Table 2, the current state produced many downgraded products. However, repairability still needs to be made to increase profits. The results of this study show that there is a need for repairability given the disruption caused by defective products in SMEs. More research needs to be done on big companies to show how the results compare to SMEs. Further research also needs to be carried out on small and medium enterprises that are not mass production and other than textiles.

CONCLUSION

Small and medium enterprises have several differences compared to large companies regarding costs, human resources, government policies, the environment, etc. These differences influence the willingness of SMEs to develop, and several have limited capital to develop. This research contribute to optimize the cost of disruption management in small and medium enterprises. A model was designed to increase production capacity based on product improvements. Repairability was considered in this research, considering that SMEs are more susceptible to disruptions due to certain limitations compared to large companies. Mathematical and conceptual models are developed to assess product repair with a trade-off repair cost and an additional inspection. The case study was a mass-production SME glove company.

This research model needs to be adopted by companies that experience product defects, especially those with a 15% product defect rate. The use of the proposed model optimizes profit. This model needs to be implemented in mass-production companies with a similar production pattern. Further research is needed to consider the differences between small and medium-sized industries other than gloves because not all regions and SME industries are glove-centered.

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