OmniaScience

Journal of Industrial Engineering and Management
JIEM, 2025 – 18(1): 72-99 – Online ISSN: 2013-0953 – Print ISSN: 2013-8423
https://doi.org/10.3926/jiem.7093

Optimizing Model for Agile Product Development in Garment Industry

Suhartini Suhartini[1,2], Mokh Suef[1*], Udisubakti Ciptomulyono[1], Erwin Widodo[1]

[1]*Institut Teknologi Sepuluh Nopember (Indonesia)*
[2]*Institut Teknologi Adhi Tama Surabaya (Indonesia)*

suhartini@itats.ac.id
[*]*Corresponding author: m_suef@ie.its.ac.id*
udisubakti@ie.its.ac.id, erwin@ie.its.ac.id

Received: December 2023
Accepted: January 2025

Abstract:

Purpose: This research aims to determine an optimal plan for product development process. The developed product is a sustainable product with an agile concept. Mathematical models are involved to determine the optimal value of the number of product ideas and it is profits. The mathematical model will be of beneficial to create product development process strategies.

Design/methodology/approach: This article develops a mathematical model of integer linear programming using LINGO 18.0 software. The results of the mathematical model to get the best value are maximizing profits by considering the number of product ideas. In determining profits, this research uses idea prices and idea costs. Total profit is the total income from realizing the product idea minus the total costs of realizing the product idea.

Findings: This research creates a mathematical model of the product development process in the garment industry. The sustainable products studied are garment products. The product development process consists of five mathematical model scenarios. The best model result is the fifth scenario, namely, the value of the number of product ideas is six units, and the profit value is IDR1220000.

Research limitations/implications: This research discusses one stage of the product development process. This stage is the planning stage. Research can be developed by discussing all stages of the product development process.

Practical implications: The mathematical models will help product development teams maximize profits among product ideas.

Social implications: The discussion of the mathematical model can be applied to other garment industries.

Originality/value: The product development process requires a mathematical model, namely a linear integer, to maximize profits from the number of sustainable product ideas.

Keywords: integer linear programming, agile, sustainable, product, garment.

To cite this article:

Suhartini, S., Suef, M., Ciptomulyono, U., & Widodo, E. (2025). Optimizing model for agile product development in garment industry. *Journal of Industrial Engineering and Management*, 18(1), 72-99. https://doi.org/10.3926/jiem.7093

1. Introduction

Companies want to develop new products to improve performance (Escrig-Tena, Segarra-Ciprés & García-Juan, 2021). New product development aims to fulfil consumer desires. Consumers want quality products, affordable prices, and timely development (Hendler, 2019). At this time, consumer demands are experiencing rapid changes. Companies are adopting a more flexible approach. Therefore, companies should have new product development approaches (Cano, García-Camús, Garzás, Moguerza & Sánchez, 2021). The aim is to meet consumer demand and increase sales. Research conducted by Perry and Towers (2013) shows that companies have a more flexible approach to the new product development process. This research carried out the product development process in the garment industry. Over the last decade, the competitive advantage of the garment industry has shifted to developing countries (Perry & Towers, 2013).

According to Cagliano, Caniato and Spina (2004), new product development is a product transformation process. The new product development process has traditionally emphasized a unilateral approach. Thus, new product development requires a faster approach (Suef, Suparno & Singgih, 2017). The product transformation process should consider opportunities, markets, and technological developments. In this era of globalization, consumers want sustainable products. Thus, sustainable product development is an opportunity to create new products. The product development process uses an agile concept to respond to consumer desires. Consumers want many variations of products.

The agile concept uses the scrum approach. The scrum framework aims to increase the efficiency of product development in meeting customer needs (Conforto, Amaral, da Silva, Di Felippo & Kamikawachi, 2016; Gemino, Horner-Reich & Serrador, 2021). According to Diebold and Dahlem (2014), scrum is a framework for teams aimed at solving complex adaptive problems and productively producing high-value products. According to Prabowo, Singgih, Karningsih and Widodo (2020), SMEs have complex problems, so SMEs carry out iterative procedures to get solutions. Thus, to overcome problems, optimization of the use of capital, ideas, and products is carried out. This research states that product ideas are a complex problem. Consumers have desires that change quickly. The product development process has several stages. The initial stage of the product development planning process is determining the product idea. Product idea planning is done quickly to reduce product development process time. The company has many product ideas to meet consumer demand.

At present, SMEs in the textile industry are characterized by large production volumes and weak competitiveness, since vertical integration strategies are scarce (Naranjo, Porras, Ortiz, Tigre, Sánchez, Tubón et al., 2023). SMEs create strategies to solve existing problems in the company (Suhartini, Mahbubah & Basjir, 2021). The garment industry has problems with the textile life cycle caused by the lack of a system for collecting clothes after they are worn by consumers Dissanayake and Sinha (2015) and low clothing utilization caused by mixed textile materials and trends such as fast fashion (Joy, Sherry, Venkatesh, Wang & Chan, 2012), more 70% of the 53 million tons of clothing produced each year is burned or thrown away in landfill sites, annual losses reach 100 billion US dollars. Therefore, textile companies must look for innovative solutions to face challenges (Schiederig, Tietze & Herstatt, 2012).

In the current literature on agile product development and sustainability, significant attention has been given to specific industries such as technology and automotive sectors (Cano et al., 2021; Conforto et al., 2016). However, limited research has been conducted on integrating agile methodologies with sustainability in the garment industry, particularly when considering the economic, environmental, and social aspects in a comprehensive framework. While studies like Prabowo et al. (2020) have explored new product development processes in small and medium-sized enterprises, the intersection of agile product development with sustainability principles remains underexplored, especially in terms of mathematical modeling to optimize product ideas and profits.

Additionally, much of the existing work still focuses on one dimension of sustainability or lacks a structured approach to addressing the dynamic market conditions faced by garment companies. This research aims to fill the gap by developing an integrated mathematical model that incorporates agile product development with sustainability considerations (economic, environmental, and social), providing a comprehensive tool for optimizing product development in the garment industry.

Fast fashion companies meet consumer demands, including trendy models and affordable prices. Currently, consumers rarely use fashion products because they support sustainable implementation (Moon, Lai, Lam & Chang, 2015). For example, Hennes & Mauritz AB (H&M) and Inditex have attempted to use 100% cotton, linen, and environmentally friendly recycled materials (Cai & Luo, 2020). Recycled materials are often more expensive than new production because recycling has several technical and non-technical obstacles to recycling mixed materials into textiles (Sandin & Peters, 2018).

According to Na and Na (2015), as many as 396 textile and garment companies in Korea have strategies to achieve sustainability. The first strategy is that around 36.9% of these companies use environmentally friendly materials. The second strategy is rarely reused clothing (4.5%), and 2.5% of companies sell used clothing after washing and repairing. Meanwhile, 2% is where the goods are modified back into finished products. The third strategy is to carry out environmentally friendly marketing promotions (58.6%) by donating clothes to environmental organizations and volunteer communities.

Research discussing agile and sustainability has been conducted by (Khan, Kumar, Liu, Gupta & Sharma, 2024), proposing a model to identify factors in achieving strategic, operational, and performance goals. It aims to assist managers in combining agile and sustainable criteria. Research by (Agag, Shehawy, Almoraish, Eid, Chaib-Lababdi, Gherissi-Labben et al., 2024) has developed a conceptual framework to explore the impact of using marketing analytics on agility and customer satisfaction. Research by (Zhining, Alli, Ahmadipour & Che-me, 2024) discusses the influence of sustainability and agility in the product development process, which enables companies to implement sustainable manufacturing to remain competitive in the market. Research by (Dewi & Hermanto, 2024) states that collaboration, knowledge transfer, information sharing, service partner development, and logistics integration have a positive effect on the agility of the product service system supply chain, where the role of dynamic capabilities for the product service system is carried out in an agile manner. Research by (Fudhla, Wirjodirdjo & Singgih, 2024) offers a powerful model for practitioners implementing sustainable business practices with a circular economy paradigm. Research by (Naranjo et al., 2023) created a mathematical model of aggregate planning that provides information on production resource requirements in textile companies with sustainable considerations.

The statement above shows that the garment industry has made efforts to make products sustainably. The company makes garment products by considering economic, environmental, and social aspects. Thus, garment companies have a product development process with an agile concept so that the company can respond quickly to consumer requests. This research will carry out a validation process with a mathematical model. Validation tests are used to get the best model. Decision-makers use mathematical models as a basis for determining the number of ideas and profits.

2. Problem Statement

Research on sustainable product development planning states that sustainable product development planning has a product lifespan that is fast or slow (Gomes de Oliveira et al., 2022a). The company carries out a product development process in fast fashion and slow fashion (Gomes de Oliveira, Miranda & de Paula-Dias, 2022). In fast fashion, companies produce with large capacities and low prices, which will result in much waste at the end of its life. Meanwhile, in the slow fashion process, the company will produce in a small capacity but at a high price, resulting in little waste. Consumer desires are changing quickly. Companies must quickly respond to the consumer needs. Apart from rapidly changing desires, consumers want sustainable products. Sustainable products have high prices due to additional costs in the production process. Thus, this research makes the product development process sustainable so that it can minimize the time and costs of the production process.

Product development has several stages of the product development process. Fung, Chan, Choi and Liu (2021) reviewed journals from 1994 to 2018, where the review results were a matrix of the product development process with three sustainable aspects. This research divides the stages of product development into four stages: planning, design, manufacturing, and launching. Based on previous research, researchers will add the number of articles. Research by Suhartini, 2023, using articles from 2012-2021 about the stages of sustainable product development. The sustainable products used are garment products. This research presents a literature review on the agile product development process.

This research aims to create a mathematical model for agile product development. This research creates a further matrix by adding the number of articles. Table 1 below shows the matrix between product development stages and sustainable aspects.

<table>
<tr><th rowspan="2">Product Development Process</th><th colspan="3">Sustainable</th></tr>
<tr><th>Economic</th><th>Environmental</th><th>Social</th></tr>
<tr><td rowspan="2">Planning</td><td>(Stål & Corvellec, 2018; Haapala, Zhao, Camelio, Sutherland, Skerlos, Dornfeld et al., 2013; Kuo, Hsu, Huang & Gong, 2014; Macchion, Danese & Vinelli, 2015; Hannouf & Assefa, 2017; Shen, Li, Dong & Perry, 2017; Pedro, German, Barbara, Jhonattan, Arturo & Maria, 2019)</td><td>(Gloria, Kohlsaat, Bautil, Wolf, Early & Ben-Zekry, 2014)</td><td>(Köksal, Strähle, Müller & Freise, 2017)</td></tr>
<tr><td colspan="3">(Hu, Li, Chen & Wang, 2014; Moon et al., 2015; Boström & Micheletti, 2016; Sarwar, Bin-Humayoun, Nawaz & Yoon, 2021; Goworek, Oxborrow, Claxton, McLaren, Cooper & Hill, 2020; Gunasekaran & Spalanzani, 2012; Karaosman, Morales-Alonso & Brun, 2017; Gomes de Oliveira et al., 2022; Wang, Su, Da & Kuang, 2021)</td></tr>
<tr><td>Design</td><td colspan="2">(Wang, Modi & Schoenherr, 2021)</td><td>–</td></tr>
<tr><td rowspan="2">Manufacture</td><td>(Alkaya & Demirer, 2014; Subic, Shabani, Hedayati & Crossin, 2012)</td><td>(Pensupa, Leu, Hu, Du, Liu, Jing et al., 2017; Vătămănescu, Dabija, Gazzola, Cegarro-Navarro & Buzzi, 2021; Guo, Choi & Shen, 2020)</td><td rowspan="2">(Mair, Druckman & Jackson, 2016)</td></tr>
<tr><td colspan="2">(Enyoghasi & Badurdeen, 2021)</td></tr>
<tr><td rowspan="2">Launching</td><td>(Narkhede, Raut, Roy, Yadav & Gardas, 2020; Garcia-Torres, Rey-Garcia & Albareda-Vivo, 2017)</td><td>(Todeschini, Cortimiglia & de Medeiros, 2020; Kim, Woo & Ramkumar, 2021)</td><td rowspan="2">(Caniato, Caridi, Crippa & Moretto, 2012; Žurga & Tavčer, 2014; Kim, Kang & Lee, 2020)</td></tr>
<tr><td colspan="2">(Jung & Jin, 2016; Labouriau & Naveiro, 2015)</td></tr>
</table>

Table 1. Matrix of the Planning Stages of the Sustainable Product Development Process

This research focuses on the planning stage and considers sustainable aspects. The research measured the number of product ideas using an agile product development process. The sustainable product studied is a garment product, namely Muslim tunic clothing. This research market segment covers the areas of Surabaya, Sidoarjo, Probolinggo, Malang, Pasuruan, Bojonegoro, and Tulungagung.

This research uses validation by building a mathematical model. Mathematical models aim to maximize profits. The mathematical model uses a variable number of product ideas. Mathematical models can determine profits by considering the number of product ideas. Thus, mathematical models are the basis for decision-makers to create product development strategies.

This study aims to achieve the following objectives:

- Develop a mathematical model for agile product development in the garment industry

  This objective will be addressed by constructing an integer linear programming model that incorporates the agile concept, focusing on optimizing product development strategies while considering profit maximization.

- Integrate sustainability aspects (economic, environmental, and social) into the agile product development model

  The sustainability factors will be incorporated into the model through specific parameters that reflect economic gains, the use of recycled materials (environmental), and ease of recycling (social), which will be tested across various scenarios.

- Validate the proposed model through scenario analysis

  The model will be validated by conducting scenario analysis, testing it under different operational conditions (best-case, worst-case, and likely scenarios) to ensure robustness and applicability in real-world settings.

- Provide practical insights for optimizing product ideas and maximizing profits

  This objective will be addressed by analyzing the results of the model, which will offer actionable insights for decision-makers in the garment industry on how to prioritize product ideas and allocate resources efficiently.

3. Methodology

This research discusses the agile garment product development process. The initial stage is to create two mathematical models. Figure 1 shows several scenarios used in the first mathematical model and the second mathematical model.

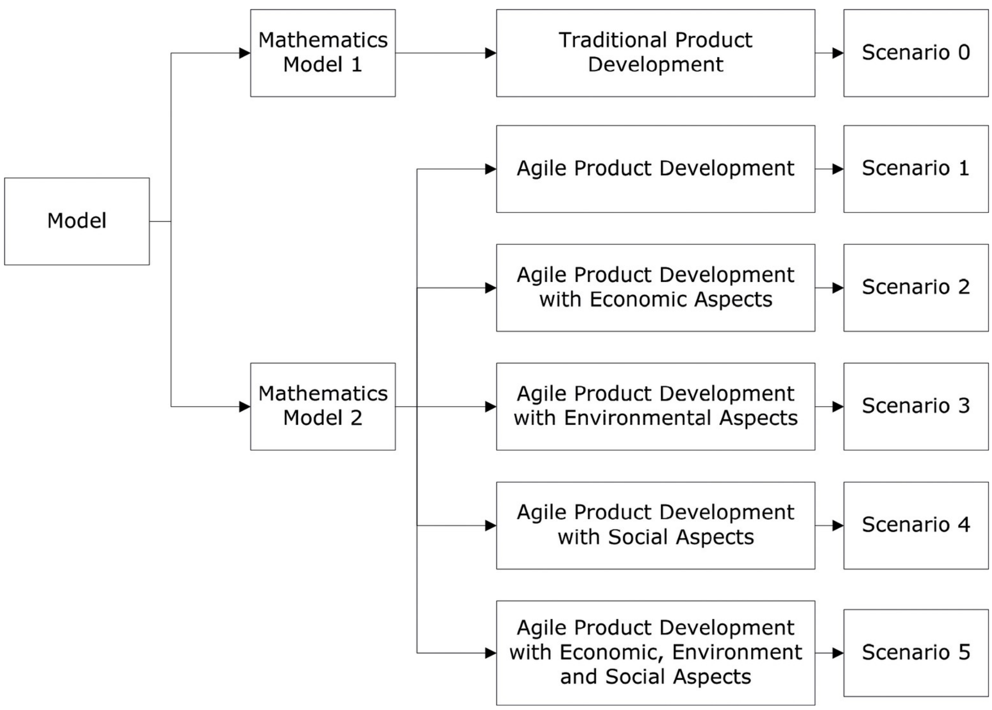


Figure 1. Mathematical models in several scenarios

The first mathematical model consists of the 0th scenario. The 0th scenario is a mathematical model of the traditional garment product development process. Meanwhile, the second mathematical model consists of five scenarios. The first scenario is a mathematical model of the agile garment product development process.

The second scenario is a mathematical model of the agile garment product development process from an economic aspect. The third scenario is a mathematical model of the agile garment product development process in environmental aspects. The fourth scenario is a mathematical model of the agile garment product development process in social aspects. The fifth scenario is a mathematical model of the agile garment product development process in economic, environmental, and social aspects. The model aims to maximize profits. Profit is obtained from total income minus total costs.

3.1. Mathematic Model 1

The first mathematical model is an integer linear programming model. The mathematical model by Trappey and Chiang (2008), discusses traditional product development. The model aims to maximize profits. In general, the equation for finding profit value in product development associated with increasing profit value Trappey and Chiang (2008) is as follows:

$$\text{Max } \Pi = TR - TC \tag{1}$$

Where:

Π : Profit
TR : Total income (total revenue)
TC : Total cost

Based on the concept of a mathematical model in maximizing profit value from product development by Trappey and Chiang (2008), it is divided into four elements, namely:

1. Output value
2. Facility fees
3. Labor costs
4. Outsourcing costs

From these four elements, the mathematical equation is as follows:

$$\text{MaxZ(profit)} = \sum_t OV_t - \left[\sum_e FC_e \cdot Tif_e + \sum_m MC_e \cdot Tih_m\right] - \sum_t OsV_t \tag{2}$$

Where:

Ov_t : Value per NPD output produced in period t (rupiah)
FC_e : Cost per unit of NPD produced from facilities e (rupiah)
Tif_e : Total rupiah used in facilities e to generate NPD (rupiah)
MC_e : The unit cost of human resource m in each NPD (rupiah)
Tih_m : The total input quantity of the human resource m to NPD (rupiah)
OsV_t : Outsourcing costs for NPD activities (rupiah)

Equation (2) represents the mathematical formulation of profit maximization in the agile product development process. For a detailed explanation of the formulation and the assumptions used, please refer to Appendix A.

The mathematical model by Trappey and Chiang (2008), then developed by Prabowo et al. (2020), uses a product development process based on an inactive problem perspective. The following is a mathematical model for product development developed by Prabowo et al. (2020).

Mathematical Model:

$$MaxZ(profit) = \left[P_i \sum_{i=1}^{m} f(x_i)\right] + \left[P_j \sum_{j=1}^{m} f(x_j)\right] - \left[C_i \sum_{i=1}^{m} f(x_i)\right] - \left[C_j \sum_{i=1}^{m} \sum_{j=1}^{k} f(x_{ij})\right] \quad (3)$$

Where:

P_i : Price of idea
P_j : Product price
$f(x_i)$: Number of design products per period
$f(x_j)$: Number of products produced per period
C_i : Cost of realizing the idea
C_j : Product cost
i : Idea index with values 1, 2, 3… m
j : Product index with values 1, 2, 3… k

Based on mathematical models (1), (2) and (3), researchers will develop a mathematical model of the product development process. The model has the objective function of maximizing profits based on the Price of the product idea and the costs of realizing the product idea. The product studied is Muslim clothing. The first mathematical model is a conventional product development process model. The mathematical model is conventionally called the 0-th scenario.

Index: i Product idea

Parameter:

J_i : Degree of product customization
A_i : Makespan time or time needed in the product development process
W_i : Target time in creating the i-th product idea
N_i : Number of design experts
b_i : Labor cost budget
M_i : Capital owned by the company
B_i : Company capital budget
K_i : Idea development budget
d_i : Labor costs
P_i^n : Price or idea value for $n \in N$
$f(x_i^n)$: Number of ideas developed per period
C_i : Cost of realizing the idea
i : Idea index with values 1, 2, 3… m

Decision Variables:

x_i : Number of products developed based on the product with the i-th product idea (unit).
T_i : Number of workers (team) in developing a product with the i-th product idea (unit)

Objective Function:

$$MaxZ(profit) = \left[P_i^n \sum_{i=1}^{m} f(x_i^n)\right] - \left[C_i \sum_{i=1}^{m} f(x_i^n)\right] \quad (4)$$

Constrains:

$$\sum_{i=1}^{m} K_i x_i \le b_i \quad (5)$$

$$\sum_{i=1}^{m} P_i x_i \leq J_i \tag{6}$$

$$\sum_{i=1}^{m} C_i x_i \leq d_i \tag{7}$$

$$\sum_{i=1}^{m} W_i x_i \leq A_i \tag{8}$$

$$\sum_{i=1}^{m} M_i x_i \leq B_i \tag{9}$$

$$\sum_{i=1}^{m} T_i x_i \leq Ni \tag{10}$$

$$K_i \geq 0;\ P_i \geq 0;\ C_i \geq 0;\ W_i \geq 0;\ M_i \geq 0;\ T_i \geq 0 \quad \text{integer each } x_i \text{ for } i\text{-}1, 2, 3\ldots\ m \tag{11}$$

A description of the constraint function of 0-th scenario mathematical model can be seen in Table 2.

Equation	Description
(5)	Labor costs (K_i) to create the i-th product idea with a labor budget (b_i)
(6)	The company's ability to make the maximum number of products (units) (P_i) by creating the i-th idea (unit) with Degree of product customization (J_i)
(7)	Development process costs (C_i) for the i-th product idea with idea development budget (d_i)
(8)	Target time (W_i) in creating the i-th product idea with desaigner skill level (A_i)
(9)	Capital (M_i) owned by the company for the i-th product idea with the budget amount for capital (B_i)
(10)	Number of experts (T_i) for the i-th product idea, taking into account the experts the company has (N_i)
(11)	All variables cannot be negative

Table 2. Constraint Function in the first mathematical model

3.2. Mathematical Model 2

Based on the mathematical model from previous research, this research creates a mathematical model of the product development process using the agile concept. The second mathematical model is also an integer linear programming mathematical model. The model focuses on determining the number of garment product ideas. The model has the goal of maximizing profits. The second mathematical model considers agile concepts and sustainable aspects. The agile concept is used to determine the number of product ideas.

This mathematical model is divided into five scenarios. Based on the figure in Table 1 regarding the product development planning matrix and sustainable aspects (Fung et al., 2021), this research determines the scenario by considering economic, environmental, and social aspects. Based on research Conforto et al. (2016), Serrador and Pinto (2015) and Diebold and Dahlem (2014) regarding the agile product development process, this research determines scenarios by considering the agile concept.

The first scenario is an agile product development process. The second scenario is an agile product development process with economic aspects. The third scenario is an agile product development process with environmental aspects. The fourth scenario is an agile product development process with social aspects. The fifth scenario is an agile product development process with economic, environmental, and social aspects.

The constraint function in the agile concept uses indices from the product development team. The constraint function uses an index from the sustainable aspect, namely the selling price of sustainable products (economic aspect), the degree of use of recycled materials (environmental aspect), and the ease of recycling (social aspect). Mathematical models are used to validate models from several scenarios. The following is a mathematical model of product development based on scenarios.

Index:

i : Idea index with values 1, 2, 3… m
s_1 : Index of sustainable economic aspects
s_2 : Index of sustainable environmental aspects
s_3 : Index of sustainable social aspects

Parameter:

J_i : Degree of product customization
T_i : Makespan time or time needed in the product development process
W_i : Target time in creating the i-th product idea
N_i : Number of design experts
b_i : Labor cost budget
M_i : Capital owned by the company
B_i : Company capital budget
d_i : Idea development budget
K_i : Labor costs
p_i^n : Price or value of ideas for $n \in N$(agile concept)
p_i^{s1} : Price or value of sustainable product ideas for $s \in S$ (economic aspect)
p_i^{s2} : Price or value of sustainable product ideas for $s \in S$ (environmental aspect)
p_i^{s3} : Price or value of sustainable product ideas for $s \in S$ (social aspect)
C_i : Cost of realizing the idea
Cs_1 : Sustainable costs from economic aspects
Cs_2 : Sustainable costs for environmental aspects
Cs_3 : Sustainable costs for social aspects

Decision Variables:

x_i : Number of designs developed for the i-th product (unit)
T_i : Number of workers (team) in creating the i-th idea (unit) with the i-th product idea (unit)
$f(x_i^n)$: Number of ideas developed per period for $n \in n$ (agile concept)
$f(x_i^s)$: Number of ideas produced per period for $s \in s$ (sustainable aspect)

Scenario 1

Objective Function:

$$\text{MaxZ(profit)} = \left[P_i^n \sum_{i=1}^{m} f(x_i) \right] + \left[P_i^a \sum_{i=1}^{m} f(x_i) \right] - \left[C_i \sum_{i=1}^{m} f(x_i) \right] - \left[C_i + C_a \sum_{i=1}^{mk} f(x_i) \right] \quad (12)$$

Constrains:

$$\sum_{i=1}^{m} K_i x_i \leq b_i \quad (13)$$

$$\sum_{i=1}^{m} P_i x_i \leq Ji \quad (14)$$

$$\sum_{i=1}^{m} C_i x_i \leq d_i \tag{15}$$

$$\sum_{i=1}^{m} W_i x_i \leq A_i \tag{16}$$

$$\sum_{i=1}^{m} M_i x_i \leq B_i \tag{17}$$

$$\sum_{i=1}^{m} T_i x_i \leq Ni \tag{18}$$

$$A_{agile}\, x_i \leq 1 \tag{19}$$

In Table 3 describes the constraint functions used in the mathematical model of the first scenario.

Equation	Description
(13)	Labor costs(K_i) to create product idea *i* with labor budget (b_i)
(14)	The company's ability to make the maximum number of products (units) (P_i) by creating idea *i* (unit) with degree of product customization (J_i)
(15)	Development process costs (C_i) for product idea *i* with Idea development budget (d_i)
(16)	Target time (W_i) in creating product ideas *i* with makespan time or time needed in the product development process (A_i)
(17)	Capital (M_i) owned by the company for product idea *i* and budget amount (B_i)
(18)	The number of experts (T_i) for product ideas considers the experts the company has (N_i)
(19)	Index value of the agile concept (A_{agile})

Table 3. Constraint Function in the second mathematical model

The first scenario is a mathematical model of the agile product development process. This model uses Equations (13) and (19) as constraint functions. In Equation (19) is the agile concept index $A_{agile.}$ The index is obtained from implementing agile using the scrum approach. In the scrum approach, the product development team will carry out several iterations to create a product idea design. Thus, the index value is determined by knowing the number of iterations carried out by the product development team.

Scenario 2

$$\text{Max(profit)} = \left[\begin{array}{l}\left[P_i^n \sum_{i=1}^{m} f(x_i)\right] + \left[P_i^a \sum_{i=1}^{m} f(x_i)\right] \\ + \left[P_i^n + P_i^{s1} \sum_{i=1}^{m} f(x_i)\right]\end{array}\right] - \left[\begin{array}{l}\left[C_i \sum_{i=1}^{m} f(x_i)\right] + \left[(C_i + C_a) \sum_{i=1}^{m} f(x_i)\right] \\ + \left[(C_i + C_{s1}) \sum_{i=1}^{m} f(x_i)\right]\end{array}\right] \tag{20}$$

$$S_{economic}\, x_i \leq 1 \tag{21}$$

The second scenario is a mathematical model of the agile product development process with economic aspects. In the second scenario, the aim is to maximize profits. This model uses Equations (13) to (19) as constraint functions and is added with Equation (21). An Equation (21) is the index value of the agile product development process by considering economic aspects. The economic aspect of developing garment products is the selling price of garment products. Thus, the index value is determined by knowing the total price of products sold in the market.

Scenario 3

$$\text{Max(profit)} = \left[\begin{array}{l}\left[P_i^n \sum_{i=1}^{m} f(x_i)\right] + \left[P_i^a \sum_{i=1}^{m} f(x_i)\right] \\ + \left[P_i^n + P_i^{s2} \sum_{i=1}^{m} f(x_i)\right]\end{array}\right] - \left[\begin{array}{l}\left[C_i \sum_{i=1}^{m} f(x_i)\right] + \left[(C_i + C_a) \sum_{i=1}^{m} f(x_i)\right] \\ + \left[(C_i + C_{s2}) \sum_{i=1}^{m} f(x_i)\right]\end{array}\right] \tag{22}$$

$$S_{environment}\, x_i \leq 1 \tag{23}$$

The third scenario is a mathematical model of the agile product development process with environmental aspects. In the second scenario, the aim is to maximize profits. This model uses Equations (13) to (19) as constraint functions and is added with Equation (23). Equation (23) is the index value of the agile product development process by considering environmental aspects. The environmental aspect of garment product development is the degree of utilization of recycled materials from garment products. Thus, the index value is determined by the degree of utilization of recycled materials from garment products.

Scenario 4

$$\text{Max(profit)} = \left[\begin{array}{l}\left[P_i^n \sum_{i=1}^{m} f(x_i)\right] + \left[P_i^a \sum_{i=1}^{m} f(x_i)\right] \\ + \left[P_i^n + P_i^{s3} \sum_{i=1}^{m} f(x_i)\right]\end{array}\right] - \left[\begin{array}{l}\left[C_i \sum_{i=1}^{m} f(x_i)\right] + \left[(C_i + C_a) \sum_{i=1}^{m} f(x_i)\right] \\ + \left[(C_i + C_{s3}) \sum_{i=1}^{m} f(x_i)\right]\end{array}\right] \tag{24}$$

$$S_{social}\, x_i \leq 1 \tag{25}$$

The fourth scenario is a mathematical model of the agile product development process with social aspects. In the second scenario, the aim is to maximize profits. This model uses Equations (13) to (19) as constraint functions and is added with Equation (25). Equation (25) is the index value of the agile product development process by considering social aspects. The social aspect of garment product development is the sustainable index value for ease of recycling. Thus, the index value is determined by knowing the ease of recycling garment products.

Scenario 5

$$\text{Max(profit)} = \left(\begin{array}{l}\left\{\begin{array}{l}\left[P_i^n \sum_{i=1}^{m} f(x_i)\right] + \left[\left(\frac{1}{4}P_i^n + P_i^a\right) \sum_{i=1}^{m} f(x_i)\right] + \left[\left(\frac{1}{4}P_i^n + P_i^{s1}\right) \sum_{i=1}^{m} f(x_i)\right] \\ + \left[\left(\frac{1}{4}P_i^n + P_i^{s2}\right) \sum_{i=1}^{m} f(x_i)\right] + \left[\left(\frac{1}{4}P_i^n + P_i^{s3}\right) \sum_{i=1}^{m} f(x_i)\right]\end{array}\right\} \\ - \left\{\begin{array}{l}\left[C_i \sum_{i=1}^{m} f(x_i)\right] + \left[\left(\frac{1}{4}C_i + C_a\right) \sum_{i=1}^{m} f(x_1)\right] + \left[\left(\frac{1}{4}C_i + C_{s1}\right) \sum_{i=1}^{m} f(x_1)\right] \\ + \left[\left(\frac{1}{4}C_i + C_{s2}\right) \sum_{i=1}^{m} f(x_1)\right] + \left[\left(\frac{1}{4}C_i + C_{s3}\right) \sum_{i=1}^{m} f(x_1)\right]\end{array}\right\}\end{array}\right) \tag{26}$$

Constrains:

$$K_i \geq 0;\ P_i \geq 0;\ C_i \geq 0;\ W_i \geq 0;\ M_i \geq 0;\ T_i \geq 0; \tag{27}$$

$$A_{agile} \geq 0; S_{economic} \geq 0; S_{environment} \geq 0; S_{social}\ x_i \geq 0; x_i > 0$$
$$\text{integer each } x_i \text{ for } i\text{-}1, 2, 3\ldots m$$

The fifth scenario is a mathematical model of the agile product development process with economic aspects, environmental aspects, and social aspects. In the fifth scenario, the aim is to maximize profits. This model uses Equations (13) to (19) and Equations (21), (23), (25) and (27) as constraint functions. An Equation (21) is the index value of the agile product development process by considering economic aspects. The economic aspect of garment product development is the selling price of garment products. An Equation (23) is the index value of the agile product development process by considering environmental aspects. The environmental aspect of garment product development is the degree of utilization of recycled materials from garment products. An Equation (25) is the index value of the agile product development process by considering social aspects. The social aspect of garment product development is the sustainable index value for ease of recycling. An Equation (27) is a variable value that cannot be negative.

By considering parameters and variables, the mathematical model has an objective function to maximize profits. The objective function is to maximize profits from total revenue minus total costs. Total income consists of four prices, namely the price of realizing a product idea with an agile concept, the price of a sustainable product idea from an economic aspect, the price of a sustainable product idea from an environmental aspect, and the price of a sustainable product idea from a social aspect. The total costs consist of the costs of realizing the idea, the costs of sustainable economic aspects, the costs of sustainable environmental aspects, and the costs of sustainable social aspects. The mathematical model consists of five scenarios. Each scenario has a constraint function. Table 4 shows the constraint function of the mathematical model for each scenario.

Scenario				
Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Agile product development process	Agile product development process with economic aspects	Agile product development process with environmental aspects	Agile product development process with social aspects	Agile product development process for economic aspects, environmental aspects, and social aspects
Objective Function: Maximum profit				
Constraints				
Equation (13) Labor costs (Ki) to create the i-th product idea with a labor budget (bi)				
Equation (14) The company's ability to make the maximum number of products (units) (Pi) by creating idea i (unit) with degree of product customization (Ji)				
Equation (15) Development process costs (Ci) for product idea i with Idea development budget (di)				
Equation (16) Target time (Wi) in creating product ideas i with makespan time or time needed in the product development process (Ai)				
Equation (17) Capital (Mi) owned by the company for product idea i and budget amount (Bi)				
Equation (18) The number of experts for product ideas considers the experts the company has (Ni)				
Equation (27) integer each xi for i-1,2,3,…m				
Equation (19) Index value of the agile concept (Aagile)	Equation (21) Sustainable index value on the selling price of sustainable products (economic aspect)	Equation (23) Sustainable index value on the degree of use of recycled materials (environmental aspect)	Equation (25) Sustainable index value on ease of recycling (social aspect)	Equation (19), (21), (23), (25)

Table 4. Objective function and constraints for each scenario

3.3. Results of Scenarios Calculations

Based on research from Prabowo et al. (2020) discusses the product development process based on company type. This research states that the garment industry in the Central Java region has an average workforce of 16 people, an average number of experts of 7 people, an average development time of 17 days, an average order of 119 products per month, an average number of regular customers is 81 customers, the average new product development produces 24 products per year. Meanwhile, product development requires capital between 50 million to 750 million every year. Based on this research, the East Java region is the research object. Garment industry data from the industry department shows that East Java has 24 garment industries. The garment industry produces Muslim clothing in as many as eight companies. Figure 2 shows the number of garment industries in Indonesia.

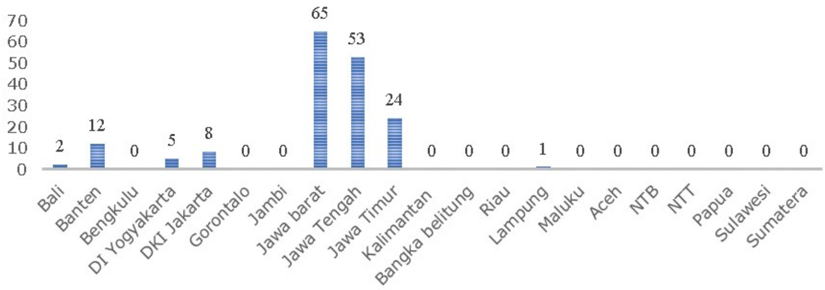


Figure 2. Number of Garment Industries in Indonesia

Based on previous research data, this research uses this data to validate the mathematical model. The first mathematical model is the 0th scenario. The conventional product development cost structure can be seen in Figure 3.

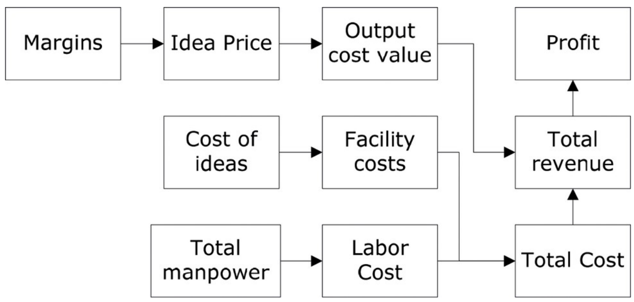


Figure 3. The cost structure of conventional planning stage product development

The idea price is the price of realizing the idea plus the product margin. The product development process uses the agile concept at the planning stage. In the mathematical model, the constraint function for the agile concept uses index values, and the sustainable aspect also uses index values. The index value was obtained from interviews in the garment industry. Researchers conducted interviews with the product development team. The purpose of conducting interviews is to find out information related to the price of product ideas, the number of product ideas developed by the company, and the costs of realizing product ideas. The sustainable index value is on the selling price of sustainable products (economic aspect), the sustainable index value is on the degree of use of recycled materials (environmental aspect), and the sustainable index value is on the ease of recycling (social aspect). The second mathematical model uses an agile product development cost structure. In total revenue and total costs, consider the agile concept and sustainability aspects. The cost structure used for agile product development can be seen in Figure 4.

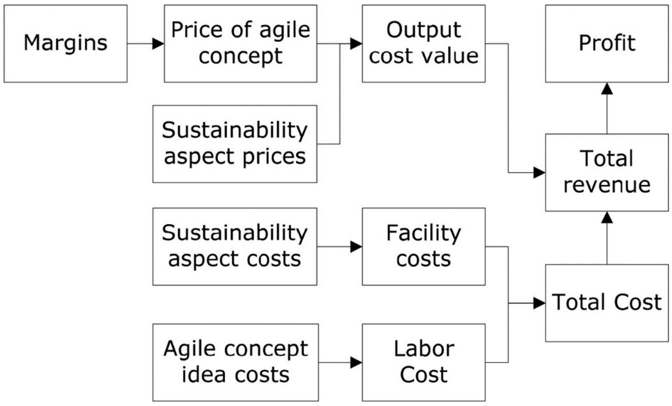


Figure 4. Cost structure for agile planning stage product development

In order to account for uncertainties in product development costs and market demand, this research employs sensitivity analysis. Key parameters, such as development costs and demand fluctuations, are varied to observe their effect on model outputs. Additionally, scenario analysis is conducted to simulate best-case, worst-case, and most-likely conditions. These approaches ensure the model remains robust under different operational uncertainties.

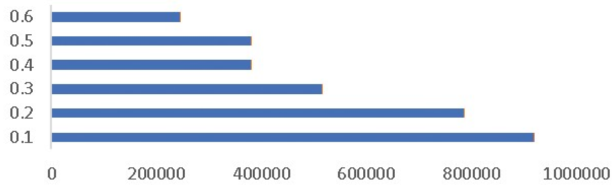
4. Results and Discussion

4.1. Mathematical Model of Agile Product Development Process

In the mathematical model, the agile product development process is divided into five scenarios. Based on the figure in Table 1 regarding the product development planning matrix and sustainable aspects (Fung et al., 2021), this research determines the scenario by considering economic, environmental, and social aspects. Based on research Conforto et al. (2016), Serrador and Pinto (2015) and Diebold and Dahlem (2014) regarding the agile product development process, this research determines scenarios by considering the agile concept. The mathematical model uses agile concepts and sustainable aspects as constraint functions. This research uses index values to determine the value of the agile concept and sustainable aspects. This research uses an index value of 0.1 for the agile concept and its economic, environmental, and social aspects. From this index value, the research will use sensitivity analysis to change the index value to determine changes in profit values in determining product ideas. The following are the calculation results for each scenario.

Scenario 1

Mathematical model of the agile product development process. The agile concept uses an index value of 0.1. The result of the mathematical model is a profit of IDR1210000 and 6 product ideas. The agile concept uses an index value of 0.2 to produce a profit of IDR920000 with a total of 5 product ideas. The agile concept uses an index value of 0.3 to produce a profit of IDR515000 with a total of 3 product ideas. The agile concept uses an index value of 0.4 to produce a profit of IDR380000 with a total of 2 product ideas. The agile concept uses an index value of 0.5 to produce a profit of IDR380000 with 2 product ideas. The agile concept uses an index value of 0.6 to produce a profit of IDR385000 with a total of 1 product idea. Figure 5 shows the profit values and product ideas for the first scenario.

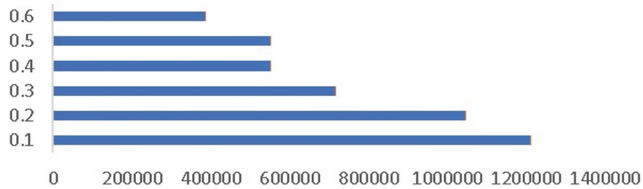


	0.1	0.2	0.3	0.4	0.5	0.6
Profit	920000	785000	515000	380000	380000	245000
Number of ideas	6	5	3	2	2	1

Figure 5. Profit values and product ideas for the first scenario

Scenario 2

The mathematical model for agile product development uses economic aspects. The agile concept uses an index value of 0.1, and the economic aspect uses an index value of 0.1. The result of the mathematical model is a profit of IDR1210000 and 6 product ideas. The agile concept uses an index value of 0.2, and the economic aspect is 0.1, resulting in a profit of IDR1045000 with 5 product ideas. The agile concept uses an index value of 0.3, and the economic aspect is 0.1, resulting in a profit of IDR715000 with 3 product ideas. The agile concept uses an index value of 0.4, and the economic aspect is 0.1, resulting in a profit of IDR550000 with 2 product ideas. The agile concept uses an index value of 0.5 and an economic aspect of 0.1 to produce a profit of IDR550,000 with a total of 2 product ideas. The agile concept uses an index value of 0.6, and the economic aspect is 0.1, resulting in a profit of IDR385000 with a total of 1 product idea. Figure 6 shows the profit values and product ideas for the second scenario.

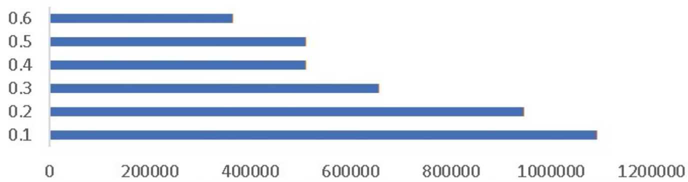


	0.1	0.2	0.3	0.4	0.5	0.6
Profit	1210000	1045000	715000	550000	550000	385000
Number of ideas	6	5	3	2	2	1

Figure 6. Profit value and product ideas for the second scenario

Scenario 3

Mathematical model of agile product development using environmental aspects. The agile concept uses an index value of 0.1, and environmental aspects use an index value of 0.1. The mathematical model produces a profit of IDR1090000 and 6 number of product ideas. The agile concept uses an index value of 0.2, and the environmental aspect is 0.1, resulting in a profit of IDR945000 with 5 product ideas. The agile concept uses an index value of 0.3, and the environmental aspect is 0.1, resulting in a profit of IDR655000 with 3 product ideas. The agile concept uses an index value of 0.4, and the environmental aspect is 0.1, resulting in a profit of IDR510000 with 2 product ideas. The agile concept uses an index value of 0.5 and an environmental aspect of 0.1 to produce a profit of IDR510,000 with a total of 2 product ideas. The agile concept uses an index value of 0.6, and the environmental aspect is 0.1, resulting in a profit of IDR365000 with a total of 1 product idea. Figure 7 shows the profit value and product ideas for the third scenario.

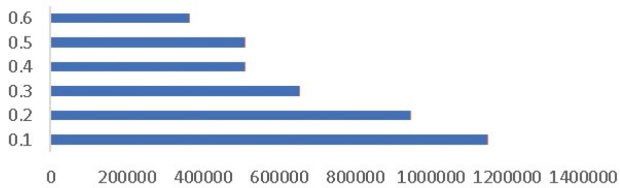


	0.1	0.2	0.3	0.4	0.5	0.6
Profit	1090000	945000	655000	510000	510000	365000
Number of ideas	6	5	3	2	2	1

Figure 7. Profit value and product ideas for the third scenario

Scenario 4

Mathematical model of agile product development using social aspects. The agile concept uses an index value of 0.1, and the social aspect uses an index value of 0.1. The result of the mathematical model is a profit of IDR1150000 and 6 number of product ideas. The agile concept uses an index value of 0.2, and the social aspect is 0.1, resulting in a profit of IDR945000 with 5 product ideas. The agile concept uses an index value of 0.3, and the social aspect is 0.1, resulting in a profit of IDR655000 with 3 product ideas. The agile concept uses an index value of 0.4, and the social aspect is 0.1, resulting in a profit of IDR 510000 with 2 product ideas. The agile concept uses an index value of 0.5 and a social aspect of 0.1, resulting in a profit of IDR510,000 with a total of 2 product ideas. The agile concept uses an index value of 0.6, and the social aspect is 0.1, resulting in a profit of IDR 365000 with a total of 1 product idea. Figure 8 shows the profit value and product ideas for the fourth scenario.

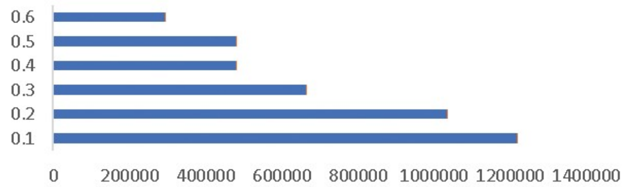


	0.1	0.2	0.3	0.4	0.5	0.6
Profit	1150000	945000	655000	510000	510000	365000
Number of ideas	6	5	3	2	2	1

Figure 8. Profit value and product ideas for the fourth scenario

Scenario 5

The mathematical model for agile product development uses economic aspects, environmental aspects, and social aspects. The agile concept uses an index value of 0.1, economic aspects use an index value of 0.1, environmental aspects use an index value of 0.1, and social aspects use an index value of 0.1. The results of the mathematical model are a profit of IDR1220000 and 6 number of product ideas. The agile concept uses an index value of 0.2, the economic aspect is 0.1, the environmental aspect is 0.1, and the social aspect is 0.1, resulting in a profit of IDR1035000 with 5 product ideas. The agile concept uses an index value of 0.3, and the economic aspect is 0.1, the environmental aspect is 0.2, the social aspect is 0.1, resulting in a profit of IDR665000 with a total of 4 product ideas. The agile concept uses an index value of 0.4, the economic aspect is 0.1, the environmental aspect is 0.1, and the social aspect is 0.1, resulting in a profit of IDR 480000 with 3 product ideas. The agile concept uses an index value of 0.5, the economic aspect is 0.1, the environmental aspect is 0.1, and the social aspect is 0,1, resulting in a profit of IDR480000 with 2 product ideas. The agile concept uses an index value of 0.6, the economic aspect is 0.6, the environmental aspect is 0.1, and the social aspect is 0.1, resulting in a profit of IDR295000 with the amount of 1 product idea. Figure 9 shows the profit values and product ideas for the fifth scenario.



	0.1	0.2	0.3	0.4	0.5	0.6
Profit	1220000	1035000	665000	480000	480000	295000
Number of ideas	6	5	3	2	2	1

Figure 9. Profit value and product ideas for the fifth scenario

4.2. Validation of Optimization Result

The validation of the optimal results was conducted using sensitivity analysis. This method evaluates the impact of changes in key parameters, such as the agile concept index and sustainability aspects, on the profit and the number of product ideas. The results indicate that the smaller the agile index value, the higher the profit and the more product ideas generated, ensuring robustness of the model under varying conditions.

Model validation using mathematical models. The results of the mathematical model show the profit value and number of product ideas for the agile concept index using 0.1. Scenario 0 shows a profit value of IDR1320000 with 12 product ideas. Scenario 1 shows a profit value of IDR920000 with 6 product ideas. Scenario 2 shows a profit value of IDR1210000 with a value of 6 product ideas. Scenario 3 shows a profit value of IDR1090000 with a value of 6 product ideas. Scenario 4 shows a profit value of IDR1150000 and 6 product ideas. Scenario 5 shows a profit value of IDR1220000 with 6 product ideas. The results of the mathematical model consisting of five scenarios show that the best profit value is scenario 5, which has a profit value of IDR1220000 with 6 product ideas and a sales value of IDR203333. Table 5 shows the validation results of each scenario.

Scenario	Index				Profit	Product idea
	Agile	Economic	Environmental	Social		
0	–	–	–	–	IDR1320000	12
1	0,1	–	–	–	IDR920000	6
2	0,1	0,1	–	–	IDR1210000	6
3	0,1	–	0,1	–	IDR1090000	6
4	0,1	–	-	0,1	IDR1150000	6
5	0,1	0,1	0,1	0,1	IDR1220000	6

Table 5. Validation results for each scenario

Based on Table 5, sensitivity analysis will be carried out by changing the index value in the agile concept. The agile concept index values are 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6. Figures 5 to 8 show changes in agile concept index values from each scenario. Sensitivity analysis between the agile concept and the profit value shows that the agile concept index value is 0.1 and the profit value is IDR1220000. Each scenario has a different profit value. Scenario 5 has the most significant profit value among the other scenarios. Thus, the profit value will increase if product development planning uses the three sustainable aspects and has the smallest agile concept index value. Analysis of the sensitivity of the agile product development process produces profit values from each scenario, which can be seen in Figure 10.

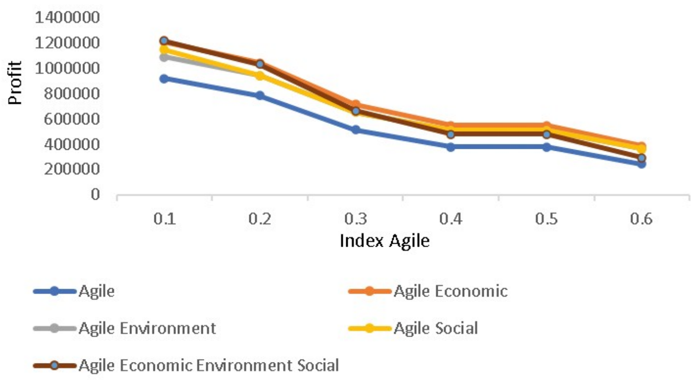


Figure 10. Sensitivity analysis of agile concepts based on scenarios

Sensitivity analysis between the agile index and the number of product ideas shows that the smallest agile concept index value, namely 0.1, produces 6 product ideas. The agile concept index value of 0.2 produces 5 product ideas. The agile concept index value of 0.3 produces 4 product ideas. The agile concept index value of 0.4 produces 3 product ideas. An agile concept index value of 0.5 produces 2 product ideas. An agile concept index value of 0.6 produces 1 product idea. Sensitivity analysis of each scenario produces a different number of product ideas. Thus, the profit value increases if the development team generates many product ideas. Figure 11 shows the sensitivity analysis between the agile concept index value and the number of product ideas.

Based on the results of the scenario discussion, a graphic illustration can be created. The following graphic illustration of the relationship between profits and product ideas can be seen in Figure 12.

Figure 12 shows the relationship between the number of product ideas and the profits of each scenario. All scenarios experience an increase in profit value. Scenario 0 has a value of IDR1320,000 with 12 product ideas. So, the profit value for a total of 6 product ideas is IDR660,000. Thus, scenario 0 produces the lowest profit value. The first scenario experiences an increase in profits. The agile concept index values of 0.4 and 0.5 produce 2 product ideas and a profit value of IDR 380,000.

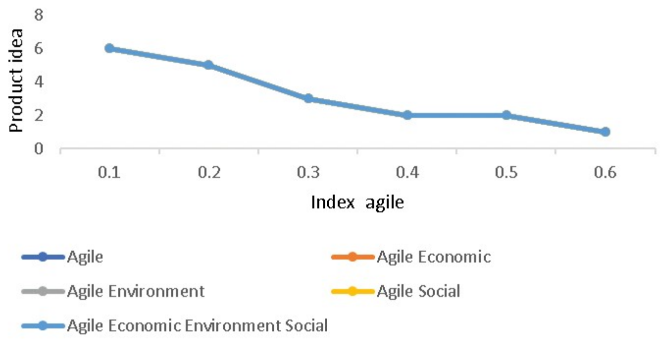


Figure 11. Sensitivity analysis of the agile concept based on the number of product ideas

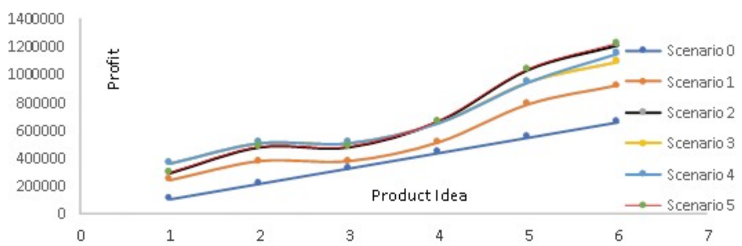


Figure 12. Relationship between profit and product ideas

The first scenario produces a profit value of 920000 with an agile concept index of 0.1, a profit value of IDR 785000 with an agile concept index of 0.2, a profit value of IDR 515000 with an Agile concept index of 0.3, and a profit value of IDR 245000 with an agile concept index of 0.6.

The second scenario experiences an increase in profits. The agile concept index values of 0.4 and 0.5 produce 2 product ideas and a profit value IDR 550,000. The second scenario produces a profit value of 1210000 with an Agile concept index of 0.1, a profit value of IDR 1045000 with an agile concept index of 0.2, a profit value of IDR 715000 with an agile concept index of 0.3, and a profit value of IDR 385000 with an agile concept index of 0.6.

The third scenario experiences an increase in profits. The agile concept index values of 0.4 and 0.5 produce 2 product ideas and a profit value IDR 510,000. The third scenario produces a profit value of IDR 1090000 with an agile concept index of 0.1, a profit value of IDR 945000 with an agile concept index of 0.2, a profit value of IDR 655000 with an agile concept index of 0.3, and a profit value of IDR 365000 with an agile concept index of 0,6.

The fourth scenario experiences an increase in profits. The agile concept index values of 0.4 and 0.5 produce 2 product ideas and a profit value IDR 510,000. The fourth scenario produces a profit value of IDR 1150000 with an Agile concept index of 0.1, a profit value of IDR 945000 with an agile concept index of 0.2, a profit value of IDR 655000 with an agile concept index of 0.3, and a profit value of IDR 365000 with an agile concept index of 0 .6. The fifth scenario experiences an increase in profits. The agile concept index values of 0.4 and 0.5 produce 2 product ideas and a profit value IDR 480,000.

The fifth scenario produces a profit value of IDR 1220000 with an Agile concept index of 0.1, a profit value of IDR 1035000 with an agile concept index of 0.2, a profit value of IDR 665000 with an agile concept index of 0.3, and a profit value of IDR 295000 with an agile concept index of 0,6. The agile concept index value only sometimes experiences the maximum profit value. The profit value and the number of product ideas are the same, as seen in the agile concept index values of 0.4 and 0.5. Thus, the value of the agile concept index can influence the value of profits and the number of product ideas.

The results from sensitivity analysis demonstrate that small variations in development costs and market demand can significantly influence the profitability and the number of product ideas. For instance, increasing the demand uncertainty by 10% resulted in a 15% decrease in profit, highlighting the importance of robust planning under uncertainty.

4.3. Advantages of Proposed Mathematical Model

Several researchers have previously created mathematical models of conventional product development processes. The mathematical model by Trappey and Chiang (2008) discusses conventional product development, and the model aims to maximize profits. Furthermore, a mathematical model was developed by Prabowo. et al. (2020). The mathematical model aims to maximize profits by considering the inactive problem perspective.

With this premise, the mathematical model of integer linear programming addresses the agile product development process. This research discusses garment products. The product development process focuses on the planning stage. The planning stage creates product ideas to increase profits.

The product development process considers the agile concept and sustainability, namely economic aspects, environmental aspects, and social aspects. The economic aspect considers the selling price of the product. Environmental aspects consider the degree of use of recycled materials. The social aspect considers the ease of recycling.

The mathematical model has five scenarios to be used as a basis for determining the maximum value for profits and the number of product ideas. Thus, mathematical models are used by companies to determine optimal values in carrying out the product development process.

The proposed mathematical model provides a practical tool for plant personnel to optimize product development strategies in the garment industry. The model helps decision-makers in the following ways:

- Prioritization of Product Ideas

  By utilizing the model's outputs, plant personnel can prioritize product ideas based on their profitability and sustainability metrics. For instance, the model identifies which product ideas generate the highest returns while considering cost constraints, labor allocation, and market demand. This allows for more informed decisions on which products to develop and bring to market, ensuring that resources are directed toward the most lucrative and sustainable options.

- Optimized Resource Allocation

  The model offers insights into how labor, capital, and materials should be allocated to maximize output. For example, by analyzing the model's scenarios, plant managers can determine the optimal number of workers and the amount of capital investment required for each product idea. This helps avoid underutilization or overextension of resources, leading to more efficient production processes.

- Scenario-Based Decision-Making

  The results from scenario analysis allow plant personnel to simulate different market conditions (such as fluctuating demand or cost variations). This enables the team to develop contingency plans and adapt their production strategies to changing market dynamics. For instance, in a scenario where demand decreases, the model can help adjust production volumes and allocate resources more efficiently to minimize losses.

- Sustainability Integration

  With sustainability becoming a critical aspect of business operations, the model also provides a way to integrate environmental and social considerations into the product development process. Plant personnel can use the model to select product ideas that minimize waste, use recycled materials, or are easier to recycle, thus aligning with corporate sustainability goals while maintaining profitability.

By applying the insights from this model, plant personnel can make data-driven decisions that optimize both financial performance and sustainability, ultimately improving the overall efficiency and responsiveness of the production system.

This research presents several key contributions and merits that distinguish it from previous studies on product development in the garment industry:

- Integration of Agile and Sustainability Concepts

  The proposed model integrates the agile product development framework with sustainability considerations—economic, environmental, and social aspects. While previous models have focused on either agile processes or sustainability separately, this research combines both dimensions, providing a more comprehensive approach to optimizing product development.

- Mathematical Optimization for Decision-Making

  By using an integer linear programming model, this research provides a systematic and quantifiable method for decision-makers to optimize product development. The model allows companies to maximize profits while considering various constraints, such as labor costs, capital investment, and sustainability requirements, thus offering a practical tool for strategic decision-making.

- Application in the Garment Industry

  Unlike many studies that focus on industries such as technology or automotive, this research specifically addresses the unique challenges of the garment industry, which faces rapid changes in consumer demand and growing pressures for sustainability. The model is tailored to the garment industry's needs, ensuring relevance and practicality for companies operating in this sector.

- Scenario-Based Flexibility

  The model provides flexibility through the use of scenario-based analysis. Companies can test different scenarios based on varying levels of market demand, sustainability priorities, and resource constraints. This allows the model to adapt to different business environments, ensuring its utility across diverse conditions.

- Sensitivity Analysis for Robustness

  Sensitivity analysis is conducted to assess the robustness of the model under various conditions. This ensures that the model remains reliable even when key parameters, such as product development costs or demand, fluctuate. This feature enhances the model's practical applicability in real-world situations, where uncertainties are common.

- Support for Strategic Planning and Sustainability

  The model not only helps companies optimize their product development processes but also aligns these processes with broader sustainability goals. By considering factors like recycled materials and ease of recycling, the model supports strategic planning for long-term environmental and social impact, making it a valuable tool for companies committed to sustainability.

Previous studies, such as those by Trappey and Chiang (2008) and Prabowo et al. (2020), focused on maximizing profits in product development, but lacked a structured integration of sustainability aspects. This research addresses this gap by combining the agile framework with sustainability considerations, offering a more holistic approach to product development that is both profitable and aligned with sustainability goals.

5. Conclusions

This research creates a mathematical model of the agile garment product development process. The mathematical model aims to select the best scenario for implementing agile in product development. The model aims to determine the total profit for the number of garment product ideas. The model consists of the 0th scenario and five scenarios. The 0th scenario is the traditional product development process. These five scenarios are a product development process with agile and sustainable concepts.

If the company determines profit from total revenue minus costs, it uses the 0th scenario. If the company determines profit by considering the agile concept, use the first scenario. If the company determines profits by considering the agile concept and economic aspects, namely the selling price of the product, then use the second scenario. If a company determines profits by considering the agile concept and environmental aspects, namely the level of use of recycled materials, then use the third scenario. If the company determines profits by considering the agile concept and social aspects, namely ease of recycling, then use the fourth scenario. If a company determines profits by considering agile concepts and sustainability aspects, then the company uses the fifth scenario. Three aspects of sustainability are selling price, level of use of recycled materials, and ease of recycling. The best agile product development model is the fifth scenario.

Mathematical models have a constraint function. One of the constraint functions is an index value. Index values include the agile concept index, economic aspect index, environmental aspect index and social aspect index. The fifth scenario is the best model because it produces maximum profit value. The model produces maximum profit because the model has a tiny index value. Thus, the product development process will produce maximum profit if the mathematical model has a tiny index value. The fifth scenario cannot maximise profit if the model has a considerable index value. The product development mathematical model produces maximum profit values if the model uses the four index values in the objective function. A model that uses only one of the index values does not produce maximum profit values. The fifth scenario produces a model that provides maximum total profit. Mathematical models for agile and sustainable product development are the basis for decision-making. The mathematical model consists of several scenarios. Each scenario can determine the company's profits.

The mathematical model discussed in this research attempts to align the objective function, namely maximizing profits from total income and costs. Total revenue is the price of the product idea. Meanwhile, total costs are the costs of agile product development process activities.

The limitation of this research is that it only discusses one type of product in the garment industry. The product development consists of planning, designing, launching, and manufacturing. This research only discusses the planning stage. Mathematical models are the basic models for product development, especially the planning stage. Mathematical models only discuss the planning stage so that research can be developed at the design, launching and manufacturing stages.

The proposed model offers significant contributions to both academia and industry by integrating agile methodologies with sustainability considerations. It provides a flexible, scenario-based tool that can help companies in the garment industry optimize their product development processes while achieving economic, environmental, and social sustainability goals.

Future work could explore the use of Monte Carlo simulations to handle a broader range of uncertainties in market demand and production costs. Such an approach would allow for probabilistic forecasting and risk assessment, providing deeper insights for decision-making. In addition, the use of response data in the product development process can help further validation using MAD (Mean Absolute Deviation), MSD (Mean Squared Deviation), and MAPE (Mean Absolute Percentage Error) methods. These three methods measure the model's accuracy; the smaller the value produced, the better the model will be. Thus, the model can be said to be able to maximize profits in determining product ideas if the deviation is less than 5%.

Acknowledgments

The author would like to thank the support of the Department of the Department of Industrial and Systems Engineering, Faculty of Industrial Technology, Sepuluh Nopember Institute of Technology, Surabaya Indonesia; The author also thanks the support of the Department of Industrial Engineering, Faculty of Industrial Technology, Adhi Tama Institute of Technology, Surabaya Indonesia.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest concerning this article's research, authorship, and publication.

Funding

The author received no financial support for the research, authorship, and publication of this article.

References

Agag, G., Shehawy, Y.M., Almoraish, A., Eid, R., Chaib-Lababdi, H., Gherissi-Labben, T. et al. (2024). Understanding the relationship between marketing analytics, customer agility, and customer satisfaction: A longitudinal perspective. *Journal of Retailing and Consumer Services,* 77(May 2023), 103663. https://doi.org/10.1016/j.jretconser.2023.103663

Alkaya, E., & Demirer, G.N. (2014). Sustainable textile production: A case study from a woven fabric manufacturing mill in Turkey. *Journal of Cleaner Production,* 65, 595-603. https://doi.org/10.1016/j.jclepro.2013.07.008

Boström, M., & Micheletti, M. (2016). Introducing the Sustainability Challenge of Textiles and Clothing. *Journal of Consumer Policy,* 39(4), 367-375. https://doi.org/10.1007/s10603-016-9336-6

Cagliano, R., Caniato, F., & Spina, G. (2004). Lean, Agile and traditional supply: How do they impact manufacturing performance? *Journal of Purchasing and Supply Management,* 10(4-5), 151-164. https://doi.org/10.1016/j.pursup.2004.11.001

Cai, M., & Luo, J. (2020). Influence of COVID-19 on Manufacturing Industry and Corresponding Countermeasures from Supply Chain Perspective. *Journal of Shanghai Jiaotong University (Science),* 25(4), 409-416. https://doi.org/10.1007/s12204-020-2206-z

Caniato, F., Caridi, M., Crippa, L., & Moretto, A. (2012). Environmental sustainability in fashion supply chains: An exploratory case based research. *International Journal of Production Economics,* 135(2), 659-670. https://doi.org/10.1016/j.ijpe.2011.06.001

Cano, E.L., García-Camús, J.M., Garzás, J., Moguerza, J.M., & Sánchez, N.N. (2021). A Scrum-based framework for new product development in the non-software industry. *Journal of Engineering and Technology Management - JET-M,* 61(June). https://doi.org/10.1016/j.jengtecman.2021.101634

Conforto, E.C., Amaral, D.C., da Silva, S.L., Di Felippo, A., & Kamikawachi, D.S.L. (2016). The agility construct on project management theory. *International Journal of Project Management,* 34(4), 660-674. https://doi.org/10.1016/j.ijproman.2016.01.007

Dewi, D.R.S., & Hermanto, Y.B. (2024). Achieving Supply Chain Agility Through Product-Service Systems Offering. *Journal of Industrial Engineering and Management,* 17(2), 611-629. https://doi.org/10.3926/jiem.7521

Diebold, P., & Dahlem, M. (2014). Agile practices in practice – A mapping study. *ACM International Conference Proceeding Series.* https://doi.org/10.1145/2601248.2601254

Dissanayake, G., & Sinha, P. (2015). An examination of the product development process for fashion remanufacturing. *Resources, Conservation and Recycling,* 104, 94-102. https://doi.org/10.1016/j.resconrec.2015.09.008

Enyoghasi, C., & Badurdeen, F. (2021). Industry 4.0 for sustainable manufacturing: Opportunities at the product, process, and system levels. *Resources, Conservation and Recycling*, 166(September 2020), 105362. https://doi.org/10.1016/j.resconrec.2020.105362

Escrig-Tena, A.B., Segarra-Ciprés, M., & García-Juan, B. (2021). Incremental and radical product innovation capabilities in a quality management context: Exploring the moderating effects of control mechanisms. *International Journal of Production Economics,* 232(November). https://doi.org/10.1016/j.ijpe.2020.107994

Fudhla, A.F., Wirjodirdjo, B., & Singgih, M.L. (2024). Integrating Reverse Cycle Strategy in Circular Business Model Innovation: A Case Study. *Foresight and STI Governance,* 18(3), 84-103. https://doi.org/10.17323/2500-2597.2024.3.84.103

Fung, Y.N., Chan, H.L., Choi, T.M., & Liu, R. (2021). Sustainable product development processes in fashion: Supply chains structures and classifications. *International Journal of Production Economics,* 231(July), 107911. https://doi.org/10.1016/j.ijpe.2020.107911

Garcia-Torres, S., Rey-Garcia, M., & Albareda-Vivo, L. (2017). Effective disclosure in the fast-fashion industry: From sustainability reporting to action. *Sustainability (Switzerland),* 9(12). https://doi.org/10.3390/su9122256

Gemino, A., Horner-Reich, B., & Serrador, P.M. (2021). Agile, Traditional, and Hybrid Approaches to Project Success: Is Hybrid a Poor Second Choice? *Project Management Journal,* 52(2), 161-175. https://doi.org/10.1177/8756972820973082

Gloria, T.P., Kohlsaat, C., Bautil, P., Wolf, B., Early, D., & Ben-Zekry, B. (2014). A statistical approach to interpret relative environmental performance within product categories. *International Journal of Life Cycle Assessment,* 19(3), 491-499. https://doi.org/10.1007/s11367-013-0661-6

Gomes de Oliveira, L., Miranda, F.G., & de Paula-Dias, M.A. (2022). Sustainable practices in slow and fast fashion stores: What does the customer perceive? *Cleaner Engineering and Technology,* 6. https://doi.org/10.1016/j.clet.2022.100413

Goworek, H., Oxborrow, L., Claxton, S., McLaren, A., Cooper, T., & Hill, H. (2020). Managing sustainability in the fashion business: Challenges in product development for clothing longevity in the UK. *Journal of Business Research,* 117(September), 629-641. https://doi.org/10.1016/j.jbusres.2018.07.021

Gunasekaran, A., & Spalanzani, A. (2012). Sustainability of manufacturing and services: Investigations for research and applications. *International Journal of Production Economics,* 140(1), 35-47. https://doi.org/10.1016/j.ijpe.2011.05.011

Guo, S., Choi, T.M., & Shen, B. (2020). Green product development under competition: A study of the fashion apparel industry. *European Journal of Operational Research,* 280(2), 523-538. https://doi.org/10.1016/j.ejor.2019.07.050

Haapala, K.R., Zhao, F., Camelio, J., Sutherland, J.W., Skerlos, S.J., Dornfeld, D.A. et al. (2013). A review of engineering research in sustainable manufacturing. *Journal of Manufacturing Science and Engineering,* 135(4). https://doi.org/10.1115/1.4024040

Hannouf, M., & Assefa, G. (2017). Life cycle sustainability assessment for sustainability improvements: A case study of high-density polyethylene production in Alberta, Canada. *Sustainability (Switzerland),* 9(12). https://doi.org/10.3390/su9122332

Hendler, S. (2019). Digital-physical product development: a qualitative analysis. *European Journal of Innovation Management,* 22(2), 315-334. https://doi.org/10.1108/EJIM-01-2018-0026

Hu, Z.H., Li, Q., Chen, X.J., & Wang, Y.F. (2014). Sustainable rent-based closed-loop supply chain for fashion products. *Sustainability (Switzerland),* 6(10), 7063-7088. https://doi.org/10.3390/su6107063

Joy, A., Sherry, J.F., Venkatesh, A., Wang, J., & Chan, R. (2012). Fast fashion, sustainability, and the ethical appeal of luxury brands. *Fashion Theory - Journal of Dress Body and Culture,* 16(3), 273-295. https://doi.org/10.2752/175174112X13340749707123

Jung, S., & Jin, B. (2016). Sustainable development of slow fashion businesses: Customer value approach. *Sustainability (Switzerland),* 8(6). https://doi.org/10.3390/su8060540

Karaosman, H., Morales-Alonso, G., & Brun, A. (2017). From a systematic literature review to a classification framework: Sustainability integration in fashion operations. *Sustainability (Switzerland),* 9(1). https://doi.org/10.3390/su9010030

Khan, M.Z., Kumar, A., Liu, Y., Gupta, P., & Sharma, D. (2024). Modeling enablers of agile and sustainable sourcing networks in a supply chain: A case of the plastic industry. *Journal of Cleaner Production,* 435(January), 140522. https://doi.org/10.1016/j.jclepro.2023.140522

Kim, J., Kang, S., & Lee, K.H. (2020). How social capital impacts the purchase intention of sustainable fashion products. *Journal of Business Research,* 117(September), 596-603. https://doi.org/10.1016/j.jbusres.2018.10.010

Kim, N., Woo, H., & Ramkumar, B. (2021). The role of product history in consumer response to online second-hand clothing retail service based on circular fashion. *Journal of Retailing and Consumer Services,* 60 (May). https://doi.org/10.1016/j.jretconser.2021.102457

Köksal, D., Strähle, J., Müller, M., & Freise, M. (2017). Social sustainable supply chain management in the textile and apparel industry-a literature review. *Sustainability (Switzerland),* 9(1), 1-32. https://doi.org/10.3390/su9010100

Kuo, T.C., Hsu, C.W., Huang, S.H., & Gong, D.C. (2014). Data sharing: A collaborative model for a green textile/clothing supply chain. *International Journal of Computer Integrated Manufacturing,* 27(3), 266-280. https://doi.org/10.1080/0951192X.2013.814157

Labouriau, F.C., & Naveiro, R.M. (2015). Using the evolutionary pattern to generate ideas in new product development. *Journal of the Brazilian Society of Mechanical Sciences and Engineering,* 37(1), 231-242. https://doi.org/10.1007/s40430-014-0146-y

Macchion, L., Danese, P., & Vinelli, A. (2015). Redefining supply network strategies to face changing environments. A study from the fashion and luxury industry. *Operations Management Research,* 8(1-2), 15-31. https://doi.org/10.1007/s12063-014-0097-6

Mair, S., Druckman, A., & Jackson, T. (2016). Global inequities and emissions in Western European textiles and clothing consumption. *Journal of Cleaner Production,* 132, 57-69. https://doi.org/10.1016/j.jclepro.2015.08.082

Moon, K.K.L., Lai, C.S.Y., Lam, E.Y.N., & Chang, J.M.T. (2015). Popularization of sustainable fashion: barriers and solutions. *Journal of the Textile Institute,* 106(9), 939-952. https://doi.org/10.1080/00405000.2014.955293

Na, Y., & Na, D.K. (2015). Investigating the sustainability of the Korean textile and fashion industry. *International Journal of Clothing Science and Technology,* 27(1), 23-33. https://doi.org/10.1108/IJCST-08-2013-0085

Naranjo, I., Porras, M., Ortiz, D., Tigre, F., Sánchez, C., Tubón, E. et al. (2023). Mathematical Models for the Formation and Evaluation of Manufacturing Cells in A Textile Company. A Case Study. *Journal of Industrial Engineering and Management,* 16(2), 382-397. https://doi.org/10.3926/jiem.4143

Narkhede, B.E., Raut, R.D., Roy, M., Yadav, V.S., & Gardas, B. (2020). Implementation barriers to lean-agile manufacturing systems for original equipment manufacturers: an integrated decision-making approach. *International Journal of Advanced Manufacturing Technology,* 108(9-10), 3193-3206. https://doi.org/10.1007/s00170-020-05486-5

Pedro, P., German, B.R., Barbara, C.A., Jhonattan, M., Arturo, M., & Maria, P.R. (2019). Sensing, smart and sustainable product analysis methodology through EEG evaluation. *IFAC-PapersOnLine,* 52(13), 2378-2383. https://doi.org/10.1016/j.ifacol.2019.11.562

Pensupa, N., Leu, S.Y., Hu, Y., Du, C., Liu, H., Jing, H. et al. (2017). Recent Trends in Sustainable Textile Waste Recycling Methods: Current Situation and Future Prospects. *Topics in Current Chemistry,* 375(5). https://doi.org/10.1007/s41061-017-0165-0

Perry, P., & Towers, N. (2013). Conceptual framework development: CSR implementation in fashion supply chains. *International Journal of Physical Distribution and Logistics Management,* 43(5), 478-501. https://doi.org/10.1108/IJPDLM-03-2012-0107

Prabowo, R., Singgih, M.L., Karningsih, P.D., & Widodo, E. (2020). New product development from inactive problem perspective in indonesian SMEs to open innovation. *Journal of Open Innovation: Technology, Market, and Complexity,* 6(1). https://doi.org/10.3390/JOITMC6010020

Sandin, G., & Peters, G.M. (2018). Environmental impact of textile reuse and recycling – A review. *Journal of Cleaner Production,* 184, 353-365. https://doi.org/10.1016/j.jclepro.2018.02.266

Sarwar, N., Bin-Humayoun, U., Nawaz, A., & Yoon, D.H. (2021). Development of sustainable, cost effective foam finishing approach for cellulosic textile employing succinic acid/xylitol crosslinking system. *Sustainable Materials and Technologies,* 30(October). https://doi.org/10.1016/j.susmat.2021.e00350

Schiederig, T., Tietze, F., & Herstatt, C. (2012). Green innovation in technology and innovation management - an exploratory literature review. *R and D Management,* 42(2), 180-192. https://doi.org/10.1111/j.1467-9310.2011.00672.x

Serrador, P., & Pinto, J.K. (2015). Does Agile work? - A quantitative analysis of agile project success. *International Journal of Project Management,* 33(5), 1040-1051. https://doi.org/10.1016/j.ijproman.2015.01.006

Shen, B., Li, Q., Dong, C., & Perry, P. (2017). Sustainability issues in textile and apparel supply chains. *Sustainability (Switzerland),* 9(9), 1-6. https://doi.org/10.3390/su9091592

Stål, H.I., & Corvellec, H. (2018). A decoupling perspective on circular business model implementation: Illustrations from Swedish apparel. *Journal of Cleaner Production,* 171, 630-643. https://doi.org/10.1016/j.jclepro.2017.09.249

Subic, A., Shabani, B., Hedayati, M., & Crossin, E. (2012). Capability framework for sustainable manufacturing of sports apparel and footwear. *Sustainability,* 4(9), 2127-2145. https://doi.org/10.3390/su4092127

Suef, M., Suparno, S., & Singgih, M.L. (2017). Categorizing product attributes efficiently in QFD-Kano: A case analysis in telecommunication. *TQM Journal,* 29(3), 512-526. https://doi.org/10.1108/TQM-03-2015-0036

Suhartini (2023). Product Development for Sustainable of Garment Product - A literature Review. *Proceedings of the 8th North America Conference on Industrial Engineering and Operations Management.* Houston, Texas, USA, https://doi.org/10.46254/NA8.20230199

Suhartini, S., Mahbubah, N.A., & Basjir, M. (2021). Marketing Strategy Design Based on Information Technology in Batik Small and Medium-Sized Enterprises in Indonesia. *Eastern-European Journal of Enterprise Technologies,* 6(13-114), 39-48. https://doi.org/10.15587/1729-4061.2021.244137

Todeschini, B.V., Cortimiglia, M.N., & de Medeiros, J.F. (2020). Collaboration practices in the fashion industry: Environmentally sustainable innovations in the value chain. *Environmental Science and Policy,* 106(April), 1-11. https://doi.org/10.1016/j.envsci.2020.01.003

Trappey, A.J.C., & Chiang, T.A. (2008). A DEA benchmarking methodology for project planning and management of new product development under decentralized profit-center business model. *Advanced Engineering Informatics,* 22(4), 438-444. https://doi.org/10.1016/j.aei.2008.06.003

Vătămănescu, E.M., Dabija, D.C., Gazzola, P., Cegarro-Navarro, J.G., & Buzzi, T. (2021). Before and after the outbreak of Covid-19: Linking fashion companies' corporate social responsibility approach to consumers' demand for sustainable products. *Journal of Cleaner Production,* 321(February). https://doi.org/10.1016/j.jclepro.2021.128945

Wang, S., Su, D., Ma, M., & Kuang, W. (2021). Sustainable product development and service approach for application in industrial lighting products. *Sustainable Production and Consumption,* 27, 1808-1821. https://doi.org/10.1016/j.spc.2021.04.003

Wang, Y., Modi, S.B., & Schoenherr, T. (2021). Leveraging sustainable design practices through supplier involvement in new product development: The role of the suppliers' environmental management capability. *International Journal of Production Economics,* 232(February), 107919. https://doi.org/10.1016/j.ijpe.2020.107919

Žurga, Z., & Tavčer, P.F. (2014). Apparel purchasing with consideration of eco-labels among Slovenian consumers. *Fibres and Textiles in Eastern Europe,* 22(5), 20-27.

Zhining, Z., Alli, H., Ahmadipour, M., & Che-me, R. (2024). A weighted fuzzy approach for the agility of sustainable product development process assessment: A case study in Chinese medium-sized enterprises. *Heliyon,* 10(13), e34138. https://doi.org/10.1016/j.heliyon.2024.e34138

Appendix A

The mathematical model that will be created aims to validate the model consisting of several scenarios. In general, the equation for finding the profit value in product development is associated with increasing the profit value (Trappey & Chiang, 2008) are as follows:

$$\text{Max } \Pi = TR - TC \quad (1)$$

Where:

Π : Profit
TR : Total income (total revenue)
TC : Total cost

The concept of a mathematical model in maximizing the profit value of product development by (Trappey & Chiang, 2008) is divided into four elements, namely:

1. Output cost value
2. Facility costs
3. Labor costs
4. Outsourcing costs

Equation 1 shows that the profit value is obtained from total revenue minus total costs. Here is a description of the profit value:

1. Total income (total revenue) (TR)

Total revenue is the value of output costs resulting from the selling price of the product idea. Thus, the revenue value (TR) can be formulated as follows

$$TR = \sum_t Ov_t \tag{2}$$

Where:

Ov_t : Value per NPD output produced in period-t (rupiah)

2. Total cost (TC)

Total cost is the sum of facility and labor costs, then reduced by outsourcing costs. The following describes the formulation of each cost.

a) Facility costs

$$Facility\ costs = \left[\sum_e FC_{e.} Tif_e\right] \tag{3}$$

Where:

FC_e : Cost per unit of NPD produced from facilities e (rupiah)
Tif_e : Total rupiah used in facilities e to generate NPD (rupiah)

b) Labor costs

$$Labor\ costs = \left[\sum_m MC_{e.} Tih_m\right] \tag{4}$$

Where:

Mc_e : The unit cost of human resource m in each NPD (rupiah)
Tih_m : The total input quantity of the human resource m to NPD (rupiah)

c) Outsourcing costs

$$Outsourcing\ costs = \sum_t OsV_t \tag{5}$$

Where:

OsV_t : Outsourcing costs for NPD activities (rupiah)

Based on Equations 1, 2, and 3, the total cost (TC) can be formulated as follows:

$$TC = \left[\sum_e FC_{e.} Tif_e + \sum_m MC_{e.} Tih_m\right] - \sum_t OsV_t \tag{6}$$

Where:

FC_e : Cost per unit of NPD produced from facilities e (rupiah)
Tif_e : Total rupiah used in facilities e to generate NPD (rupiah)
MC_e : The unit cost of human resource m in each NPD (rupiah)
Tih_m : The total input quantity of the human resource m to NPD (rupiah)
OsV_t : Outsourcing costs for NPD activities (rupiah)

From the total profit value Based on Equations 1, 2, and 6, the profit value obtained from total income minus total costs can be formulated as follows:

$$\text{MaxZ(profit)} = \sum_t OV_t - \left[\sum_e FC_e \cdot Tif_e + \sum_m MC_e \cdot Tih_m\right] - \sum_t OsV_t \tag{7}$$

Where:

Ov_t : Value per NPD output produced in period t (rupiah)
FC_e : Cost per unit of NPD produced from facilities e (rupiah)
Tif_e : Total rupiah used in facilities e to generate NPD (rupiah)
MC_e : The unit cost of human resource m in each NPD (rupiah)
Tih_m : The total input quantity of the human resource m to NPD (rupiah)
OsV_t : Outsourcing costs for NPD activities