Available online at: http://publikasi.mercubuana.ac.id/index.php/ijiem

IJIEM (Indonesian Journal of Industrial Engineering & Management)

ISSN (Print) : 2614-7327 ISSN (Online) : 2745-9063

Product Development of Urban Aquaculture Supporting Equipment Based on Solar Cell Technology and Speed Bump System Using the Design For Manufacture and Assembly (DFMA) Method

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ARTICLE INFORMATION

Article history:

Received: 17 November 2023
Revised: 26 May 2024
Accepted: 24 July 2024

Category: Research paper

Keywords:
Solar cell technology
Speed bump
Renewable energy
Design for manufacture and assembly
Urban aquaculture

DOI: 10.22441/ijiem.v5i3.24194

A B S T R A C T

Urban aquaculture, like urban farming, entails using aquaculture technology to transform tiny, previously unutilized pieces of land in highly inhabited metropolitan areas into a useful area. Urban aquaculture, in broad terms, can be defined as the fish farming on small plots of land. Depending on the sort of consumable fish commodity to be grown, urban aquaculture can be implemented through home aquaculture and community aquaculture utilizing a variety of techniques. Creating a mandatory product involves the stages of development and design. At this stage, all product components, production costs, design, and assembly time are taken into account. Through sustainable product design and evaluation, it is possible to address the assembly performance and difficulties in the assembly process, as well as assembly time and costs. The design and development of this product use the Design for Manufacturing and Assembly (DFMA) method. DFMA is a method used to determine the product design with the best time and cost. In general, this method can also be used in development to improve the quality and measure the improvement of urban aquaculture product designs. It is hoped that urban aquaculture will provide an alternative product design to achieve high-quality products and low production costs.

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1. INTRODUCTION

A resilient city is an urban idea that is capable of meeting all of the demands of its citizens with the help of the resources that are found there (Abdillah et al., 2023). Food security and the idea of a resilient city are intimately intertwined because both are essential human needs (Nugraha et al., 2019). Urban farming and fishery techniques can help attain food security in urban areas. Urban farming is the practice of growing food for local use in densely populated residential areas. Urban farming, for instance, has been adopted in several Indonesian cities, including Surakarta, Sleman, Makassar, and other significant cities (Abdillah et al., 2023; Abdurrohman et al., 2021; Surya et al., 2020).

How to Cite: Tranggono, T., Nugraha, I., Winursito, Y. C., Dewi, S., Syaifullah, H., & Islami, M. C. P. A. (2024). Product Development of Urban Aquaculture Supporting Equipment Based on Solar Cell Technology and Speed Bump System Using the Design For Manufacture and Assembly (DFMA) Method. *IJIEM (Indonesian Journal of Industrial Engineering & Management)*, 5(3), 812-817. https://doi.org/10.22441/ijiem.v5i3.24194

According to (Abdillah et al., 2023), research shows that urban farming plays a key role in promoting food security in Indonesia. This study can make urbanization reduces space for traditional agriculture, making urban aquaculture a compact solution for food production. However, it requires renewable energy, as traditional systems rely on costly, non-renewable sources. Solar cells and energy from speed bumps provide sustainable alternatives while ensuring water quality through advanced equipment. These innovations address urban food security, climate change, and energy efficiency, supporting localized, eco-friendly food production in cities.

Urban fisheries are a method of turning confined space in heavily populated places into a food supply, much like urban farming. Fish are raised in confined spaces using aquaculture technology in urban aquaculture, one type of urban fisheries. Urban aquaculture encompasses both household fish cultivation (home aquaculture) and community-based fish cultivation (community aquaculture), with different techniques used depending on the species of fish being raised. Although tilapia, catfish, and Nile tilapia are more frequently grown in rural regions, catfish is also grown in urban settings due to their easier care. Urban locations present challenges for fish farming, including a lack of available clean water, available land, and time for farmers who may also have other primary employment. Renewable energy sources can be used in urban aquaculture to overcome these problems. Advanced technology is also necessary to tackle time management challenges. Internet of Things (IoT) technology can be used to construct remote-controlled automation systems, such as temperature management, feeding, oxygen level monitoring, and aerator operation. A reliable and sustainable power source is essential for fish farming that makes use of technology. The utilization of solar energy through solar panels is a desirable alternative in Indonesia, which is situated along the equator, to supply the electricity needs of urban fish farming systems.

Based on these problems, it is necessary to design technology that can handle problems that arise while implementing urban aquaculture using the DFMA technique. To find product designs that are both time and cost efficient, the DFMA method is used (Butt & Jedi, 2020). This technique can be used more broadly to improve the quality of products and track advancements in sink design (Xin et al., 2019). The main goal of DFMA is to develop product designs that allow for the elimination of parts or subparts that do not provide value in light of consumer needs (Naiju, 2021). In-depth analysis is used to examine assembly and or manufacturing challenges that may develop in product design, as well as to scrutinize the design, quality, material selection, components, and production processes utilized by competitors (Gao et al., 2020). DFMA is chosen because it ensures the equipment is cost-effective, easy to produce and maintain, and optimized for the specific challenges of urban aquaculture, including energy efficiency and limited space. The goal of this research is to find a way to attain sustained food self-sufficiency in urban areas while simultaneously assisting the government's initiatives to enhance community welfare and food security.

2. LITERATURE REVIEW

Design For Manufacture and Assembly (DFMA) is a method in design that aims to facilitate the assembly process where the existing design is simplified as much as possible and adjusted to the ability in design by considering aspects in designing the system building (Mundanda & Ramadhana, 2020). DFMA also determined as a method to evaluate the design of product with considering the ease of manufacture process and the assembly process (Priadythama et al., 2017). The basic concept of DFMA is to analyze and solve problems that arise in the manufacturing process and component assembly process in the early stages of design, so that the risk of product damage that may occur in the final product can be anticipated as soon as possible. Thus production time and costs can be reduced as much as possible (Nazarudin & Suryadi, 2021).

DFMA is an integration between Design for Manufacture (DFM) and Design for Assembly (DFA) (Ginting & Ricky, 2021) (Munanda & Ramadhana, 2020) (Yuan et al., 2020). DFA is a part of DFMA that aims to minimize the cost of assembling a product. In DFA several methods are used such as analysis, estimation, planning, and simulation to calculate all possibilities that may occur during the assembly process (Jung & Yu, 2022). Furthermore, adjustments are made to the shape of the components so that the assembly process can be done quickly and easily to minimize assembly time and in turn can reduce production costs. While design for manufacture (DFM) can be said to be a limitation related to the initial phase of designing a product (Barbosa & Carvalho, 2014). At this stage, engineers can select materials, technologies and estimate possible costs incurred. Then, the existing product design plan is analyzed and reviewed so that errors can be corrected as soon as possible based on the feedback received (Nazarudin & Suryadi, 2021). Broadly speaking, DFM is relates to the process of making individual parts, whereas DFA involves the ways of assembling them (Abrishami & Martín-Durán, 2021).

This method has been widely used in the process of designing and re-designing various products. (Priadythama et al., 2017) used DFMA to design low cost and high customization products. DFMA also used in the design of a palm frond chopper (Nasution, 2021) and the design of in-market Table Top Chain (TTC) conveyor system used by major food companies in Saudi Arabia (Butt & Jedi, 2020). In addition to use in product design, DFMA also be used to assist designers in improving quality, reducing assembly costs, as well as to measure design improvements of products (Priadythama et al., 2017). By using the DFMA method, the manufacturing process is carried out more efficiently in production time, then reduces production costs to a minimum without reducing component safety (Apriadi & Prayogi, 2022). DFMA has to a very great extent improved the implementation of lean manufacturing. It has also led to shorter manufacturing and design cycles. DFMA enables manufacturers to perform cost estimation at the early stages, i.e. design stage (Lu et al., 2021). Various processes like parts consolidation, material consideration, and also the right selection of manufacturing processes have helped attain the goals also enhance the implementation of lean (Bao et al., 2022). DFMA is designed to give engineers a structured way to ease assembly and overall manufacturability of a product (Naiju, 2021).

3. RESEARCH METHOD

In the design and development of the Urban Aquaculture Supporting Equipment Based on Solar Cell Technology and Speed Bump System product, it is carried out through the following problem-solving steps (Figure 1).

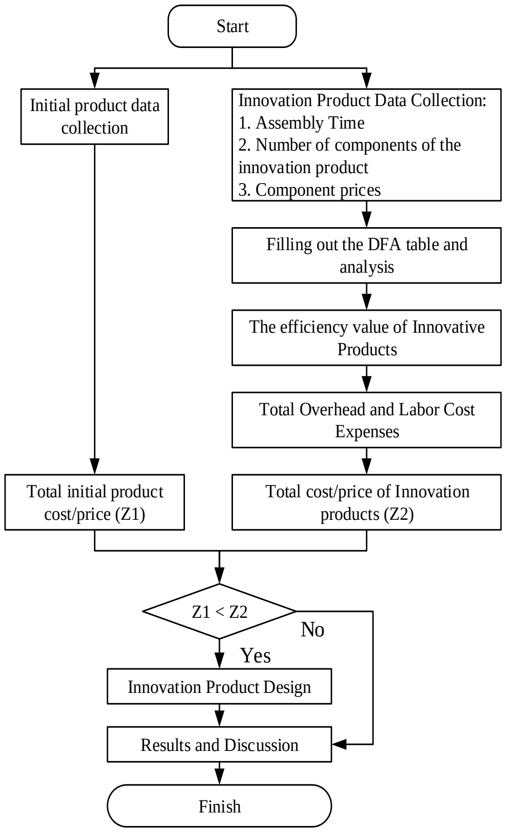

Figure 1. Research method

The following is an explanation of the research flowchart in Figure 1 above:

1. Data Collection: In this stage, data collection for the initial product and innovative product is conducted. For the innovative product, the following steps are performed: (a) Filling out and analyzing the DFA table. (b) Calculating the efficiency of the innovative product. (c) Calculating the total overhead costs and labor costs.
2. Calculating the total cost per unit for the initial product and innovative product.
3. Selection of the product with the lowest total cost (If the selected product is innovative, then product design for the innovative product is carried out).
4. Analysis and conclusion process.

4. RESULT AND DISCUSSION

Solar panels serve as a source of electricity that can be harnessed by absorbing solar energy. The electrical energy generated by the solar panels is then stored in a battery as an energy source to operate an aerator. Meanwhile, the SCC (Solar Charge Controller) is responsible for regulating the direct current (DC) from the solar panels being fed into the battery and managing the current from the battery to the load. This module prevents overcharging, which could lead to battery depletion, ensuring the solar power system operates efficiently. The accumulator functions as the storage for electrical energy generated by solar light. Inverter, on the other hand, is a crucial component in this solar panel setup, converting DC current into AC (alternating current) so that the electrical energy can be used to power the aerator (Figure 2).

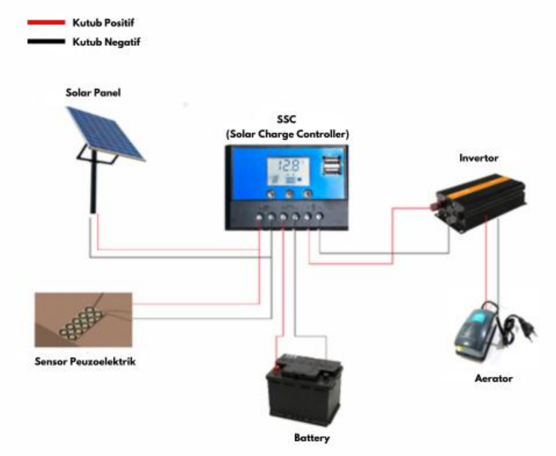

Figure 2. Solar cell technology and speed bump system topology

4.1 Load Calculation PTLS

Table 1. Existing load

Load	Ampere	Voltage	Watt	Operation (watt/hour)
Solar Charger Controller	50	12	600	24
Aerator	7	12	84	24
Accu	7	12	84	24
Inventer	25	12	300	24

The required load for aerator with a current of 50 A at 12 V, and it has a rated power of 84 W. It can be used for 24 hours, generating a total energy of 1152 Wh (watt-hours).

SCC = 600 x 24 = 14.400 Watt-hour
Aerator = 84 x 24 = 2.016 Watt-hour
Accu = 84 x 24 = 2.016 Watt-hour
Inventer = 300 x =7.200 Watt-hour
Total Daily Energy = 25.632 watt-hour
Irradiasi (Surabaya city) = 4306 kWh/m^2

4.2 Module Capacity Calculation

To calculate the peak power of a solar module, you can use the average daily irradiance data and the available surface area of the solar module. Peak power of solar modules is typically measured in watts per square meter (W/m²). Here is the formula to calculate peak power:

$$\text{Kw(p) PTLS} = \frac{Total\ Daily\ Energy}{Irradiance\ rate}$$

$$= \frac{25.632}{4306}$$

$$= 595 \approx 600 \text{ wp}$$

4.3 Potential Losses

To calculate the number of solar modules to be used, it is necessary to have data on the load being used and the possibility of losses, as detailed in the following calculations.

E_{losses} = 25% x Total Daily Energy
= 25% x 25.632
= 6.408 watt

$E_{\text{Load Supply Requirements}}$ = $E_{\text{Average Daily Load}}$ + E_{losses}
= 25.632 + 6.408
= 32.040 watt

4.4 Solar Panel Calculation

After determining the energy requirements for supplying the load, the number of solar modules to be used can be calculated. Taking into account the daily sunshine duration of 24 hours and using photovoltaic modules with a capacity of 600 Wp, polycrystalline type, the number of panels can be determined using the following calculation.

$E_{\text{Solar Panel}}$ = Irradiation Time x Solar Panel Capacity
= 24 hours x 600 wp
= 14.400 wh

$$N_{\text{Solar Panel}} = \frac{E\ Load\ Supply\ Requirement}{E\ Solar\ Panel}$$

$$= \frac{32.040}{14.400}$$

$$= 2{,}2 \approx 2 \text{ Solar Panel}$$

So, the required solar panels for this research are one 600 Wp solar panel.

4.5 Cost Saving Estimate

The price per kWh for low-voltage-large

businesses with a capacity of 6,600 VA-200 KVA is IDR. 1444.70/kWh.

Device → 600 wp → 25.632 kWh

$$Cost\ Saving = \frac{Energy\ Saving (Watt - hour)}{1.000} x\ Tarif\ per\ kWh$$

$$= \frac{25.632}{1.000} x\ 1.444,,70$$

$$= 37.030\ day$$

Cost Estimate = IDR. 37.030/day
A month = IDR. 37.030 x 30
= IDR. 1.110.900/month

Using the device, can save energy consumption by 25.632 kWh per day. Assuming electricity consumption falls under the category of low-voltage large businesses with a capacity of 6,600 VA-200 KVA, with a price of IDR. 1,444.70 per kWh, the device can save IDR. 37.030 per day or save up to IDR. 1.110.900 per month.

4.6 Equipment on Solar Cell Technology

Based on figure 2 above, the functions of each component used in this study are as follows: *Solar cell*. The power source that can be used is by harnessing solar energy. The energy produced can be considered clean energy because it doesn't use fossil fuels that can contribute to global warming. The electrical energy generated by the solar panels will be stored in a battery as an energy source to power the aerator. *Peuzoelectric*. The power source that can be used involves utilizing pressure on the sensor to generate electrical energy. Similar to solar panels, the electrical energy produced by this sensor will be stored in a battery as an energy source to power the aerator. *Solar Charge Control (SCC)*. This module serves to control the direct current flow from the solar panel to the battery and regulate the current from the battery to the load. The module prevents overcharging of the battery by limiting the amount and rate of charge going into the battery. It also prevents battery depletion by shutting down the system if the stored power falls below 50 percent capacity and charges the battery to the correct voltage level, ensuring that the solar power system operates efficiently. *Accu*. The accumulator, commonly referred to as a battery (accu), is a device used to store electrical energy. In this study, the battery is used to store the electrical energy generated by the solar panel and piezoelectric sensor. *Inverter*. The inverter is an essential component in this solar panel system to convert DC (Direct Current) into AC (Alternating Current), allowing the electrical energy to be used to operate the aerator or other electrical equipment.

5. CONCLUSION

Based on the research results, the following conclusions can be drawn: Total Daily Energy is 25.632 watts/hour, Module Capacity Calculation is 600 wp, and Potential Losses is 1440 watts, then the required solar panels for this research are one 600 Wp solar panel. Products developed in urban aquaculture innovation are proven to have cost-saving benefits. By using this device, energy consumption can be reduced by 25.632 kWh per day. Assuming electricity consumption is included in the low voltage large business category with a capacity of 6,600 VA-200 KVA, with a price of IDR. 1,444.70 per kWh, this device is able to produce savings of IDR. 37.030 per day or maximum IDR. 1.110.900 per month.

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